Warnings, Cautions, and Notes as Used in this Publication

**Warning**

Warning notices are used in this publication to emphasize that hazardous voltages, currents, temperatures, or other conditions that could cause personal injury exist in this equipment or may be associated with its use.

In situations where inattention could cause either personal injury or damage to equipment, a Warning notice is used.

**Caution**

Caution notices are used where equipment might be damaged if care is not taken.

**Note**

Notes merely call attention to information that is especially significant to understanding and operating the equipment.

This document is based on information available at the time of its publication. While efforts have been made to be accurate, the information contained herein does not purport to cover all details or variations in hardware or software, nor to provide for every possible contingency in connection with installation, operation, or maintenance. Features may be described herein which are not present in all hardware and software systems. GE Fanuc Automation assumes no obligation of notice to holders of this document with respect to changes subsequently made.

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This section describes the safety precautions related to the use of CNC units. It is essential that these precautions be observed by users to ensure the safe operation of machines equipped with a CNC unit (all descriptions in this section assume this configuration). Note that some precautions are related only to specific functions, and thus may not be applicable to certain CNC units.

Users must also observe the safety precautions related to the machine, as described in the relevant manual supplied by the machine tool builder. Before attempting to operate the machine or create a program to control the operation of the machine, the operator must become fully familiar with the contents of this manual and relevant manual supplied by the machine tool builder.

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DEFINITION OF WARNING, CAUTION, AND NOTE

This manual includes safety precautions for protecting the user and preventing damage to the machine. Precautions are classified into Warning and Caution according to their bearing on safety. Also, supplementary information is described as a Note. Read the Warning, Caution, and Note thoroughly before attempting to use the machine.

WARNING

Applied when there is a danger of the user being injured or when there is a danger of both the user being injured and the equipment being damaged if the approved procedure is not observed.

CAUTION

Applied when there is a danger of the equipment being damaged, if the approved procedure is not observed.

NOTE

The Note is used to indicate supplementary information other than Warning and Caution.

Read this manual carefully, and store it in a safe place.
### GENERAL WARNINGS AND CAUTIONS

#### WARNING

1. Never attempt to machine a workpiece without first checking the operation of the machine. Before starting a production run, ensure that the machine is operating correctly by performing a trial run using, for example, the single block, feedrate override, or machine lock function or by operating the machine with neither a tool nor workpiece mounted. Failure to confirm the correct operation of the machine may result in the machine behaving unexpectedly, possibly causing damage to the workpiece and/or machine itself, or injury to the user.

2. Before operating the machine, thoroughly check the entered data. Operating the machine with incorrectly specified data may result in the machine behaving unexpectedly, possibly causing damage to the workpiece and/or machine itself, or injury to the user.

3. Ensure that the specified feedrate is appropriate for the intended operation. Generally, for each machine, there is a maximum allowable feedrate. The appropriate feedrate varies with the intended operation. Refer to the manual provided with the machine to determine the maximum allowable feedrate. If a machine is run at other than the correct speed, it may behave unexpectedly, possibly causing damage to the workpiece and/or machine itself, or injury to the user.

4. When using a tool compensation function, thoroughly check the direction and amount of compensation. Operating the machine with incorrectly specified data may result in the machine behaving unexpectedly, possibly causing damage to the workpiece and/or machine itself, or injury to the user.

5. The parameters for the CNC and PMC are factory-set. Usually, there is no need to change them. When, however, there is no alternative other than to change a parameter, ensure that you fully understand the function of the parameter before making any change. Failure to set a parameter correctly may result in the machine behaving unexpectedly, possibly causing damage to the workpiece and/or machine itself, or injury to the user.

6. Immediately after switching on the power, do not touch any of the keys on the MDI panel until the position display or alarm screen appears on the CNC unit. Some of the keys on the MDI panel are dedicated to maintenance or other special operations. Pressing any of these keys may place the CNC unit in other than its normal state. Starting the machine in this state may cause it to behave unexpectedly.

7. The operator’s manual and programming manual supplied with a CNC unit provide an overall description of the machine’s functions, including any optional functions. Note that the optional functions will vary from one machine model to another. Therefore, some functions described in the manuals may not actually be available for a particular model. Check the specification of the machine if in doubt.
WARNING

8. Some functions may have been implemented at the request of the machine–tool builder. When using such functions, refer to the manual supplied by the machine–tool builder for details of their use and any related cautions.

CAUTION

1. Do not remove the internal parts, including the ATA card and compact flash card, from within the CNC.

NOTE

Programs, parameters, and macro variables are stored in nonvolatile memory in the CNC unit. Usually, they are retained even if the power is turned off. Such data may be deleted inadvertently, however, or it may prove necessary to delete all data from nonvolatile memory as part of error recovery.

To guard against the occurrence of the above, and assure quick restoration of deleted data, backup all vital data, and keep the backup copy in a safe place.
This section covers the major safety precautions related to programming. Before attempting to perform programming, read the supplied operator’s manual and programming manual carefully such that you are fully familiar with their contents.

**WARNING**

1. **Coordinate system setting**
   
   If a coordinate system is established incorrectly, the machine may behave unexpectedly as a result of the program issuing an otherwise valid move command. Such an unexpected operation may damage the tool, the machine itself, the workpiece, or cause injury to the user.

2. **Positioning by nonlinear interpolation**
   
   When performing positioning by nonlinear interpolation (positioning by nonlinear movement between the start and end points), the tool path must be carefully confirmed before performing programming. Positioning involves rapid traverse. If the tool collides with the workpiece, it may damage the tool, the machine itself, the workpiece, or cause injury to the user.

3. **Function involving a rotation axis**
   
   When programming polar coordinate interpolation or normal–direction (perpendicular) control, pay careful attention to the speed of the rotation axis. Incorrect programming may result in the rotation axis speed becoming excessively high, such that centrifugal force causes the chuck to lose its grip on the workpiece if the latter is not mounted securely. Such mishap is likely to damage the tool, the machine itself, the workpiece, or cause injury to the user.

4. **Inch/metric conversion**
   
   Switching between inch and metric inputs does not convert the measurement units of data such as the workpiece origin offset, parameter, and current position. Before starting the machine, therefore, determine which measurement units are being used. Attempting to perform an operation with invalid data specified may damage the tool, the machine itself, the workpiece, or cause injury to the user.

5. **Constant surface speed control**
   
   When an axis subject to constant surface speed control approaches the origin of the workpiece coordinate system, the spindle speed may become excessively high. Therefore, it is necessary to specify a maximum allowable speed. Specifying the maximum allowable speed incorrectly may damage the tool, the machine itself, the workpiece, or cause injury to the user.
WARNING

6. Stroke check

After switching on the power, perform a manual reference position return as required. Stroke check is not possible before manual reference position return is performed. Note that when stroke check is disabled, an alarm is not issued even if a stroke limit is exceeded, possibly damaging the tool, the machine itself, the workpiece, or causing injury to the user.

7. Tool post interference check

A tool post interference check is performed based on the tool data specified during automatic operation. If the tool specification does not match the tool actually being used, the interference check cannot be made correctly, possibly damaging the tool or the machine itself, or causing injury to the user.

After switching on the power, or after selecting a tool post manually, always start automatic operation and specify the tool number of the tool to be used.

8. Absolute/incremental mode

If a program created with absolute values is run in incremental mode, or vice versa, the machine may behave unexpectedly.

9. Plane selection

If an incorrect plane is specified for circular interpolation, helical interpolation, or a canned cycle, the machine may behave unexpectedly. Refer to the descriptions of the respective functions for details.

10. Torque limit skip

Before attempting a torque limit skip, apply the torque limit. If a torque limit skip is specified without the torque limit actually being applied, a move command will be executed without performing a skip.

11. Programmable mirror image

Note that programmed operations vary considerably when a programmable mirror image is enabled.

12. Compensation function

If a command based on the machine coordinate system or a reference position return command is issued in compensation function mode, compensation is temporarily canceled, resulting in the unexpected behavior of the machine.

Before issuing any of the above commands, therefore, always cancel compensation function mode.
4 WARNINGS AND CAUTIONS RELATED TO HANDLING

This section presents safety precautions related to the handling of machine tools. Before attempting to operate your machine, read the supplied operator’s manual and programming manual carefully, such that you are fully familiar with their contents.

**WARNING**

1. **Manual operation**
   
   When operating the machine manually, determine the current position of the tool and workpiece, and ensure that the movement axis, direction, and feedrate have been specified correctly. Incorrect operation of the machine may damage the tool, the machine itself, the workpiece, or cause injury to the operator.

2. **Manual reference position return**
   
   After switching on the power, perform manual reference position return as required. If the machine is operated without first performing manual reference position return, it may behave unexpectedly. Stroke check is not possible before manual reference position return is performed. An unexpected operation of the machine may damage the tool, the machine itself, the workpiece, or cause injury to the user.

3. **Manual numeric command**
   
   When issuing a manual numeric command, determine the current position of the tool and workpiece, and ensure that the movement axis, direction, and command have been specified correctly, and that the entered values are valid. Attempting to operate the machine with an invalid command specified may damage the tool, the machine itself, the workpiece, or cause injury to the operator.

4. **Manual handle feed**
   
   In manual handle feed, rotating the handle with a large scale factor, such as 100, applied causes the tool and table to move rapidly. Careless handling may damage the tool and/or machine, or cause injury to the user.

5. **Disabled override**
   
   If override is disabled (according to the specification in a macro variable) during threading, rigid tapping, or other tapping, the speed cannot be predicted, possibly damaging the tool, the machine itself, the workpiece, or causing injury to the operator.

6. **Origin/preset operation**
   
   Basically, never attempt an origin/preset operation when the machine is operating under the control of a program. Otherwise, the machine may behave unexpectedly, possibly damaging the tool, the machine itself, the tool, or causing injury to the user.
7. Workpiece coordinate system shift

Manual intervention, machine lock, or mirror imaging may shift the workpiece coordinate system. Before attempting to operate the machine under the control of a program, confirm the coordinate system carefully.

If the machine is operated under the control of a program without making allowances for any shift in the workpiece coordinate system, the machine may behave unexpectedly, possibly damaging the tool, the machine itself, the workpiece, or causing injury to the operator.

8. Software operator’s panel and menu switches

Using the software operator’s panel and menu switches, in combination with the MDI panel, it is possible to specify operations not supported by the machine operator’s panel, such as mode change, override value change, and jog feed commands.

Note, however, that if the MDI panel keys are operated inadvertently, the machine may behave unexpectedly, possibly damaging the tool, the machine itself, the workpiece, or causing injury to the user.

9. Manual intervention

If manual intervention is performed during programmed operation of the machine, the tool path may vary when the machine is restarted. Before restarting the machine after manual intervention, therefore, confirm the settings of the manual absolute switches, parameters, and absolute/incremental command mode.

10. Feed hold, override, and single block

The feed hold, feedrate override, and single block functions can be disabled using custom macro system variable #3004. Be careful when operating the machine in this case.

11. Dry run

Usually, a dry run is used to confirm the operation of the machine. During a dry run, the machine operates at dry run speed, which differs from the corresponding programmed feedrate. Note that the dry run speed may sometimes be higher than the programmed feed rate.

12. Cutter and tool nose radius compensation in MDI mode

Pay careful attention to a tool path specified by a command in MDI mode, because cutter or tool nose radius compensation is not applied. When a command is entered from the MDI to interrupt in automatic operation in cutter or tool nose radius compensation mode, pay particular attention to the tool path when automatic operation is subsequently resumed. Refer to the descriptions of the corresponding functions for details.

13. Program editing

If the machine is stopped, after which the machining program is edited (modification, insertion, or deletion), the machine may behave unexpectedly if machining is resumed under the control of that program. Basically, do not modify, insert, or delete commands from a machining program while it is in use.
5 WARNINGS RELATED TO DAILY MAINTENANCE

WARNING

1. Memory backup battery replacement

Only those personnel who have received approved safety and maintenance training may perform this work.

When replacing the batteries, be careful not to touch the high-voltage circuits (marked △ and fitted with an insulating cover).

Touching the uncovered high-voltage circuits presents an extremely dangerous electric shock hazard.

NOTE

The CNC uses batteries to preserve the contents of its memory, because it must retain data such as programs, offsets, and parameters even while external power is not applied.

If the battery voltage drops, a low battery voltage alarm is displayed on the machine operator’s panel or screen.

When a low battery voltage alarm is displayed, replace the batteries within a week. Otherwise, the contents of the CNC’s memory will be lost.

Refer to the maintenance section of the operator’s manual or programming manual for details of the battery replacement procedure.
2. Absolute pulse coder battery replacement

Only those personnel who have received approved safety and maintenance training may perform this work.

When replacing the batteries, be careful not to touch the high-voltage circuits (marked △ and fitted with an insulating cover).

Touching the uncovered high-voltage circuits presents an extremely dangerous electric shock hazard.

NOTE

The absolute pulse coder uses batteries to preserve its absolute position.
If the battery voltage drops, a low battery voltage alarm is displayed on the machine operator’s panel or screen.
When a low battery voltage alarm is displayed, replace the batteries within a week. Otherwise, the absolute position data held by the pulse coder will be lost.
Refer to the FANUC SERVO AMPLIFIER α series Maintenance Manual or FANUC SERVO AMPLIFIER α series Maintenance Manual for details of the battery replacement procedure.
3. Fuse replacement

Before replacing a blown fuse, however, it is necessary to locate and remove the cause of the blown fuse.

For this reason, only those personnel who have received approved safety and maintenance training may perform this work.

When replacing a fuse with the cabinet open, be careful not to touch the high-voltage circuits (marked △ and fitted with an insulating cover).

Touching an uncovered high-voltage circuit presents an extremely dangerous electric shock hazard.
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I. GENERAL
1 GENERAL

About this manual

This manual consists of the following parts:

**I. GENERAL**
Describes chapter organization, applicable models, related manuals, and notes for reading this manual.

**II. PROGRAMMING**
Describes each function: Format used to program functions in the NC language, characteristics, and restrictions. When a program is created through conversational automatic programming function, refer to the manual for the conversational automatic programming function (Table 1).

**III. OPERATION**
Describes the manual operation and automatic operation of a machine, procedures for inputting and outputting data, and procedures for editing a program.

**IV. MAINTENANCE**
Describes procedures for replacing batteries.

**APPENDIX**
Lists tape codes, valid data ranges, and error codes.

Some functions described in this manual may not be applied to some products. For detail, refer to the DESCRIPTIONS manual (B–63522EN).

This manual does not describe parameters in detail. For details on parameters mentioned in this manual, refer to the manual for parameters (B–63530EN).

This manual describes all optional functions. Look up the options incorporated into your system in the manual written by the machine tool builder.

The models covered by this manual, and their abbreviations are:

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The following table lists the manuals related to Series 16i, Series 18i, Series 21i, Series 160i, Series 180i, Series 210i, Series 160is, Series 180is, Series 210is–MODEL B. This manual is indicated by an asterisk (*)

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<td>B–63344EN</td>
</tr>
<tr>
<td>CAP (M series)</td>
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</tr>
<tr>
<td>FANUC Super CAP; M OPERATOR’S MANUAL</td>
<td>B–63294EN</td>
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<tr>
<td>MANUAL GUIDE For Milling PROGRAMMING MANUAL</td>
<td>B–63423EN</td>
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<tr>
<td>MANUAL GUIDE For Milling OPERATOR’S MANUAL</td>
<td>B–63424EN</td>
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<tr>
<td>PMC</td>
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<tr>
<td>PMC Ladder Language PROGRAMMING MANUAL</td>
<td>B–61863E</td>
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<tr>
<td>PMC C Language PROGRAMMING MANUAL</td>
<td>B–61863E–1</td>
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<tr>
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<tr>
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<td>B–62924EN</td>
</tr>
<tr>
<td>Profibus–DP Board OPERATOR’S MANUAL</td>
<td>B–62924EN</td>
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<tr>
<td>Ethernet Board/DATA SERVER Board OPERATOR’S MANUAL</td>
<td>B–63354EN</td>
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<td>FAST Ethernet Board/FAST DATA SERVER OPERATOR’S MANUAL</td>
<td>B–63644EN</td>
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<tr>
<td>DeviceNet Board OPERATOR’S MANUAL</td>
<td>B–63404EN</td>
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<tr>
<td>PC function</td>
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<tr>
<td>Screen Display Function OPERATOR’S MANUAL</td>
<td>B–63164EN</td>
</tr>
</tbody>
</table>

### Related manuals of SERVO MOTOR ai series

<table>
<thead>
<tr>
<th>Manual name</th>
<th>Specification number</th>
</tr>
</thead>
<tbody>
<tr>
<td>FANUC AC SERVO MOTOR ai series DESCRIPTIONS</td>
<td>B–65262EN</td>
</tr>
<tr>
<td>FANUC AC SERVO MOTOR ai series PARAMETER MANUAL</td>
<td>B–65270EN</td>
</tr>
<tr>
<td>FANUC AC SPINDLE MOTOR ai series DESCRIPTIONS</td>
<td>B–65272EN</td>
</tr>
<tr>
<td>FANUC AC SPINDLE MOTOR ai series PARAMETER MANUAL</td>
<td>B–65280EN</td>
</tr>
<tr>
<td>FANUC SERVO AMPLIFIER ai series DESCRIPTIONS</td>
<td>B–65282EN</td>
</tr>
<tr>
<td>FANUC SERVO MOTOR ai series MAINTENANCE MANUAL</td>
<td>B–65285EN</td>
</tr>
</tbody>
</table>
Related manuals of SERVO MOTOR α series

The following table lists the manuals related to SERVO MOTOR α series

<table>
<thead>
<tr>
<th>Manual name</th>
<th>Specification number</th>
</tr>
</thead>
<tbody>
<tr>
<td>FANUC AC SERVO MOTOR α series DESCRIPTIONS</td>
<td>B-65142</td>
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<td>FANUC AC SERVO MOTOR α series PARAMETER MANUAL</td>
<td>B-65150</td>
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<td>FANUC AC SPINDLE MOTOR α series DESCRIPTIONS</td>
<td>B-65152</td>
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<tr>
<td>FANUC AC SPINDLE MOTOR α series PARAMETER MANUAL</td>
<td>B-65160</td>
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<tr>
<td>FANUC SERVO AMPLIFIER α series DESCRIPTIONS</td>
<td>B-65162</td>
</tr>
<tr>
<td>FANUC SERVO MOTOR α series MAINTENANCE MANUAL</td>
<td>B-65165</td>
</tr>
</tbody>
</table>

Either of the following servo motors and the corresponding spindle can be connected to the CNC covered in this manual.

- FANUC SERVO MOTOR αi series
- FANUC SERVO MOTOR α series

This manual mainly assumes that the FANUC SERVO MOTOR i series of servo motor is used. For servo motor and spindle information, refer to the manuals for the servo motor and spindle that are actually connected.
1.1 GENERAL FLOW OF OPERATION OF CNC MACHINE TOOL

When machining the part using the CNC machine tool, first prepare the program, then operate the CNC machine by using the program.

1) First, prepare the program from a part drawing to operate the CNC machine tool.
How to prepare the program is described in the Chapter II. PROGRAMMING.

2) The program is to be read into the CNC system. Then, mount the workpieces and tools on the machine, and operate the tools according to the programming. Finally, execute the machining actually. How to operate the CNC system is described in the Chapter III. OPERATION.

Before the actual programming, make the machining plan for how to machine the part.

Machining plan

1. Determination of workpieces machining range
2. Method of mounting workpieces on the machine tool
3. Machining sequence in every machining process
4. Machining tools and machining

Decide the machining method in every machining process.

<table>
<thead>
<tr>
<th>Machining process</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machining procedure</td>
<td>Face cutting</td>
<td>Side cutting</td>
<td>Hole machining</td>
</tr>
<tr>
<td>1. Machining method</td>
<td>Rough</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Semi</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Finish</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Machining tools</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Machining conditions</td>
<td>Feedrate</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cutting depth</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Tool path</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Prepare the program of the tool path and machining condition according to the workpiece figure, for each machining.
1.2
NOTES ON READING THIS MANUAL

CAUTION
1 The function of an CNC machine tool system depends not only on the CNC, but on the combination of the machine tool, its magnetic cabinet, the servo system, the CNC, the operator’s panels, etc. It is too difficult to describe the function, programming, and operation relating to all combinations. This manual generally describes these from the stand–point of the CNC. So, for details on a particular CNC machine tool, refer to the manual issued by the machine tool builder, which should take precedence over this manual.
2 Headings are placed in the left margin so that the reader can easily access necessary information. When locating the necessary information, the reader can save time by searching though these headings.
3 This manual describes as many reasonable variations in equipment usage as possible. It cannot address every combination of features, options and commands that should not be attempted.
If a particular combination of operations is not described, it should not be attempted.

1.3
NOTES ON VARIOUS KINDS OF DATA

CAUTION
Machining programs, parameters, variables, etc. are stored in the CNC unit internal non–volatile memory. In general, these contents are not lost by the switching ON/OFF of the power. However, it is possible that a state can occur where precious data stored in the non–volatile memory has to be deleted, because of deletions from a maloperation, or by a failure restoration. In order to restore rapidly when this kind of mishap occurs, it is recommended that you create a copy of the various kinds of data beforehand.
II. PROGRAMMING
1 GENERAL
1.1 TOOL MOVEMENT ALONG WORKPIECE PARTS FIGURE–INTERPOLATION

Explanations

- Tool movement along a straight line

  The tool moves along straight lines and arcs constituting the workpiece parts figure (See II–4).

  The function of moving the tool along straight lines and arcs is called the interpolation.

  ![Fig. 1.1 (a) Tool movement along a straight line](image)

- Tool movement along an arc

  Program
  
  G01 X_ Y_ ;
  
  ![Fig. 1.1 (b) Tool movement along an arc](image)
Symbols of the programmed commands G01, G02, ... are called the preparatory function and specify the type of interpolation conducted in the control unit.

(a) Movement along straight line
G01 Y_ _;
X––Y––––;

(b) Movement along arc
G03X—Y—R—;

Control unit

Interpolation

a) Movement along straight line
b) Movement along arc

Fig. 1.1 (c) Interpolation function

NOTE
Some machines move tables instead of tools but this manual assumes that tools are moved against workpieces.
Movement of the tool at a specified speed for cutting a workpiece is called the feed.

Feedrates can be specified by using actual numerics. For example, to feed the tool at a rate of 150 mm/min, specify the following in the program: $F150.0$

The function of deciding the feed rate is called the feed function (See II–5).
A CNC machine tool is provided with a fixed position. Normally, tool change and programming of absolute zero point as described later are performed at this position. This position is called the reference position.

**Fig. 1.3.1 (a) Reference position**

The tool can be moved to the reference position in two ways:

1. **Manual reference position return (See III–3.1)**
   Reference position return is performed by manual button operation.

2. **Automatic reference position return (See II–6)**
   In general, manual reference position return is performed first after the power is turned on. In order to move the tool to the reference position for tool change thereafter, the function of automatic reference position return is used.
1.3.2
Coordinate System on Part Drawing and Coordinate System Specified by CNC – Coordinate System

Explanations

- **Coordinate system**

The following two coordinate systems are specified at different locations: (See II–7)

1) Coordinate system on part drawing
   The coordinate system is written on the part drawing. As the program data, the coordinate values on this coordinate system are used.

2) Coordinate system specified by the CNC
   The coordinate system is prepared on the actual machine tool table. This can be achieved by programming the distance from the current position of the tool to the zero point of the coordinate system to be set.
The positional relation between these two coordinate systems is determined when a workpiece is set on the table.

![Diagram showing the positional relation between two coordinate systems](image)

**Fig. 1.3.2 (c) Coordinate system specified by CNC and coordinate system on part drawing**

The tool moves on the coordinate system specified by the CNC in accordance with the command program generated with respect to the coordinate system on the part drawing, and cuts a workpiece into a shape on the drawing.

Therefore, in order to correctly cut the workpiece as specified on the drawing, the two coordinate systems must be set at the same position.

To set the two coordinate systems at the same position, simple methods shall be used according to workpiece shape, the number of machinings.

1. Using a standard plane and point of the workpiece.

![Diagram showing method of setting standard point](image)

- **Methods of setting the two coordinate systems in the same position**
(2) Mounting a workpiece directly against the jig

Meet the tool center to the reference position. And set the coordinate system specified by CNC at this position. (Jig shall be mounted on the predetermined point from the reference position.)

(3) Mounting a workpiece on a pallet, then mounting the workpiece and pallet on the jig

(Jig and coordinate system shall be specified by the same as (2)).
1.3.3
How to Indicate Command Dimensions for Moving the Tool – Absolute, Incremental Commands

**Explanations**

- **Absolute command**

  Command for moving the tool can be indicated by absolute command or incremental command (See II–8.1).

  The tool moves to a point at “the distance from zero point of the coordinate system” that is to the position of the coordinate values.

- **Incremental command**

  Specify the distance from the previous tool position to the next tool position.
1.4 CUTTING SPEED – SPINDLE SPEED FUNCTION

The speed of the tool with respect to the workpiece when the workpiece is cut is called the cutting speed.
As for the CNC, the cutting speed can be specified by the spindle speed in rpm unit.

\[
N = \frac{1000 \times v}{\pi \times D}
\]

Hence the following command is required:

\[ S250; \]

Commands related to the spindle speed are called the spindle speed function (See II–9).

Examples

<When a workpiece should be machined with a tool 100 mm in diameter at a cutting speed of 80 m/min.>
The spindle speed is approximately 250 rpm, which is obtained from \[ N = \frac{1000 \times 80}{\pi \times 100} \]. Hence the following command is required:

\[ S250; \]

Commands related to the spindle speed are called the spindle speed function (See II–9).
1.5 SELECTION OF TOOL USED FOR VARIOUS MACHINING – TOOL FUNCTION

When drilling, tapping, boring, milling or the like, is performed, it is necessary to select a suitable tool. When a number is assigned to each tool and the number is specified in the program, the corresponding tool is selected.

Examples

<When No.01 is assigned to a drilling tool>
When the tool is stored at location 01 in the ATC magazine, the tool can be selected by specifying T01. This is called the tool function (See II–10).
When machining is actually started, it is necessary to rotate the spindle, and feed coolant. For this purpose, on-off operations of spindle motor and coolant valve should be controlled.

The function of specifying the on-off operations of the components of the machine is called the miscellaneous function. In general, the function is specified by an M code (See II–11). For example, when M03 is specified, the spindle is rotated clockwise at the specified spindle speed.
1.7 PROGRAM CONFIGURATION

A group of commands given to the CNC for operating the machine is called the program. By specifying the commands, the tool is moved along a straight line or an arc, or the spindle motor is turned on and off. In the program, specify the commands in the sequence of actual tool movements.

![Program configuration diagram]

Fig. 1.7 (a) Program configuration

A group of commands at each step of the sequence is called the block. The program consists of a group of blocks for a series of machining. The number for discriminating each block is called the sequence number, and the number for discriminating each program is called the program number (See II–12).
Explanations

• Block

The block and the program have the following configurations.

![Block Configuration Diagram](image)

**Fig. 1.7 (b) Block configuration**

A block starts with a sequence number to identify the block and ends with an end–of–block code. This manual indicates the end–of–block code by ; (LF in the ISO code and CR in the EIA code).

• Program

![Program Configuration Diagram](image)

**Fig. 1.7 (c) Program configuration**

Normally, a program number is specified after the end–of–block (;) code at the beginning of the program, and a program end code (M02 or M30) is specified at the end of the program.
When machining of the same pattern appears at many portions of a program, a program for the pattern is created. This is called the subprogram. On the other hand, the original program is called the main program. When a subprogram execution command appears during execution of the main program, commands of the subprogram are executed. When execution of the subprogram is finished, the sequence returns to the main program.
1.8 TOOL FIGURE AND TOOL MOTION BY PROGRAM

Explanations

- **Machining using the end of cutter – Tool length compensation function** (See II–14.1)

  Usually, several tools are used for machining one workpiece. The tools have different tool length. It is very troublesome to change the program in accordance with the tools. Therefore, the length of each tool used should be measured in advance. By setting the difference between the length of the standard tool and the length of each tool in the CNC (data display and setting : see III–11), machining can be performed without altering the program even when the tool is changed. This function is called tool length compensation.

- **Machining using the side of cutter – Cutter compensation function** (See II–14.4,14.5,14.6)

  Because a cutter has a radius, the center of the cutter path goes around the workpiece with the cutter radius deviated.

If radius of cutters are stored in the CNC (Data Display and Setting : see III–11), the tool can be moved by cutter radius apart from the machining part figure. This function is called cutter compensation.
1.9 TOOL MOVEMENT RANGE – STROKE

Limit switches are installed at the ends of each axis on the machine to prevent tools from moving beyond the ends. The range in which tools can move is called the stroke.

Tools cannot enter this area. The area is specified by data in memory or a program.

Besides strokes defined with limit switches, the operator can define an area which the tool cannot enter using a program or data in memory. This function is called stroke check (see III-6.3).
2

CONTROLLED AXES
2.1 CONTROLLED AXES

Series 16i, Series 160i, Series 160is

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of basic controlled axes</td>
<td>3 axes</td>
<td>3 axes for each path (6 axes in total)</td>
</tr>
<tr>
<td>Controlled axes expansion (total)</td>
<td>Max. 8 axes (included in Cs axis)</td>
<td>Max. 8 axes for each path (included in Cs axis)</td>
</tr>
<tr>
<td>Basic simultaneously controlled axes</td>
<td>2 axes</td>
<td>2 axes for each path (4 axes in total)</td>
</tr>
<tr>
<td>Simultaneously controlled axes expansion (total)</td>
<td>Max. 6 axes</td>
<td>Max. 6 axes for each path</td>
</tr>
</tbody>
</table>

**NOTE**
The number of simultaneously controllable axes for manual operation jog feed, manual reference position return, or manual rapid traverse) is 1 or 3 (1 when bit 0 (JAX) of parameter 1002 is set to 0 and 3 when it is set to 1).

Series 18i, Series 180i, Series 180is

<table>
<thead>
<tr>
<th>Item</th>
<th>18i–MB5, 180i–MB5, 180is–MB</th>
<th>18i–MB, 180i–MB, 180is–MB</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of basic controlled axes</td>
<td>3 axes</td>
<td></td>
</tr>
<tr>
<td>Controlled axes expansion (total)</td>
<td>Max. 6 axes (included in Cs axis)</td>
<td></td>
</tr>
<tr>
<td>Basic simultaneously controlled axes</td>
<td>2 axes</td>
<td></td>
</tr>
<tr>
<td>Simultaneously controlled axes expansion (total)</td>
<td>Max. 5 axes</td>
<td>Max. 4 axes</td>
</tr>
</tbody>
</table>

**NOTE**
The number of simultaneously controllable axes for manual operation jog feed, manual reference position return, or manual rapid traverse) is 1 or 3 (1 when bit 0 (JAX) of parameter 1002 is set to 0 and 3 when it is set to 1).
2.2  
**AXIS NAME**

The names of three basic axes are always X, Y, and Z. The name of an additional axis can be set to A, B, C, U, V, or W by using parameter 1020. Parameter No. 1020 is used to determine the name of each axis. When this parameter is set to 0 or a character other than the valid characters is specified, an axis name from 1 to 8 is assigned by default. In two-path control, the basic three axis names are fixed to X, Y, and Z for either path, but the name of an additional axis can be selected from A, B, C, U, V, and W by parameter 1020. Duplicate axis names cannot be used in the same path, but the same axis name can be used in different paths.

**Limitations**

- **Default axis name**
  
  When a default axis name (1 to 8) is used, operation in the MEM mode and MDI mode is disabled.

- **Duplicate axis names**

  If a duplicate axis name is specified in the parameter, operation is enabled only for the axis specified first.

**NOTE**

In two-path control, axis information displayed on the CRT screen, such as the current position, may contain an axis name with a suffix indicating the related path (X1, X2, etc). This is intended to provide a comprehensible indication of the path to which the axis belongs. The suffix cannot be used in a program; the axis name should be specified as X, Y, Z, U, V, W, A, B, or C.
2.3 INCREMENT SYSTEM

The increment system consists of the least input increment (for input) and least command increment (for output). The least input increment is the least increment for programming the travel distance. The least command increment is the least increment for moving the tool on the machine. Both increments are represented in mm, inches, or deg.

The increment system is classified into IS–B and IS–C. Select IS–B or IS–C using bit 1 (ISC) of parameter 1004. When the IS–C increment system is selected, it is applied to all axes and the 1/10 increment system option is required.

<table>
<thead>
<tr>
<th>Name of increment system</th>
<th>Least input increment</th>
<th>Least command increment</th>
<th>Maximum stroke</th>
</tr>
</thead>
<tbody>
<tr>
<td>IS–B</td>
<td>0.001mm</td>
<td>0.001mm</td>
<td>99999.999mm</td>
</tr>
<tr>
<td></td>
<td>0.0001inch</td>
<td>0.0001inch</td>
<td>9999.9999inch</td>
</tr>
<tr>
<td></td>
<td>0.001deg</td>
<td>0.001deg</td>
<td>99999.999deg</td>
</tr>
<tr>
<td>IS–C</td>
<td>0.0001mm</td>
<td>0.0001mm</td>
<td>9999.9999mm</td>
</tr>
<tr>
<td></td>
<td>0.00001inch</td>
<td>0.00001inch</td>
<td>9999.9999inch</td>
</tr>
<tr>
<td></td>
<td>0.0001deg</td>
<td>0.0001deg</td>
<td>99999.9999deg</td>
</tr>
</tbody>
</table>

The least command increment is either metric or inch depending on the machine tool. Set metric or inch to the parameter INM (No.100#0). For selection between metric and inch for the least input increment, G code (G20 or G21) or a setting parameter selects it.

Combined use of the inch system and the metric system is not allowed. There are functions that cannot be used between axes with different unit systems (circular interpolation, cutter compensation, etc.). For the increment system, see the machine tool builder’s manual.
2.4 MAXIMUM STROKE

Maximum stroke = Least command increment \times 99999999
See 2.3 Increment System.

Table 2.4 (a) Maximum strokes

<table>
<thead>
<tr>
<th>Increment system</th>
<th>Maximum stroke</th>
</tr>
</thead>
<tbody>
<tr>
<td>IS–B</td>
<td>Metric machine system</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Inch machine system</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>IS–C</td>
<td>Metric machine system</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Inch machine system</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NOTE
1. A command exceeding the maximum stroke cannot be specified.
2. The actual stroke depends on the machine tool.
3 PREPARATORY FUNCTION (G FUNCTION)

A number following address G determines the meaning of the command for the concerned block.

G codes are divided into the following two types.

<table>
<thead>
<tr>
<th>Type</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>One-shot G code</td>
<td>The G code is effective only in the block in which it is specified.</td>
</tr>
<tr>
<td>Modal G code</td>
<td>The G code is effective until another G code of the same group is specified.</td>
</tr>
</tbody>
</table>

(Example)
G01 and G00 are modal G codes in group 01.

\[
\begin{align*}
G01X\rightarrow; \\
Z; \\
X; \\
G00Z\rightarrow;
\end{align*}
\]

G01 is effective in this range.
Explanations

1. When the clear state (bit 6 (CLR) of parameter No. 3402) is set at power–up or reset, the modal G codes are placed in the states described below.
   (1) The modal G codes are placed in the states marked with □ as indicated in Table 3.
   (2) G20 and G21 remain unchanged when the clear state is set at power–up or reset.
   (3) Which status G22 or G23 at power on is set by parameter G23 (No. 3402#7). However, G22 and G23 remain unchanged when the clear state is set at reset.
   (4) The user can select G00 or G01 by setting bit 0 (G01) of parameter No. 3402.
   (5) The user can select G90 or G91 by setting bit 3 (G91) of parameter No. 3402.
   (6) The user can select G17, G18, or G19 by setting bit 1 (parameter G18) and bit 2 (parameter G19) of parameter No. 3402.

2. G codes other than G10 and G11 are one–shot G codes.

3. When a G code not listed in the G code list is specified, or a G code that has no corresponding option is specified, P/S alarm No. 010 is output.

4. Multiple G codes can be specified in the same block if each G code belongs to a different group. If multiple G codes that belong to the same group are specified in the same block, only the last G code specified is valid.

5. If a G code belonging to group 01 is specified in a canned cycle, the canned cycle is cancelled. This means that the same state set by specifying G80 is set. Note that the G codes in group 01 are not affected by a G code specifying a canned cycle.

6. G codes are indicated by group.

7. The group of G60 is switched according to the setting of the MDL bit (bit 0 of parameter 5431). (When the MDL bit is set to 0, the 00 group is selected. When the MDL bit is set to 1, the 01 group is selected.)
### G code list for M series (1/4)

<table>
<thead>
<tr>
<th>G code</th>
<th>Group</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>G00</td>
<td></td>
<td>Positioning</td>
</tr>
<tr>
<td>G01</td>
<td>01</td>
<td>Linear interpolation</td>
</tr>
<tr>
<td>G02</td>
<td></td>
<td>Circular interpolation/Helical interpolation CW</td>
</tr>
<tr>
<td>G03</td>
<td></td>
<td>Circular interpolation/Helical interpolation CCW</td>
</tr>
<tr>
<td>G02.2, G03.2</td>
<td></td>
<td>Involute interpolation</td>
</tr>
<tr>
<td>G02.3, G03.3</td>
<td></td>
<td>Exponential function interpolation</td>
</tr>
<tr>
<td>G02.4, G03.4</td>
<td></td>
<td>Three-dimensional circular interpolation</td>
</tr>
<tr>
<td>G04</td>
<td>00</td>
<td>Dwell, Exact stop</td>
</tr>
<tr>
<td>G05</td>
<td></td>
<td>High speed cycle machining</td>
</tr>
<tr>
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<tr>
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<td>G31.9</td>
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<td>G45</td>
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<th>Function</th>
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<th>Group</th>
<th>Function</th>
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<td>Synchronization start of electronic gear box (EGB) (for two axes programming)</td>
</tr>
<tr>
<td>G81</td>
<td>09</td>
<td>Drilling cycle, spot boring cycle or external operation function</td>
</tr>
<tr>
<td>G81.1</td>
<td>00</td>
<td>Chopping function</td>
</tr>
<tr>
<td>G81.5</td>
<td>24</td>
<td>Synchronization start of electronic gear box (EGB) (for two axes programming)</td>
</tr>
<tr>
<td>G82</td>
<td>09</td>
<td>Drilling cycle or counter boring cycle</td>
</tr>
<tr>
<td>G83</td>
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<tr>
<td>G84</td>
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<td>G85</td>
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<tr>
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<td></td>
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<tr>
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</tr>
<tr>
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<tr>
<td>G161</td>
<td></td>
<td>In–feed control function(for grinding machine)</td>
</tr>
</tbody>
</table>
4

INTERPOLATION FUNCTIONS
4.1 POSITIONING (G00)

The G00 command moves a tool to the position in the workpiece system specified with an absolute or an incremental command at a rapid traverse rate.
In the absolute command, coordinate value of the end point is programmed.
In the incremental command the distance the tool moves is programmed.

Format

\[
\text{G00 } \text{IP};
\]

\(\text{IP}\): For an absolute command, the coordinates of an end position, and for an incremental command, the distance the tool moves.

Explanations

Either of the following tool paths can be selected according to bit 1 of parameter LRP No. 1401.

- **Nonlinear interpolation positioning**
  The tool is positioned with the rapid traverse rate for each axis separately. The tool path is normally straight.

- **Linear interpolation positioning**
  The tool path is the same as in linear interpolation (G01). The tool is positioned within the shortest possible time at a speed that is not more than the rapid traverse rate for each axis.

![Diagram of tool paths]

The rapid traverse rate in G00 command is set to the parameter No. 1420 for each axis independently by the machine tool builder. In the positioning mode actuated by G00, the tool is accelerated to a predetermined speed at the start of a block and is decelerated at the end of a block. Execution proceeds to the next block after confirming the in–position.
“In–position” means that the feed motor is within the specified range. This range is determined by the machine tool builder by setting to parameter (No. 1826).
In–position check for each block can be disabled by setting bit 5 (NCI) of parameter No.1601 accordingly.
Limitations

The rapid traverse rate cannot be specified in the address F. Even if linear interpolation positioning is specified, nonlinear interpolation positioning is used in the following cases. Therefore, be careful to ensure that the tool does not foul the workpiece.

- G28 specifying positioning between the reference and intermediate positions.
- G53
For accurate positioning without play of the machine (backlash), final positioning from one direction is available.

An overrun and a positioning direction are set by the parameter (No. 5440). Even when a commanded positioning direction coincides with that set by the parameter, the tool stops once before the end point. G60, which is an one-shot G-code, can be used as a modal G-code in group 01 by setting 1 to the parameter (No. 5431 bit 0 MDL). This setting can eliminate specifying a G60 command for every block. Other specifications are the same as those for an one-shot G60 command.

When an one-shot G code is specified in the single direction positioning mode, the one-shot G command is effective like G codes in group 01.

### Examples

<table>
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<tr>
<th>When one-shot G60 commands are used.</th>
<th>When modal G60 command is used.</th>
</tr>
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</tr>
<tr>
<td>G60 X0Y0;</td>
<td>X0Y0; Single direction positioning</td>
</tr>
<tr>
<td>G60 X100;</td>
<td>X100;</td>
</tr>
<tr>
<td>G60 Y100;</td>
<td>Y100;</td>
</tr>
<tr>
<td>G04 X10;</td>
<td>G04X10; Single direction positioning mode cancel</td>
</tr>
<tr>
<td>G00 X0Y0;</td>
<td>G00X0Y0;</td>
</tr>
</tbody>
</table>
Restrictions

- During canned cycle for drilling, no single direction positioning is effected in Z axis.
- No single direction positioning is effected in an axis for which no overrun has been set by the parameter.
- When the move distance 0 is commanded, the single direction positioning is not performed.
- The direction set to the parameter is not effected by mirror image.
- The single direction positioning does not apply to the shift motion in the canned cycles of G76 and G87.
4.3 LINEAR INTERPOLATION (G01)

Tools can move along a line

Format

G01 [IP] F_;
IP: For an absolute command, the coordinates of an end point, and for an incremental command, the distance the tool moves.
F_: Speed of tool feed (Feedrate)

Explanations

A tool moves along a line to the specified position at the feedrate specified in F.
The feedrate specified in F is effective until a new value is specified. It need not be specified for each block.
The feedrate commanded by the F code is measured along the tool path.
If the F code is not commanded, the feedrate is regarded as zero.
The feedrate of each axis direction is as follows.

\[
\begin{align*}
G01 & \alpha \beta \gamma \zeta F_; \\
\text{Feed rate of } \alpha \text{ axis direction:} & \quad F_\alpha = \frac{\alpha}{L} \times f \\
\text{Feed rate of } \beta \text{ axis direction:} & \quad F_\beta = \frac{\beta}{L} \times f \\
\text{Feed rate of } \gamma \text{ axis direction:} & \quad F_\gamma = \frac{\gamma}{L} \times f \\
\text{Feed rate of } \zeta \text{ axis direction:} & \quad F_\zeta = \frac{\zeta}{L} \times f \\
L & = \sqrt{\alpha^2 + \beta^2 + \gamma^2 + \zeta^2}
\end{align*}
\]

The feed rate of the rotary axis is commanded in the unit of deg/min (the unit is decimal point position).

When the straight line axis \( \alpha \) (such as X, Y, or Z) and the rotating axis \( \beta \) (such as A, B, or C) are linearly interpolated, the feed rate is that in which the tangential feed rate in the \( \alpha \) and \( \beta \) cartesian coordinate system is commanded by F(mm/min).
\( \beta \)-axis feedrate is obtained; at first, the time required for distribution is calculated by using the above formula, then the \( \beta \)-axis feedrate unit is changed to deg/min.
A calculation example is as follows.
G91 G01 X20.0 B 40.0 F 300.0 ;
This changes the unit of the C axis from 40.0 deg to 40mm with metric input. The time required for distribution is calculated as follows:

\[
\frac{\sqrt{20^2 + 40^2}}{300} \approx 0.14907 \text{ (min)}
\]

The feed rate for the C axis is

\[
\frac{40}{0.14907} \approx 268.3 \text{ deg/min}
\]

In simultaneous 3 axes control, the feed rate is calculated the same way as in 2 axes control.

**Examples**

- **Linear interpolation**

  (G91) G01 X200.0 Y100.0 F 200.0 ;

- **Feedrate for the rotation axis**

  G91 G01 C –90.0 G 300.0 ; Feed rate of 300 deg/min
4.4 CIRCULAR INTERPOLATION (G02, G03)

The command below will move a tool along a circular arc.

Format

Arc in the XpYp plane

G17  \{  G02 \  G03  \} \ Xp\_Yp\_  \{  I\_ J\_ R\_  \}  \ F\_  ;

Arc in the ZpXp plane

G18  \{  G02 \  G03  \} \ Xp\_ p\_  \{  I\_ K\_ R\_  \}  \ F\_  

Arc in the YpZp plane

G19  \{  G02 \  G03  \} \ Yp\_ Zp\_  \{  J\_ K\_ R\_  \}  \ F\_  

Table. 4.4  Description of the Command Format

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
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<td>Specification of arc on XpYp plane</td>
</tr>
<tr>
<td>G18</td>
<td>Specification of arc on ZpXp plane</td>
</tr>
<tr>
<td>G19</td>
<td>Specification of arc on YpZp plane</td>
</tr>
<tr>
<td>G02</td>
<td>Circular Interpolation  Clockwise direction (CW)</td>
</tr>
<tr>
<td>G03</td>
<td>Circular Interpolation  Counterclockwise direction (CCW)</td>
</tr>
<tr>
<td>Xp_</td>
<td>Command values of X axis or its parallel axis (set by parameter No. 1022)</td>
</tr>
<tr>
<td>Yp_</td>
<td>Command values of Y axis or its parallel axis (set by parameter No. 1022)</td>
</tr>
<tr>
<td>Zp_</td>
<td>Command values of Z axis or its parallel axis (set by parameter No. 1022)</td>
</tr>
<tr>
<td>I_</td>
<td>Xp_ axis distance from the start point to the center of an arc with sign</td>
</tr>
<tr>
<td>J_</td>
<td>Yp_ axis distance from the start point to the center of an arc with sign</td>
</tr>
<tr>
<td>k_</td>
<td>Zp_ axis distance from the start point to the center of an arc with sign</td>
</tr>
<tr>
<td>R_</td>
<td>Arc radius (with sign)</td>
</tr>
<tr>
<td>F_</td>
<td>Feedrate along the arc</td>
</tr>
</tbody>
</table>
**Explanations**

- **Direction of the circular interpolation**
  “Clockwise” (G02) and “counterclockwise” (G03) on the X_pY_p plane (Z_pX_p plane or Y_pZ_p plane) are defined when the X_pY_p plane is viewed in the positive-to-negative direction of the Z_p axis (Y_p axis or X_p axis, respectively) in the Cartesian coordinate system. See the figure below.

- **Distance moved on an arc**
  The end point of an arc is specified by address X_p, Y_p or Z_p, and is expressed as an absolute or incremental value according to G90 or G91. For the incremental value, the distance of the end point which is viewed from the start point of the arc is specified.

- **Distance from the start point to the center of arc**
  The arc center is specified by addresses I, J, and K for the X_p, Y_p, and Z_p axes, respectively. The numerical value following I, J, or K, however, is a vector component in which the arc center is seen from the start point, and is always specified as an incremental value irrespective of G90 and G91, as shown below. I, J, and K must be signed according to the direction.

I0, J0, and K0 can be omitted. When X_p, Y_p, and Z_p are omitted (the end point is the same as the start point) and the center is specified with I, J, and K, a 360° arc (circle) is specified.

G021; Command for a circle
If the difference between the radius at the start point and that at the end point exceeds the permitted value in a parameter (No.3410), an P/S alarm (No.020) occurs.
• **Arc radius**

The distance between an arc and the center of a circle that contains the arc can be specified using the radius, R, of the circle instead of I, J, and K. In this case, one arc is less than 180°, and the other is more than 180° are considered. When an arc exceeding 180° is commanded, the radius must be specified with a negative value. If Xp, Yp, and Zp are all omitted, if the end point is located at the same position as the start point and when R is used, an arc of 0° is programmed G02R ; (The cutter does not move.)

```
For arc (1)(less than 180°)
G91 G02 Xp60.0 Yp20.0 R50.0 F300.0 ;
For arc (2)(greater than 180°)
G91 G02 Xp60.0 Yp20.0 R-50.0 F300.0 ;
```

![Diagram showing arc radius](image)

• **Feedrate**

The feedrate in circular interpolation is equal to the feed rate specified by the F code, and the feedrate along the arc (the tangential feedrate of the arc) is controlled to be the specified feedrate. The error between the specified feedrate and the actual tool feedrate is ±2% or less. However, this feed rate is measured along the arc after the cutter compensation is applied.

• **Restrictions**

If I, J, K, and R addresses are specified simultaneously, the arc specified by address R takes precedence and the other are ignored.

If an axis not comprising the specified plane is commanded, an alarm is displayed.

For example, if axis U is specified as a parallel axis to X axis when plane XY is specified, an P/S alarm (No.028)is displayed.

When an arc having a center angle approaching 180° is specified, the calculated center coordinates may contain an error. In such a case, specify the center of the arc with I, J, and K.
Examples

The above tool path can be programmed as follows:

1. In absolute programming
   
   G92X200.0 Y40.0 Z0;
   
   G90 G03 X140.0 Y100.0 R60.0 F300.;
   
   G02 X120.0 Y60.0 R50.0;
   
   or
   
   G92X200.0 Y40.0 Z0;
   
   G90 G03 X140.0 Y100.0 I=60.0 F300.;
   
   G02 X120.0 Y60.0 I=50.0;

2. In incremental programming
   
   G91 G03 X-60.0 Y60.0 R60.0 F300.;
   
   G02 X-20.0 Y-40.0 R50.0;
   
   or
   
   G91 G03 X-60.0 Y60.0 I-60.0 F300.;
   
   G02 X-20.0 Y-40.0 I-50.0;
4.5 HELICAL INTERPOLATION (G02, G03)

Format

Helical interpolation which moved helically is enabled by specifying up to two other axes which move synchronously with the circular interpolation by circular commands.

\[
\begin{align*}
G17 & \{ G02 \text{ } G03 \} \{ Xp_{-}Yp_{-} \{ I_{-}J_{-} \{ R_{-} \} \} \alpha_{-}(\beta_{-})F_{-}; \} \\
G18 & \{ G02 \text{ } G03 \} \{ Xp_{-}Zp_{-} \{ I_{-}K_{-} \{ R_{-} \} \} \alpha_{-}(\beta_{-})F_{-}; \} \\
G19 & \{ G02 \text{ } G03 \} \{ Yp_{-}Zp_{-} \{ J_{-}K_{-} \{ R_{-} \} \} \alpha_{-}(\beta_{-})F_{-}; \}
\end{align*}
\]

\( \alpha, \beta \): Any one axis where circular interpolation is not applied.
Up to two other axes can be specified.

Explanations

The command method is to simply or secondary add a move command axis which is not circular interpolation axes. An F command specifies a feed rate along a circular arc. Therefore, the feed rate of the linear axis is as follows:

\[
F_x = \frac{\text{Length of linear axis}}{\text{Length of circular arc}}
\]

Determine the feed rate so the linear axis feed rate does not exceed any of the various limit values. Bit 0 (HFC) of parameter No. 1404 can be used to prevent the linear axis feedrate from exceeding various limit values.

Restrictions

- Cutter compensation is applied only for a circular arc.
- Tool offset and tool length compensation cannot be used in a block in which a helical interpolation is commanded.
4.6 HELICAL INTERPOLATION B (G02, G03)

Format

Helical interpolation B moves the tool in a helical manner. This interpolation can be executed by specifying the circular interpolation command together with up to four additional axes in simple high-precision contour control mode (see II–19.7).

Explanations

Basically, the command can be specified by adding two movement axes to a standard helical interpolation command (see II–4.5). Address F should be followed by a tangential velocity, which has been determined by also taking movement along the linear axes into consideration.

Limitations

- The command of helical interpolation B can be specified only in AI contour control mode.
- Cutter compensation is applied only to an arc.
- In a block containing the helical interpolation command, the tool offset command or tool length compensation command cannot be specified.
4.7 SPIRAL INTERPOLATION, CONICAL INTERPOLATION (G02, G03)

Format

- Spiral interpolation

Spiral interpolation is enabled by specifying the circular interpolation command together with a desired number of revolutions or a desired increment (decrement) for the radius per revolution. Conical interpolation is enabled by specifying the spiral interpolation command together with one or two additional axes of movement, as well as a desired increment (decrement) for the position along the additional axes per spiral revolution.

<table>
<thead>
<tr>
<th>XpYp plane</th>
<th>ZpXp plane</th>
<th>YpZp plane</th>
</tr>
</thead>
</table>
| \[G17\] \{ \begin{align*} \text{G02} & \quad \text{G03} \\
|          & \quad \text{X, Y, J, I, Q, L, F ;} \end{align*} \right. \right. \right. |
| \[G18\] \{ \begin{align*} \text{G02} & \quad \text{G03} \\
|          & \quad \text{Z, X, K, I, Q, L, F ;} \end{align*} \right. \right. \right. |
| \[G19\] \{ \begin{align*} \text{G02} & \quad \text{G03} \\
|          & \quad \text{Y, Z, J, K, Q, L, F ;} \end{align*} \right. \right. \right. |

\(X, Y, Z\) Coordinates of the end point

\(L\) Number of revolutions (positive value without a decimal point)(**1)

\(Q\) Radius increment or decrement per spiral revolution(**1)

\(I, J, K\) Signed distance from the start point to the center

(fsame as the distance specified for circular interpolation)

\(F\) Feedrate

**(1)** Either the number of revolutions (\(L\)) or the radius increment or decrement (\(Q\)) can be omitted. When \(L\) is omitted, the number of revolutions is automatically calculated from the distance between the current position and the center, the position of the end point, and the radius increment or decrement. When \(Q\) is omitted, the radius increment or decrement is automatically calculated from the distance between the current position and the center, the position of the end point, and the number of revolutions. If both \(L\) and \(Q\) are specified but their values contradict, \(Q\) takes precedence. Generally, either \(L\) or \(Q\) should be specified. The \(L\) value must be a positive value without a decimal point. To specify four revolutions plus 90\(^\circ\), for example, round the number of revolutions up to five and specify L5.
• Conical interpolation

XpYp plane

G17 \{ G02
G03 \} X_ Y_ Z_ I_ J_ K_ Q_ L_ F_ ;

ZpXp plane

G18 \{ G02
G03 \} Z_ X_ Y_ K_ I_ J_ Q_ L_ F_ ;

YpZp plane

G19 \{ G02
G03 \} Y_ Z_ X_ J_ K_ I_ Q_ L_ F_ ;

X, Y, Z Coordinates of the end point
L Number of revolutions (positive value without a decimal point)(*1)
Q (Radius increment or decrement per spiral revolution)(*1)
I, J, K Two of the three values represent a signed vector from the start point to the center. The remaining value is a height increment or decrement per spiral revolution in conical interpolation(*1)(*2)
When the XpYp plane is selected:
The I and J values represent a signed vector from the start point to the center.
The K value represents a height increment or decrement per spiral revolution.
When the ZpXp plane is selected:
The K and I values represent a signed vector from the start point to the center.
The J value represents a height increment or decrement per spiral revolution.
When the YpZp plane is selected:
The J and K values represent a signed vector from the start point to the center.
The I value represents a height increment or decrement per spiral revolution.
F Feedrate (determined by taking movement along the linear axes into consideration)

(*1) One of the height increment/decrement (I, J, K), radius increment/decrement (Q), and the number of revolutions (L) must be specified. The other two items can be omitted.

- Sample command for the XpYp plane

G17 \{ G02
G03 \} X_ Y_ I_ J_ Z_ ; \{ K_ Q_ L_ \} F_ ;

If both L and Q are specified, but their values contradict, Q takes precedence. If both L and a height increment or decrement are specified, but their values contradict, the height increment or decrement takes precedence. If both Q and a height increment or decrement are specified, but their values contradict, Q takes precedence. The L value must be a positive value without a decimal point. To specify four revolutions plus 90°, for example, round the number of revolutions up to five and specify L5.

(*2) When two axes (of height) other than plane axes are specified, the height increment or decrement (I, J, K) cannot be specified. Specify either a desired radius increment or decrement (Q) or a desired number of revolutions (L).
Explanations

- **Function of spiral interpolation**
  Spiral interpolation in the XY plane is defined as follows:
  \[(X - X_0)^2 + (Y - Y_0)^2 = (R + Q')^2\]
  where
  - \(X_0\): X coordinate of the center
  - \(Y_0\): Y coordinate of the center
  - \(R\): Radius at the beginning of spiral interpolation
  - \(Q'\): Variation in radius

  When the programmed command is assigned to this function, the following expression is obtained:
  \[(X - X_S - I)^2 + (Y - Y_S - J)^2 = \left(\frac{\theta}{360} + \left(L' + \frac{\theta}{360}\right) Q\right)^2\]
  where
  - \(X_S\): X coordinate of the start point
  - \(Y_S\): Y coordinate of the start point
  - \(I\): X coordinate of the vector from the start point to the center
  - \(J\): Y coordinate of the vector from the start point to the center
  - \(R\): Radius at the beginning of spiral interpolation
  - \(Q\): Radius increment or decrement per spiral revolution
  - \(L'\): (Current number of revolutions) \(- 1\)
  - \(\theta\): Angle between the start point and the current position (degrees)

- **Movement between blocks**
  Block overlap between a spiral/conical interpolation block and other blocks is performed only in simple high-precision contour control mode (see II–NO TAG). In other modes, the movement is decelerated and stopped in the block before the spiral/conical interpolation block, after which interpolation starts. After completion of the spiral/conical interpolation block, the movement is decelerated and stopped, then the next block is executed.

- **Controlled axes**
  For conical interpolation, two axes of a plane and two additional axes, that is, four axes in total, can be specified. A rotation axis can be specified as the additional axis.

- **Cutter compensation C**
  The spiral or conical interpolation command can be programmed in cutter compensation C mode. At the start and end points of the block, a virtual circle around the center of the spiral interpolation is drawn. Cutter compensation is performed along the virtual circle, then spiral interpolation is performed about the result of the cutter compensation. When both the start point and end point are at the center, no virtual circle can be drawn. If drawing is attempted, P/S alarm No. 5124 is issued.

- **Feedrate clamping by arc radius**
  During spiral interpolation, the function for clamping the feedrate by arc radius (parameters 1730 to 1732) is enabled. The feedrate may decrease as the tool approaches the center of the spiral.

- **Dry run**
  When the dry run signal is inverted from 0 to 1 or from 1 to 0 during movement along an axis, the movement is accelerated or decelerated to the desired speed without first reducing the speed to zero.
Limitations

- **Radius**
  In spiral or conical interpolation, R for specifying an arc radius cannot be specified.

- **Corner deceleration**
  Corner deceleration between the spiral/conical interpolation block and other blocks can be performed only in simple high-precision contour control mode.

- **Feed functions**
  The functions of feed per rotation, inverse time feed, F command with one digit, and automatic corner override cannot be used.

- **Program restart**
  A program including spiral or conical interpolation cannot be restarted.

- **Retrace**
  A program including spiral or conical interpolation cannot be retraced.

- **Normal direction control**
  Spiral interpolation and conical interpolation cannot be specified in normal direction control mode.

Examples

- **Spiral interpolation**

The path indicated above is programmed with absolute and incremental values, as shown below:

This sample path has the following values:

- Start point : (0, 100.0)
- End point (X, Y) : (0, -30.0)
- Distance to the center (I, J) : (0, -100.0)
- Radius increment or decrement (Q) : -20.0
- Number of revolutions (L) : 4.
(1) With absolute values, the path is programmed as follows:
G90 G02 X0 Y–30.0 I0 J–100.0 Q–20.0 L4 F300;
(2) With incremental values, the path is programmed as follows:
G91 G02 X0 Y–130.0 I0 J–100.0 Q–20.0 L4 F300;
(Either the Q or L setting can be omitted.)

• Conical Interpolation

The sample path shown above is programmed with absolute and incremental values as follows:
This sample path has the following values:
- Start point : (0, 100.0, 0)
- End point (X, Y, Z) : (0, –37.5, 62.5)
- Distance to the center (I, J) : (0, –100.0)
- Radius increment or decrement (Q) : –25.0
- Height increment or decrement (K) : 25.0
- Number of revolutions (L) : 3

(1) With absolute values, the path is programmed as follows:
G90 G02 X0 Y–37.5 Z62.5 I0 J–100.0 K25.0 Q–25.0 L3 F300;
(2) With incremental values, the path is programmed as follows:
G91 G02 X0 Y–137.5 Z62.5 I0 J–100.0 K25.0 Q–25.0 L3 F300;
4.8 POLAR COORDINATE INTERPOLATION (G12.1, G13.1)

Polar coordinate interpolation is a function that exercises contour control in converting a command programmed in a Cartesian coordinate system to the movement of a linear axis (movement of a tool) and the movement of a rotary axis (rotation of a workpiece). This function is useful for grinding a cam shaft.

Format

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>G12.1</td>
<td>Starts polar coordinate interpolation mode (enables polar coordinate interpolation) Specify linear or circular interpolation using coordinates in a Cartesian coordinate system consisting of a linear axis and rotary axis (virtual axis).</td>
</tr>
<tr>
<td>G13.1</td>
<td>Polar coordinate interpolation mode is cancelled (for not performing polar coordinate interpolation) Specify G12.1 and G13.1 in Separate Blocks.</td>
</tr>
</tbody>
</table>

Explanations

- **Polar coordinate interpolation plane**

G12.1 starts the polar coordinate interpolation mode and selects a polar coordinate interpolation plane (Fig. 4.8 (a)). Polar coordinate interpolation is performed on this plane.

![Fig. 4.8 (a) Polar coordinate interpolation plane.]

When the power is turned on or the system is reset, polar coordinate interpolation is canceled (G13.1).
The linear and rotation axes for polar coordinate interpolation must be set in parameters (No. 5460 and 5461) beforehand.

**CAUTION**
The plane used before G12.1 is specified (plane selected by G17, G18, or G19) is canceled. It is restored when G13.1 (canceling polar coordinate interpolation) is specified. When the system is reset, polar coordinate interpolation is canceled and the plane specified by G17, G18, or G19 is used.
In the polar coordinate interpolation mode, program commands are specified with Cartesian coordinates on the polar coordinate interpolation plane. The axis address for the rotation axis is used as the axis address for the second axis (virtual axis) in the plane. Whether a diameter or radius is specified for the first axis in the plane is the same as for the rotation axis regardless of the specification for the first axis in the plane. The virtual axis is at coordinate 0 immediately after G12.1 is specified. Polar interpolation is started assuming the angle of 0 for the position of the tool when G12.1 is specified.

Specify the feedrate as a speed (relative speed between the workpiece and tool) tangential to the polar coordinate interpolation plane (Cartesian coordinate system) using F.

**G codes which can be specified in the polar coordinate interpolation mode**

- G01 ............. Linear interpolation
- G02, G03 ........ Circular interpolation
- G04 ............. Dwell, Exact stop
- G40, G41, G42 . . . Cutter compensation
  (Polar coordinate interpolation is applied to the path after cutter compensation.)
- G65, G66, G67 . . . Custom macro command
- G90, G91 ........ Absolute command, incremental command
- G94, G95 ........ Feed per minute, feed per revolution

**Circular interpolation in the polar coordinate plane**

The addresses for specifying the radius of an arc for circular interpolation (G02 or G03) in the polar coordinate interpolation plane depend on the first axis in the plane (linear axis).

- I and J in the Xp–Yp plane when the linear axis is the X–axis or an axis parallel to the X–axis.
- J and K in the Yp–Zp plane when the linear axis is the Y–axis or an axis parallel to the Y–axis.
- K and I in the Zp–Xp plane when the linear axis is the Z–axis or an axis parallel to the Z–axis.

The radius of an arc can be specified also with an R command.

**Movement along axes not in the polar coordinate interpolation plane in the polar coordinate interpolation mode**

The tool moves along such axes normally, independent of polar coordinate interpolation.

**Current position display in the polar coordinate interpolation mode**

Actual coordinates are displayed. However, the remaining distance to move in a block is displayed based on the coordinates in the polar coordinate interpolation plane (Cartesian coordinates).

**Limitations**

**Coordinate system for the polar coordinate interpolation**

Before G12.1 is specified, a local coordinate system (or workpiece coordinate system) where the center of the rotary axis is the origin of the coordinate system must be set. In the G12.1 mode, the coordinate system must not be changed (G92, G52, G53, relative coordinate reset, G54 through G59, etc.).
- **Tool offset command**
  The polar coordinate interpolation mode cannot be started or terminated (G12.1 or G13.1) in the tool offset mode (G41 or G42). G12.1 or G13.1 must be specified in the tool offset canceled mode (G40).

- **Tool length offset command**
  Tool length offset must be specified in the polar coordinate interpolation cancel mode before G12.1 is specified. It cannot be specified in the polar coordinate interpolation mode. Furthermore, no offset values can be changed in the polar coordinate interpolation mode.

- **Tool offset command**
  A tool offset must be specified before the G12.1 mode is set. No offset can be changed in the G12.1 mode.

- **Program restart**
  For a block in the G12.1 mode, the program cannot be restarted.

- **Cutting feedrate for the rotation axis**
  Polar coordinate interpolation converts the tool movement for a figure programmed in a Cartesian coordinate system to the tool movement in the rotation axis (C-axis) and the linear axis (X-axis). When the tool moves closer to the center of the workpiece, the C-axis component of the feedrate becomes larger and may exceed the maximum cutting feedrate for the C-axis (set in parameter (No. 1422)), causing an alarm (see the figure below). To prevent the C-axis component from exceeding the maximum cutting feedrate for the C-axis, reduce the feedrate specified with address F or create a program so that the tool (center of the tool when cutter compensation is applied) does not move close to the center of the workpiece.

### WARNING

Consider lines L1, L2, and L3. ΔX is the distance the tool moves per time unit at the feedrate specified with address F in the Cartesian coordinate system. As the tool moves from L1 to L2 to L3, the angle at which the tool moves per time unit corresponding to ΔX in the Cartesian coordinate system increases from 1 to 2 to 3.

In other words, the C-axis component of the feedrate becomes larger as the tool moves closer to the center of the workpiece. The C component of the feedrate may exceed the maximum cutting feedrate for the C-axis because the tool movement in the Cartesian coordinate system has been converted to the tool movement for the C-axis and the X-axis.

\[
L : \text{Distance (in mm) between the tool center and workpiece center when the tool center is the nearest to the workpiece center}
\]

\[
R : \text{Maximum cutting feedrate (deg/min) of the C axis}
\]

Then, a speed specifiable with address F in polar coordinate interpolation can be given by the formula below. Specify a speed allowed by the formula. The formula provides a theoretical value; in practice, a value slightly smaller than a theoretical value may need to be used due to a calculation error.

\[
F < L \times R \times \frac{\pi}{180} \text{ (mm/min)}
\]
### Example of Polar Coordinate Interpolation Program

Based on X Axis (Linear Axis) and C Axis (Rotary Axis)

```
O0001 ;
    ;
N010 T0101
    ;
N0100 G90 G00 X60.0 C0 Z_ ;  Positioning to start position
N0200 G12.1 ;                                        Start of polar coordinate interpolation
N0201 G42 G01 X20.0 F_  ;
N0202 C10.0 ;
N0203 G03 X10.0 C20.0 R10.0 ;
N0204 G01 X–20.0 ;
N0205 C–10.0 ;
N0206 G03 X–10.0 C–20.0 I10.0 J0 ;
N0207 G01 X20.0 ;
N0208 C0 ;
N0209 G40 X60.0 ;
N0210 G13.1 ;
N0300 Z_ ;
N0400 X_ C_ ;
    ;
N0900 M30 ;
```

Geometry program
(program based on cartesian coordinates on X–C’ plane)

Cancellation of polar coordinate interpolation
4.9 CYLINDRICAL INTERPOLATION (G07.1)

The amount of travel of a rotary axis specified by an angle is once internally converted to a distance of a linear axis along the outer surface so that linear interpolation or circular interpolation can be performed with another axis. After interpolation, such a distance is converted back to the amount of travel of the rotary axis. The cylindrical interpolation function allows the side of a cylinder to be developed for programming. So programs such as a program for cylindrical cam grooving can be created very easily.

Format

```
G07.1 r ; Starts the cylindrical interpolation mode (enables cylindrical interpolation).

G07.1 0 ; The cylindrical interpolation mode is cancelled.

G107 can be used instead of G07.1.
```

Explanations

- **Plane selection (G17, G18, G19)**

  Use parameter (No. 1022) to specify whether the rotation axis is the X–, Y–, or Z–axis, or an axis parallel to one of these axes. Specify the G code to select a plane for which the rotation axis is the specified linear axis. For example, when the rotation axis is an axis parallel to the X–axis, G17 must specify an Xp–Yp plane, which is a plane defined by the rotation axis and the Y–axis or an axis parallel to the Y–axis. Only one rotation axis can be set for cylindrical interpolation.

- **Feedrate**

  A feedrate specified in the cylindrical interpolation mode is a speed on the developed cylindrical surface.

- **Circular interpolation (G02,G03)**

  In the cylindrical interpolation mode, circular interpolation is possible with the rotation axis and another linear axis. Radius R is used in commands in the same way as described in II–4.4. The unit for a radius is not degrees but millimeters (for metric input) or inches (for inch input).

  < Example  Circular interpolation between the Z axis and C axis >

  For the C axis of parameter (No.1022), 5 (axis parallel with the X axis) is to be set. In this case, the command for circular interpolation is

  G18 Z__C__;
  G02 (G03) Z__C__R__;

  For the C axis of parameter (No.1022), 6 (axis parallel with the Y axis) may be specified instead. In this case, however, the command for circular interpolation is

  G19 C__Z__;
  G02 (G03) Z__C__R__;
• Tool offset

To perform tool offset in the cylindrical interpolation mode, cancel any ongoing cutter compensation mode before entering the cylindrical interpolation mode. Then, start and terminate tool offset within the cylindrical interpolation mode.

• Cylindrical interpolation accuracy

In the cylindrical interpolation mode, the amount of travel of a rotary axis specified by an angle is once internally converted to a distance of a linear axis on the outer surface so that linear interpolation or circular interpolation can be performed with another axis. After interpolation, such a distance is converted back to an angle. For this conversion, the amount of travel is rounded to a least input increment.

So when the radius of a cylinder is small, the actual amount of travel can differ from a specified amount of travel. Note, however, that such an error is not accumulative.

If manual operation is performed in the cylindrical interpolation mode with manual absolute on, an error can occur for the reason described above.

\[
\text{The actual amount of travel} = \left\lfloor \frac{\text{MOTION REV} \times \text{Specified value}}{2 \times 2\pi R} \right\rfloor
\]

\[
\text{MOTION REV} : \quad \text{The amount of travel per rotation of the rotation axis (Setting value of parameter No. 1260)}
\]

\[
R : \quad \text{Workpiece radius}
\]

\[
\text{R} : \quad \text{Rounded to the least input increment}
\]

Limitations

• Arc radius specification in the cylindrical interpolation mode

In the cylindrical interpolation mode, an arc radius cannot be specified with word address I, J, or K.

• Circular interpolation and cutter compensation

If the cylindrical interpolation mode is started when cutter compensation is already applied, circular interpolation is not correctly performed in the cylindrical interpolation mode.

• Positioning

In the cylindrical interpolation mode, positioning operations (including those that produce rapid traverse cycles such as G28, G53, G73, G74, G76, G80 through G89) cannot be specified. Before positioning can be specified, the cylindrical interpolation mode must be cancelled. Cylindrical interpolation (G07.1) cannot be performed in the positioning mode (G00).

• Coordinate system setting

In the cylindrical interpolation mode, a workpiece coordinate system (G92, G54 through G59) or local coordinate system (G52) cannot be specified.

• Cylindrical interpolation mode setting

In the cylindrical interpolation mode, the cylindrical interpolation mode cannot be reset. The cylindrical interpolation mode must be cancelled before the cylindrical interpolation mode can be reset.

• Tool offset

A tool offset must be specified before the cylindrical interpolation mode is set. No offset can be changed in the cylindrical interpolation mode.

• Index table indexing function

Cylindrical interpolation cannot be specified when the index table index function is being used.
Examples

Example of a Cylindrical Interpolation Program

```
O0001 (CYLINDRICAL INTERPOLATION );
N01 G00 G90 Z100.0 C0 ;
N02 G01 G91 G18 Z0 C0 ;
N03 G07.1 C57299 ; (*)
N04 G90 G01 G42 Z120.0 D01 F250 ;
N05 C30.0 ;
N06 G02 Z90.0 C60.0 R30.0 ;
N07 G01 Z70.0 ;
N08 G03 Z60.0 C70.0 R10.0 ;
N09 G01 C150.0 ;
N10 G03 Z70.0 C190.0 R75.0 ;
N11 G01 Z110.0 C230.0 ;
N12 G02 Z120.0 C270.0 R75.0 ;
N13 G01 C360.0 ;
N14 G40 Z100.0 ;
N15 G07.1 C0 ;
N16 M30 ;
```

* A command with a decimal point can also be used.
4.10 INVOLUTE INTERPOLATION (G02.2, G03.2)

Format

- Involute curve machining can be performed by using involute interpolation. Involute interpolation ensures continuous pulse distribution even in high-speed operation in small blocks, thus enabling smooth and high-speed machining. Furthermore, machining tapes can be created easily and efficiently, reducing the required length of tape.

- Involute interpolation on the X–Y plane
  
  \[
  \text{G17 G02.2 X__Y__I__J__R__F__} ; \\
  \text{G17 G03.2 X__Y__I__J__R__F__} ; \\
  \text{G18 G02.2 Z__X__I__K__R__F__} ; \\
  \text{G18 G03.2 Z__X__I__K__R__F__} ; \\
  \text{G19 G02.2 Y__Z__J__K__R__F__} ; \\
  \text{G19 G03.2 Y__Z__J__K__R__F__} ; \\
  \]

Where,
- \( \text{G02.2} \): Involute interpolation (clockwise)
- \( \text{G03.2} \): Involute interpolation (counterclockwise)
- \( \text{G17/G18/G19} \): X–Y / Z–X / Y–Z plane selection
- \( \text{X, Y, Z} \): Involute curve end coordinate
- \( \text{I, J, K} \): Center of the base circle for an involute curve viewed from the start point
- \( \text{R} \): Base circle radius
- \( \text{F} \): Cutting feedrate
Explanations

- **Involute curve**
  
  An involute curve on the X–Y plane is defined as follows:
  
  \[
  X(\theta) = R \left[ \cos \theta + \left( \theta - \theta_0 \right) \sin \theta \right] + X_0 \\
  Y(\theta) = R \left[ \sin \theta - \left( \theta - \theta_0 \right) \cos \theta \right] + Y_0
  \]

  where,
  
  \(X_0, Y_0\) : Coordinates of the center of a base circle
  
  \(R\) : Base circle radius
  
  \(\theta_0\) : Angle of the start point of an involute curve
  
  \(\theta\) : Angle of the point where a tangent from the current position to the base circle contacts the base circle
  
  \(X(\theta), Y(\theta)\) : Current position on the X–axis and Y–axis

  ![Fig. 4.10 (a) Involute Curve](image)

  Involute curves on the Z–X plane and Y–Z plane are defined in the same way as an involute curve on the X–Y plane.

- **Start point and end point**
  
  The end point of an involute curve is specified using address X, Y, or Z. An absolute value or incremental value is used to specify an X, Y, or Z value. When using an incremental value, specify the coordinates of the end point viewed from the start point of the involute curve. When no end point is specified, P/S alarm No. 241 is issued. If the specified start point or end point lies within the base circle, P/S alarm No. 242 is issued. The same alarm is issued if cutter compensation C causes the offset vector to enter the base circle. Be particularly careful when applying an offset to the inside of an involute curve.

- **Base circle specification**
  
  The center of a base circle is specified with I, J, and K, corresponding to X, Y, and Z. The value following I, J, or K is a vector component defined when the center of the base circle is viewed from the start point of the involute curve; this value must always be specified as an incremental value, regardless of the G90/G91 setting. Assign a sign to I, J, and K according to the direction. If I, J, and K are all left unspecified, or I0J0K0 is specified, P/S alarm No. 241 or No. 242 is issued. If R is not specified, or R < 0, P/S alarm No. 241 or No. 242 is issued.
• **Choosing from two types of involute curves**

When only a start point and I, J, and K data are given, two types of involute curves can be created. One type of involute curve extends towards the base circle, and the other extends away from the base circle. When the specified end point is closer to the center of the base circle than the start point, the involute curve extends toward the base circle. In the opposite case, the involute curve extends away from the base circle.

• **Feedrate**

The cutting feedrate specified in an F code is used as the feedrate for involute interpolation. The feedrate along the involute curve (feedrate along the tangent to the involute curve) is controlled to satisfy the specified feedrate.

• **Plane selection**

As with circular interpolation, the plane to which to apply involute interpolation can be selected using G17, G18, and G19.

• **Cutter compensation C**

Cutter compensation C can be applied to involute curve machining. As with linear and circular interpolation, G40, G41, and G42 are used to specify cutter compensation.

G40 : Cutter compensation cancel
G41 : Cutter compensation left
G42 : Cutter compensation right

Cutter compensation for an involute curve is implemented as described below.

First, near the start point of an involute curve, an arc with a curvature close to the curvature of the involute curve is found. Next, an offset intersection between the arc and the linear line or arc in the previous block is found. Similarly, an offset intersection is found near the end point. Then, the involute curve passing through the two points is used as the tool center path.

In involute interpolation mode, cutter compensation cannot be started or cancelled.
• **Specifiable G codes**

The following G codes can be specified in involute interpolation mode:
- G04 : Dwell
- G10 : Data setting
- G17 : X–Y plane selection
- G18 : Z–X plane selection
- G19 : Y–Z plane selection
- G65 : Macro call
- G66 : Macro modal call
- G67 : Macro modal call cancel
- G90 : Absolute command
- G91 : Incremental command

• **Modes that allow involute interpolation specification**

Involute interpolation can be specified in the following G code modes:
- G41 : Cutter compensation left
- G42 : Cutter compensation right
- G51 : Scaling
- G51.1 : Programmable mirror image
- G68 : Coordinate rotation

• **End point error**

As shown below the end point may not be located on an involute curve that passes through the start point.
When an involute curve that passes through the start point deviates from the involute curve that passes through the end point by more than the value set in parameter No. 5610, P/S alarm No. 243 is issued.
When there is an end point error, the feedrate is not guaranteed.

![Fig. 4.10 (b) End Point Error in Counterclockwise Involute Interpolation (G03.2)](image)
Limitations

- **Number of involute curve turns**
  Both the start point and end point must be within 100 turns from the point where the involute curve starts. An involute curve can be specified to make one or more turns in a single block. If the specified start point or end point is beyond 100 turns from the point where the involute curve starts, P/S alarm No. 242 is issued.

- **Unspecifiable functions**
  In involute interpolation mode, chamfer corner R (with an arbitrary angle), helical cutting, or axis-by-axis scaling functions cannot be specified.

- **Modes that do not allow involute interpolation specification**
  Involute interpolation cannot be used in the following modes:
  - G41.1 (G151) : Normal direction control left side on
  - G42.1 (G152) : Normal direction control right side on
  - G07.1 (G107) : Cylindrical interpolation
  - G12.1 : Polar coordinate interpolation mode
  - G16 : Polar coordinates command
  - G72.1 : Drawing copy

- **Cutting accuracy**
  The curvature of an involute curve varies rather sharply near the base circle. In such locations, a larger load is applied to the cutter when the programmed feedrate is used for cutting; in this case, the surface produced may be somewhat uneven.
4.11
EXPONENTIAL INTERPOLATION (G02.3, G03.3)

Exponential interpolation exponentially changes the rotation of a workpiece with respect to movement on the rotary axis. Furthermore, exponential interpolation performs linear interpolation with respect to another axis. This enables tapered groove machining with a constant helix angle (constant helix taper machining). This function is best suited for grooving and grinding tools such as end mills.

Format

positive rotation (\(\omega = 0\))

\[
\text{G02.3 X__ Y__ Z__ I__ J__ K__ R__ F__ Q__;}
\]

Negative rotation (\(\omega = 1\))

\[
\text{G03.3 X__ Y__ Z__ I__ J__ K__ R__ F__ Q__;}
\]

- \(X__\): Specifies an end point with an absolute or incremental value.
- \(Y__\): Specifies an end point with an absolute or incremental value.
- \(Z__\): Specifies an end point with an absolute or incremental value.
- \(I__\): Specifies angle \(I\) (from \(\pm 1\) to \(\pm 89\) deg in units of \(0.001\) deg).
- \(J__\): Specifies angle \(J\) (from \(\pm 1\) to \(\pm 89\) deg in units of \(0.001\) deg).
- \(K__\): Specifies the amount to divide the linear axis for exponential interpolation (span value). Specify a positive value. When no value is specified, the value specified in parameter (No. 5643) is used.
- \(R__\): Specifies constant \(R\) for exponential interpolation.
- \(F__\): Specifies the initial feedrate. Specified in the same way as an ordinary F code. Specify a composite feedrate including a feedrate on the rotary axis.
- \(Q__\): Specifies the feedrate at the end point. The same unit used for \(F\) is used. The CNC internally performs interpolation between the initial feedrate (\(F\)) and final feedrate (\(Q\)), depending on the travel distance on the linear axis.
Explanations

- **Exponential relational expressions**

Exponential relational expressions for a linear axis and rotary axis are defined as follows:

\[
X(\theta) = R \times (e^{\frac{\theta}{\tan(I)}} - 1) \times \frac{1}{\tan(I)} \quad \text{Movement on the linear axis (1)}
\]

\[
A(\theta) = (-1)^{\omega} \times 360 \times \frac{\theta}{2\pi} \quad \text{Movement on the linear axis (2)}
\]

Where,

\[
K = \frac{\tan(J)}{\tan(I)} \quad \text{Rotation direction}
\]

\[
\omega = 0/1
\]

R, I, and J are constants, and \(\theta\) represents an angle (radian)

The following is obtained from Expression (1)

\[
\theta(X) = K \times \ln(\frac{X \times \tan(I)}{R} + 1)
\]

When there is movement from \(X_1\) to \(X_2\) on the linear axis, the amount of movement on the rotary axis is determined by:

\[
\Delta \theta = K \times \left( \ln \left( \frac{X_2 \times \tan(I)}{R} + 1 \right) - \ln \left( \frac{X_1 \times \tan(I)}{R} + 1 \right) \right)
\]

Specify Expressions (1) and (2) in the format described earlier.

Limitations

- **Cases where linear interpolation is performed**

Even when the G02.3 or G03.3 mode is set, linear interpolation is performed in the following cases:

- When the linear axis specified in parameter (No. 5641) is not specified, or the amount of movement on the linear axis is 0
- When the rotary axis specified in parameter (No. 5642) is specified
- When the amount for dividing the linear axis (span value) is 0

Neither tool length compensation nor cutter compensation can be used in the G02.3 and G03.3 modes.
CAUTION
The amount for dividing the linear axis for exponential interpolation (span value) affects figure precision. However, if an excessively small value is set, the machine may stop during interpolation. Try to specify an optimal span value depending on the machine being used.

Examples

Constant helix machining for producing a tapered figure

Constant helix machining for producing a reverse tapered figure
Relational expressions

\[ Z(\theta) = \left( \frac{r}{2} - U \times \tan(\theta) \right) \times \frac{\theta}{\tan(\theta)} \times \frac{\tan(B)}{\tan(I)} + Z(0) \quad \ldots (3) \]

\[ X(\theta) = \left( \frac{r}{2} - U \times \tan(\theta) \right) \times \frac{\theta}{\tan(\theta)} \times \frac{1}{\tan(I)} \quad \ldots (4) \]

\[ A(\theta) = (-1)^{\omega} \times 360 \times \frac{\theta}{2\pi} \]

where

- \( K = \frac{\tan(J)}{\tan(\theta)} \)
- \( X(\theta), Z(\theta), A(\theta) \): Absolute value on the X-axis, Z-axis, and A-axis from the origin
- \( r \): Left end diameter
- \( U \): Excess length
- \( I \): Taper angle
- \( B \): Groove bottom taper angle
- \( J \): Helix angle
- \( X \): Amount of movement on the linear axis
- \( \omega \): Helix direction (0: Positive, 1: Negative)
- \( \theta \): Workpiece rotation angle

From expressions (3) and (4), the following is obtained;

\[ Z(\theta) = \tan(B) \times X(\theta) + Z(0) \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots (5) \]

The groove bottom taper angle (B) is determined from the end point position on the X-axis and Z-axis according to Expression 5. The amount of movement on the Z-axis is determined from a groove bottom taper angle (B) and X-axis position.

From Expressions (1) and (4), the following is determined:

\[ R = \frac{r}{2} - U \times \tan(I) \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (6) \]

Constant R is determined from the left end diameter (r) and excess length (U) according to Expression (6). Specify a taper angle (I) in address I, and specify a helix angle (J) in address J. Note, however, that a negative value must be specified as the taper angle (I) for constant helix machining in order to produce a reverse tapered figure. Select a helix direction with G02.3 or G03.3. The user can perform constant helix machining to produce a tapered figure or a reverse tapered figure.
Either of two types of machining can be selected, depending on the program command.

- For those portions where the accuracy of the figure is critical, such as at corners, machining is performed exactly as specified by the program command.
- For those portions having a large radius of curvature where a smooth figure must be created, points along the machining path are interpolated with a smooth curve, calculated from the polygonal lines specified with the program command (smooth interpolation).

Smooth interpolation can be specified when CDSP (bit 5 of parameter No. 8485) is set to 1 in high-speed contour control mode (between G05 P10000 and G05 P0). Smooth interpolation performed in high-speed contour control mode is described below. For details of high-speed contour control, see Section 20.5.

### Format

Starting of smooth interpolation mode

\[ \text{G05.1 Q2X0Y0Z0;} \]

Cancelation of smooth interpolation mode

\[ \text{G05.1 Q 0;} \]

### Explanations

- **Characteristics of smooth interpolation**

To machine a part having sculptured surfaces, such as metal moldings used in automobiles and airplanes, a part program usually approximates the sculptured surfaces with minute line segments. As shown in the following figure, a sculptured curve is normally approximated using line segments with a tolerance of about 10 μm.
When a program approximates a sculptured curve with line segments, the length of each segment differs between those portions that have mainly a small radius of curvature and those that have mainly a large radius of curvature. The length of the line segments is short in those portions having a small radius of curvature, while it is long in those portions having a large radius of curvature. The high-precision contour control moves the tool along a programmed path thus enabling highly precise machining. This means that the tool movement precisely follows the line segments used to approximate a sculptured curve. This may result in a non-smooth machined curve if control is applied to machining a curve where the radius of curvature is large and changes only gradually. Although this effect is caused by high-precision machining, which precisely follows a pre-programmed path, the uneven corners that result will be judged unsatisfactory when smooth surfaces are required.

<table>
<thead>
<tr>
<th>Profile</th>
<th>Portions having mainly a small radius of curvature</th>
<th>Portions having mainly a large radius of curvature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example of machined parts</td>
<td>Automobile parts</td>
<td>Decorative parts, such as body side moldings</td>
</tr>
<tr>
<td>Length of line segment</td>
<td>Short</td>
<td>Long</td>
</tr>
<tr>
<td>Resulting surfaces pro-</td>
<td>Smooth surface even when machining is performed</td>
<td>Uneven surfaces may result when machining is</td>
</tr>
<tr>
<td>duced using high-precis-</td>
<td>exactly as specified by a program</td>
<td>performed exactly as specified by a program</td>
</tr>
<tr>
<td>ion contour control</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Example of uneven surfaces (polygon) resulting from machining that precisely follows the line segments.

In smooth interpolation mode, the CNC automatically determines, according to the program command, whether an accurate figure is required, such as at corners, or a smooth figure is required where the radius of curvature is large. If a block specifies a travel distance or direction which differs greatly from that in the preceding block, smooth interpolation is not performed for that block. Linear interpolation is performed exactly as specified by the program command. Programming is thus very simple.
4. INTERPOLATION FUNCTIONS

Examples

- **Conditions for performing smooth interpolation**
  Smooth interpolation is performed when all the following conditions are satisfied. If any of the following conditions is not satisfied for a block, that block is executed without smooth interpolation then the conditions are checked for the next block.

  1. The machining length specified in the block is shorter than the length specified with parameter No. 8486.
  2. The machining length is other than 0.
  3. The modes are:
     - G01: Linear interpolation
     - G13.1: Polar coordinate interpolation cancel
     - G15: Polar coordinate command cancel
     - G40: Cutter compensation cancel
     (except for 3–dimensional tool compensation)
     - G64: Cutting mode
     - G80: Canned cycle cancel
     - G94: Feed per minute
  4. Machining is specified only along the axes specified with G05.1Q2.
  5. The block is judged to be unsuitable for smooth interpolation, as performed with the internal algorithm of the CNC.

- **Commands which cancel smooth interpolation**
  1. Auxiliary and second auxiliary functions
  2. M98, M99: Subprogram call
     - M198: Calling a subprogram in external memory
Limitations

- **Controlled axes**
  Smooth interpolation can be specified only for the X–, Y–, and Z–axes and any axes parallel to these axes (up to three axes at one time).

- **High–precision contour control mode**
  Commands for turning on and off smooth interpolation mode must be executed in high–precision contour control mode.

Examples

Example program for smooth interpolation

```
G05 P10000 ;       N10 X–1000 Z350 ;
.                      .
.                      .
G91 ;                  N13 X–1000 Z–50 ;
G05.1 Q2 X0 Y0 Z0 ;   N14 X–1000 Z–50 ;
N01 G01 X1000 Z–300 ;  N15 X–1000 Z50 ;
N02 X1000 Z–200 ;     N16 X–1000 Z200 ;
N03 X1000 Z–50 ;      N17 X–1000 Z300 ;
N04 X1000 Z50 ;       G05.1 Q0 ;
N05 X1000 Z50 ;       .
N06 X1000 Z–25 ;      .
N07 X1000 Z–175 ;     G05 P0 ;
N08 X1000 Z–350 ;     .
N09 Y1000 ;           .
```

Interpolated by smooth curve

Linear interpolation
Many computer-aided design (CAD) systems used to design metal dies for automobiles and airplanes utilize non-uniform rational B-spline (NURBS) to express a sculptured surface or curve for the metal dies. This function enables NURBS curve expression to be directly specified to the CNC. This eliminates the need for approximating the NURBS curve with minute line segments. This offers the following advantages:

1. No error due to approximation of a NURBS curve by small line segments
2. Short part program
3. No break between blocks when small blocks are executed at high speed
4. No need for high-speed transfer from the host computer to the CNC

When this function is used, a computer-aided machining (CAM) system creates a NURBS curve according to the NURBS expression output from the CAD system, after compensating for the length of the tool holder, tool diameter, and other tool elements. The NURBS curve is programmed in the NC format by using these three defining parameters: control point, weight, and knot.

NURBS interpolation must be specified in high-precision contour control mode (between G05 P10000 and G05 P0). The CNC executes NURBS interpolation while smoothly accelerating or decelerating the movement so that the acceleration on each axis will not exceed the allowable maximum acceleration of the machine. In this way, the CNC automatically controls the speed in order to prevent excessive strain being imposed on the machine. For details of high-precision contour control, see Section II–19.8.
### 4. INTERPOLATION FUNCTIONS

**Format**

<table>
<thead>
<tr>
<th>Format</th>
<th>Explanations</th>
</tr>
</thead>
<tbody>
<tr>
<td>G05 P10000 ;</td>
<td>(Start high-precision contour control mode)</td>
</tr>
<tr>
<td>...</td>
<td></td>
</tr>
<tr>
<td>G06.2 [P_] X_ Y_ Z_[R_] <em>F</em> ;</td>
<td>NURBS interpolation mode is selected when G06.2 is programmed in high-precision contour control mode. G06.2 is a modal G code of group 01. NURBS interpolation mode ends when a G code of group 01 other than G06.2 (G00, G01, G02, G03, etc.) is specified. NURBS interpolation mode must end before the command for ending high-precision contour control mode is programmed.</td>
</tr>
<tr>
<td>K_ X_ Y_ Z_[R_] ;</td>
<td></td>
</tr>
<tr>
<td>K_ X_ Y_ Z_[R_] ;</td>
<td></td>
</tr>
<tr>
<td>K_ X_ Y_ Z_[R_] ;</td>
<td></td>
</tr>
<tr>
<td>...</td>
<td></td>
</tr>
<tr>
<td>K_ X_ Y_ Z_[R_] ;</td>
<td></td>
</tr>
<tr>
<td>K_ ;</td>
<td></td>
</tr>
<tr>
<td>...</td>
<td></td>
</tr>
<tr>
<td>K_ ;</td>
<td></td>
</tr>
<tr>
<td>G01 ...</td>
<td></td>
</tr>
<tr>
<td>...</td>
<td></td>
</tr>
<tr>
<td>G05 P0 ;</td>
<td>(End high-precision contour control mode)</td>
</tr>
<tr>
<td>G06.2 ;</td>
<td>Start NURBS interpolation mode</td>
</tr>
<tr>
<td>P_ ;</td>
<td>Rank of NURBS curve</td>
</tr>
<tr>
<td>X_ Y_ Z_ ;</td>
<td>Control point</td>
</tr>
<tr>
<td>R_ ;</td>
<td>Weight</td>
</tr>
<tr>
<td>K_ ;</td>
<td>Knot</td>
</tr>
<tr>
<td>F_ ;</td>
<td>Feedrate</td>
</tr>
</tbody>
</table>

**Explanations**

- **NURBS interpolation mode**

NURBS interpolation mode is selected when G06.2 is programmed in high-precision contour control mode. G06.2 is a modal G code of group 01. NURBS interpolation mode ends when a G code of group 01 other than G06.2 (G00, G01, G02, G03, etc.) is specified. NURBS interpolation mode must end before the command for ending high-precision contour control mode is programmed.

- **Rank of NURBS**

A rank of NURBS can be specified with address P. The rank setting, if any, must be specified in the first block. If the rank setting is omitted, a rank of four (degree of three) is assumed for NURBS. The valid data range for P is 2 to 4. The P values have the following meanings:

- P2: NURBS having a rank of two (degree of one)
- P3: NURBS having a rank of three (degree of two)
- P4: NURBS having a rank of four (degree of three) (default)

This rank is represented by k in the defining expression indicated in the description of NURBS curve below. For example, a NURBS curve having a rank of four has a degree of three. The NURBS curve can be expressed by the constants $t^3$, $t^2$, and $t^1$.

- **Weight**

The weight of a control point programmed in a single block can be defined. When the weight setting is omitted, a weight of 1.0 is assumed.
The number of specified knots must equal the number of control points plus the rank value. In the blocks specifying the first to last control points, each control point and a knot are specified in an identical block. After these blocks, as many blocks (including only a knot) as the rank value are specified. The NURBS curve programmed for NURBS interpolation must start from the first control point and end at the last control point. The first k knots (where k is the rank) must have the same values as the last k knots (multiple knots). If the absolute coordinates of the start point of NURBS interpolation do not match the position of the first control point, P/S alarm No. 5117 is issued. (To specify incremental values, G06.2 X0 Y0 Z0 K_ must be programmed.)

Using these variables:

- k : Rank
- P_i : Control point
- W_i : Weight
- X_i : Knot (X_i ≤ X_i + 1)
  - Knot vector [X_0, X_1, ..., X_m] (m = n + k)
- t : Spline parameter,

the spline basis function N can be expressed with the de Boor–Cox recursive formula, as indicated below:

\[
N_{i,k}(t) = \begin{cases} 
1 & (x_i \leq t \leq x_{i+1}) \\
0 & (t < x_i \text{ or } x_{i+1} < t) 
\end{cases}
\]

\[
N_{i,k}(t) = \frac{(t-x_i) N_{i,k-1}(t)}{x_{i+k-1}-x_i} + \frac{(x_{i+k}-t) N_{i+k-1,k-1}(t)}{x_{i+k}-x_{i+1}}
\]

The NURBS curve P(t) of interpolation can be expressed as follows:

\[
P(t) = \frac{\sum_{i=0}^{n} N_i(t)w_i P_i}{\sum_{i=0}^{n} N_i(t)w_i} \quad \quad (x_0 \leq t \leq x_m)
\]

A reset during NURBS interpolation results in the clear state. The modal code of group 1 enters the state specified in the G01 bit (bit 0 of parameter 3402).

Limitations

- Controlled axes
  - NURBS interpolation can be performed on up to three axes. The axes of NURBS interpolation must be specified in the first block. A new axis cannot be specified before the beginning of the next NURBS curve or before NURBS interpolation mode ends.

- Command in NURBS interpolation mode
  - In NURBS interpolation mode, any command other than the NURBS interpolation command (miscellaneous function and others) cannot be specified.

- Manual intervention
  - If manual intervention is attempted while manual absolute mode is set, P/S alarm No. 5118 is issued.

- Cutter compensation
  - Cutter compensation cannot be simultaneously executed. NURBS interpolation can only be specified after cutter compensation has been canceled.
Alarms

<table>
<thead>
<tr>
<th>No.</th>
<th>Displayed message</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PS5115</td>
<td>SPL: Error</td>
<td>An illegal rank is specified.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No knot is specified.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>An illegal knot is specified.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Too many axes are specified.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other program error.</td>
</tr>
<tr>
<td>PS5116</td>
<td>SPL: Error</td>
<td>A look-ahead block contains a program error.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The knot does not increase at a constant rate.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>An inhibited mode is specified in NURBS inter-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>polation mode.</td>
</tr>
<tr>
<td>PS5117</td>
<td>SPL: Error</td>
<td>The first NURBS control point is illegal.</td>
</tr>
<tr>
<td>PS5118</td>
<td>SPL: Error</td>
<td>An attempt was made to resume NURBS interpola-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>tion after manual intervention in manual</td>
</tr>
<tr>
<td></td>
<td></td>
<td>absolute mode.</td>
</tr>
</tbody>
</table>

Example

<Sample NURBS interpolation program>

G05 P10000;
G90;
...
G06.2 K0. X0. Z0.;
   K0. X300. Z100.;
   K0. X700. Z100.;
   K0. X1300. Z–100.;
   K0.5 X1700. Z–100.;
   K0.5 X2000. Z0.;
   K1.0;
   K1.0;
   K1.0;
   K1.0;
G01 Y0.5;
G06.2 K0. X2000. Z0.;
   K0. X1700. Z–100.;
   K0. X1300. Z–100.;
   K0. X700. Z100.;
   K0.5 X300. Z100.;
   K0.5 X0. Z0.;
   K1.0;
   K1.0;
   K1.0;
   K1.0;
G01 Y0.5;
G06.2 ... ...
G01 ... 
G05P0;
4.14 HYPOTHETICAL AXIS INTERPOLATION (G07)

In helical interpolation, when pulses are distributed with one of the circular interpolation axes set to a hypothetical axis, sine interpolation is enabled. When one of the circular interpolation axes is set to a hypothetical axis, pulse distribution causes the speed of movement along the remaining axis to change sinusoidally. If the major axis for threading (the axis along which the machine travels the longest distance) is set to a hypothetical axis, threading with a fractional lead is enabled. The axis to be set as the hypothetical axis is specified with G07.

Format

```
G07 α 0;  Hypothetical axis setting
G07 α 1;  Hypothetical axis cancel
```

Where, α is any one of the addresses of the controlled axes.

Explanations

- Sine interpolation

The α axis is regarded as a hypothetical axis for the period of time from the G07 α 0 command until the G07 α 1 command appears. Suppose sine interpolation is performed for one cycle in the YZ plane. The hypothetical axis is then the X axis.

\[ X^2 + Y^2 = r^2 \quad (r \text{ is the radius of an arc}) \]

\[ Y = r \sin \left( \frac{2\pi z}{1} \right) \]

(1 is the distance traveled along the Z-axis in one cycle.)

- Interlock, stroke limit, and external deceleration

Interlock, stroke limit, and external deceleration can also apply to the hypothetical axis.

- Handle interrupt

An interrupt caused by the handle also applies to the hypothetical axis. This means that movement for a handle interrupt is performed.
Limitations
• Manual operation
  The hypothetical axis can be used only in automatic operation. In manual
  operation, it is not used, and movement takes place.
• Move command
  Specify hypothetical axis interpolation only in the incremental mode.
• Coordinate rotation
  Hypothetical axis interpolation does not support coordinate rotation.

Examples
• Sine interpolation

N001  G07  X0  ;
N002  G91  G17  G03  X–20.2  Y0.0  I–10.0  Z20.0  F100  ;
N003  G01  X10.0  ;
N004  G07  X1  ;
From the N002 to N003 blocks, the X-axis is set to a hypothetical axis. The N002 block specifies helical cutting in which the Z-axis is the linear axis. Since no movement takes place along the X axis, movement along the Y-axis is performed while performing sine interpolation along the Z-axis.
In the N003 block, there is no movement along the X-axis, and so the machine dwells until interpolation terminates.

• Changing the feedrate to form a sine curve
  (Sample program)
  G07Z0  ; The Z-axis is set to a hypothetical axis.
  G02X0Z0I10.0F4.  ; The feedrate on the X-axis changes sinusoidally.
  G07Z1  ; The use of the Z-axis as a hypothetical axis is canceled.
4.15 THREAD CUTTING (G33)

Format

\[
G33 \text{IP } F_\theta ; \\
F : \text{Long axis direction lead}
\]

Explanations

Straight threads with a constant lead can be cut. The position coder mounted on the spindle reads the spindle speed in real-time. The read spindle speed is converted to the feedrate per minute to feed the tool.

In general, thread cutting is repeated along the same tool path in rough cutting through finish cutting for a screw. Since thread cutting starts when the position coder mounted on the spindle outputs a 1-turn signal, threading is started at a fixed point and the tool path on the workpiece is unchanged for repeated thread cutting. Note that the spindle speed must remain constant from rough cutting through finish cutting. If not, incorrect thread lead will occur.

In general, the lag of the servo system, etc. will produce somewhat incorrect leads at the starting and ending points of a thread cut. To compensate for this, a thread cutting length somewhat longer than required should be specified.

Table 4.15 (a) lists the ranges for specifying the thread lead.

<table>
<thead>
<tr>
<th>Least command increment</th>
<th>Command value range of the lead</th>
</tr>
</thead>
<tbody>
<tr>
<td>mm input</td>
<td></td>
</tr>
<tr>
<td>0.001 mm</td>
<td>F1 to F50000 (0.01 to 500.00mm)</td>
</tr>
<tr>
<td>0.0001 mm</td>
<td>F1 to F50000 (0.01 to 500.00mm)</td>
</tr>
<tr>
<td>Inch input</td>
<td></td>
</tr>
<tr>
<td>0.0001 inch</td>
<td>F1 to F99999 (0.0001 to 9.9999inch)</td>
</tr>
<tr>
<td>0.00001 inch</td>
<td>F1 to F99999 (0.0001 to 9.9999inch)</td>
</tr>
</tbody>
</table>
The spindle speed is limited as follows:

\[
1 \leq \text{spindle speed} \leq \frac{\text{Maximum feedrate}}{\text{Thread lead}}
\]

- Spindle speed: min\(^{-1}\)
- Thread lead: mm or inch
- Maximum feedrate: mm/min or inch/min; maximum command-specified feedrate for feed-per-minute mode or maximum feedrate that is determined based on mechanical restrictions including those related to motors, whichever is smaller

2. Cutting feedrate override is not applied to the converted feedrate in all machining process from rough cutting to finish cutting. The feedrate is fixed at 100%.

3. The converted feedrate is limited by the upper feedrate specified.

4. Feed hold is disabled during threading. Pressing the feed hold key during thread cutting causes the machine to stop at the end point of the next block after threading (that is, after the G33 mode is terminated).

**Examples**

Thread cutting at a pitch of 1.5mm

G33 Z10. F1.5;
4.16 SKIP FUNCTION (G31)

Linear interpolation can be commanded by specifying axial move following the G31 command, like G01. If an external skip signal is input during the execution of this command, execution of the command is interrupted and the next block is executed.

The skip function is used when the end of machining is not programmed but specified with a signal from the machine, for example, in grinding. It is used also for measuring the dimensions of a workpiece.

Format

G31 I P_ ;

G31: One–shot G code (If is effective only in the block in which it is specified)

Explanations

The coordinate values when the skip signal is turned on can be used in a custom macro because they are stored in the custom macro system variable #5061 to #5068, as follows:

- #5061 X axis coordinate value
- #5062 Y axis coordinate value
- #5063 Z axis coordinate value
- #5064 4th axis coordinate value
- #5065 5th axis coordinate value
- #5066 6th axis coordinate value
- #5067 7th axis coordinate value
- #5068 8th axis coordinate value

WARNING

Disable feedrate override, dry run, and automatic acceleration/deceleration (however, these become available by setting the parameter SKF No.6200#7 to 1.) when the feedrate per minute is specified, allowing for an error in the position of the tool when a skip signal is input. These functions are enabled when the feedrate per rotation is specified.

NOTE

If G31 command is issued while cutter compensation C is applied, an P/S alarm of No.035 is displayed. Cancel the cutter compensation with the G40 command before the G31 command is specified.
Examples

- The next block to G31 is an incremental command

![Diagram](image1)

Fig. 4.16 (a) The next block is an incremental command

- The next block to G31 is an absolute command for 1 axis

![Diagram](image2)

Fig. 4.16 (b) The next block is an absolute command for 1 axis

- The next block to G31 is an absolute command for 2 axes

![Diagram](image3)

Fig. 4.16 (c) The next block is an absolute command for 2 axes
4.17 MULTISTAGE SKIP (G31)

In a block specifying P1 to P4 after G31, the multistage skip function stores coordinates in a custom macro variable when a skip signal (4–point or 8–point; 8–point when a high–speed skip signal is used) is turned on. Parameters No. 6202 to No. 6205 can be used to select a 4–point or 8–point (when a high–speed skip signal is used) skip signal. One skip signal can be set to match multiple Pn or Qn (n=1,2,3,4) as well as to match a Pn or Qn on a one–to–one basis. Parameters DS1 to DS8 (No. 6206 #0A#7) can be used for dwell. A skip signal from equipment such as a fixed–dimension size measuring instrument can be used to skip programs being executed. In plunge grinding, for example, a series of operations from rough machining to spark–out can be performed automatically by applying a skip signal each time rough machining, semi–fine machining, fine–machining, or spark–out operation is completed.

Move command

G31 IP __ F __ P __ ;

IP : End point
F : Feedrate
P : P1–P4

Dwell

G04 X (P)__ (Q__) ;

X(P)_ : Dwell time
Q_ : Q1 – Q4

Explanations

Multistage skip is caused by specifying P1, P2, P3, or P4 in a G31 block. For an explanation of selecting (P1, P2, P3, or P4), refer to the manual supplied by the machine tool builder. Specifying Q1, Q2, Q3, or Q4 in G04 (dwell command) enables dwell skip in a similar way to specifying G31. A skip may occur even if Q is not specified. For an explanation of selecting (Q1, Q2, Q3, or Q4), refer to the manual supplied by the machine tool builder.

• Correspondence to skip signals

Parameter Nos. 6202 to 6205 can be used to specify whether the 4–point or 8–point skip signal is used (when a high–speed skip signal is used). Specification is not limited to one–to–one correspondence. It is possible to specify that one skip signal correspond to two or more Pn’s or Qn’s (n=1, 2, 3, 4). Also, bits 0 (DS1) to 7 (DS8) of parameter No. 6206 can be used to specify dwell.

CAUTION

Dwell is not skipped when Qn is not specified and parameters DS1–DS8 (No. 6206#0–#7) are not set.
The skip function operates based on a high-speed skip signal (connected directly to the NC; not via the PMC) instead of an ordinary skip signal. In this case, up to eight signals can be input. Delay and error of skip signal input is 0 – 2 msec at the NC side (not considering those at the PMC side). This high-speed skip signal input function keeps this value to 0.1 msec or less, thus allowing high precision measurement.

For details, refer to the appropriate manual supplied from the machine tool builder.

Format

```
G31 P_;
```

G31: One-shot G code (If is effective only in the block in which it is specified)
**4.19 CONTINUOUS HIGH–SPEED SKIP FUNCTION (G31)**

The continuous high-speed skip function enables reading of absolute coordinates by using the high-speed skip signal. Once a high-speed skip signal has been input in a G31P90 block, absolute coordinates are read into custom macro variables #5061 to #5068. The input of a skip signal does not stop axial movement, thus enabling reading of the coordinates of two or more points.

The rising and falling edges of the high-speed skip signal can be used as a trigger, depending on the parameter BHIS (No. 6201#5) setting.

### Format

```
G31 P90 α__ F__
```

- **α__**: Skip axis address and amount of travel
- **F__**: Only one axis can be specified. G31 is a one-shot G code.

### Explanations

- **Custom macro variables**
  - Once a high-speed skip signal has been input in a G31P90 block, absolute coordinates are read into custom macro variables #5061 to #5068. These variables are immediately updated once the tool reaches the next skip position. The feedrate must, therefore, be specified such that the tool does not reach the next skip position before the application completes reading of the variables. For details of the application, refer to the appropriate manual supplied from the machine tool builder.

  ```
  #5061  Coordinate along the first axis
  #5062  Coordinate along the second axis
  #5063  Coordinate along the third axis
  #5064  Coordinate along the fourth axis
  #5065  Coordinate along the fifth axis
  #5066  Coordinate along the sixth axis
  #5067  Coordinate along the seventh axis
  #5068  Coordinate along the eighth axis
  ```

- **High–speed skip signal**
  - This function is enabled only when a high-speed skip signal is used.
  - The high-speed skip signal to be used is selected with bits 0 to 7 of parameter No. 6208 (9S1 to 9S8).

- **End of block**
  - The G31P90 block is terminated when the tool reaches the end point.

### Limitations

- **Controlled axes**
  - Only one axis can be specified in the block for the continuous high-speed skip function (G31P90). If two or more axes are specified, P/S alarm No. 5068 is issued.
5

FEED FUNCTIONS
The feed functions control the feedrate of the tool. The following two feed functions are available:

1. Rapid traverse
   - When the positioning command (G00) is specified, the tool moves at a rapid traverse feedrate set in the CNC (parameter No. 1420).

2. Cutting feed
   - The tool moves at a programmed cutting feedrate.

Override can be applied to a rapid traverse rate or cutting feedrate using the switch on the machine operator’s panel.

To prevent a mechanical shock, acceleration/deceleration is automatically applied when the tool starts and ends its movement (Fig. 5.1 (a)).

![Diagram of feed functions](image)

**Fig. 5.1 (a) Automatic acceleration/deceleration (example)**
If the direction of movement changes between specified blocks during cutting feed, a rounded-corner path may result (Fig. 5.1 (b)).

In circular interpolation, a radial error occurs (Fig. 5.1 (c)).

The rounded-corner path shown in Fig. 5.1 (b) and the error shown in Fig. 5.1 (c) depend on the feedrate. So, the feedrate needs to be controlled for the tool to move as programmed.
5.2
RAPID TRAVERSE

Format

G00 IP_ ;

G00 : G code (group 01) for positioning (rapid traverse)
IP_ : Dimension word for the end point

Explanations

The positioning command (G00) positions the tool by rapid traverse. In
rapid traverse, the next block is executed after the specified feedrate
becomes 0 and the servo motor reaches a certain range set by the machine
tool builder (in–position check).
A rapid traverse rate is set for each axis by parameter No. 1420, so no rapid
traverse feedrate need be programmed.
The following overrides can be applied to a rapid traverse rate with the
switch on the machine operator’s panel:F0, 25, 50, 100%
F0: Allows a fixed feedrate to be set for each axis by parameter No. 1421.
For detailed information, refer to the appropriate manual of the machine
tool builder.
Feedrate of linear interpolation (G01), circular interpolation (G02, G03), etc. are commanded with numbers after the F code.

In cutting feed, the next block is executed so that the feedrate change from the previous block is minimized.

Four modes of specification are available:

1. Feed per minute (G94)
   After F, specify the amount of feed of the tool per minute.
2. Feed per revolution (G95)
   After F, specify the amount of feed of the tool per spindle revolution.
3. Inverse time feed (G93)
   Specify the inverse time (FRN) after F.
4. F1–digit feed
   Specify a desired one–digit number after F. Then, the feedrate set with the CNC for that number is set.

**Format**

<table>
<thead>
<tr>
<th>Feed per minute</th>
<th>Feed per revolution</th>
<th>Inverse time feed (G93)</th>
<th>F1–digit feed</th>
</tr>
</thead>
<tbody>
<tr>
<td>G94 ; G code (group 05) for feed per minute</td>
<td>G95 ; G code (group 05) for feed per revolution</td>
<td>G93 ; Inverse time feed command</td>
<td>Fn ;</td>
</tr>
<tr>
<td>F_ ; Feedrate command (mm/min or inch/min)</td>
<td>F_ ; Feedrate command (mm/rev or inch/rev)</td>
<td>G code (05 group)</td>
<td>n : Number from 1 to 9</td>
</tr>
</tbody>
</table>

**Explanations**

- **Tangential speed constant control**

Cutting feed is controlled so that the tangential feedrate is always set at a specified feedrate.
After specifying G94 (in the feed per minute mode), the amount of feed of the tool per minute is to be directly specified by setting a number after F. G94 is a modal code. Once a G94 is specified, it is valid until G95 (feed per revolution) is specified. At power–on, the feed per minute mode is set.

An override from 0% to 254% (in 1% steps) can be applied to feed per minute with the switch on the machine operator’s panel. For detailed information, see the appropriate manual of the machine tool builder.

WARNING
No override can be used for some commands such as for threading.

After specifying G95 (in the feed per revolution mode), the amount of feed of the tool per spindle revolution is to be directly specified by setting a number after F. G95 is a modal code. Once a G95 is specified, it is valid until G94 (feed per minute) is specified.

An override from 0% to 254% (in 1% steps) can be applied to feed per revolution with the switch on the machine operator’s panel. For detailed information, see the appropriate manual of the machine tool builder.

CAUTION
When the speed of the spindle is low, feedrate fluctuation may occur. The slower the spindle rotates, the more frequently feedrate fluctuation occurs.
• **Inverse time feed (G93)**

When G93 is specified, the inverse time specification mode (G93 mode) is set. Specify the inverse time (FRN) with an F code.

A value from 0.001 to 9999.999 can be specified as FRN, regardless of whether the input mode is inches or metric, or the increment system is IS–B or IS–C.

<table>
<thead>
<tr>
<th>F code specification value</th>
<th>FRN</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1</td>
<td>0.001</td>
</tr>
<tr>
<td>F1 *1</td>
<td>1.000</td>
</tr>
<tr>
<td>F1.0</td>
<td>1.000</td>
</tr>
<tr>
<td>F9999999</td>
<td>9999.999</td>
</tr>
<tr>
<td>F9999 *1</td>
<td>9999.000</td>
</tr>
<tr>
<td>F9999.999</td>
<td>9999.999</td>
</tr>
</tbody>
</table>

**NOTE**

*1 Value specified in fixed–point format with bit 0 (DPI) of parameter No. 3401 set to 1

**Explanations**

**For linear interpolation (G01)**

\[
FRN = \frac{1}{\text{time (min)}} = \frac{\text{feedrate}}{\text{distance}}
\]

- To end a block in 1 (min)
  \[
  FRN = \frac{1}{\text{time (min)}} = \frac{1}{1 \text{ (min)}} = 1
  \]
  Specify F1.0.

- To end a block in 10 (sec)
  \[
  FRN = \frac{1}{\text{time (sec) / 60}} = \frac{1}{10/60 \text{ (sec)}} = 6
  \]
  Specify F6.0.

- To find the movement time required when F0.5 is specified
  \[
  \text{Time (min)} = \frac{1}{\text{FRN}} = \frac{1}{0.5} = 2
  \]
  2 (min) is required.

- To find the movement time required when F10.0 is specified
  \[
  \text{Time (sec)} = \frac{1 \times 60}{\text{FRN}} = \frac{60}{10} = 6
  \]
  6 (sec) is required.

**For circular interpolation (G01)**

\[
FRN = \frac{1}{\text{time (min)}} = \frac{\text{feedrate}}{\text{arc radius}}
\]

**NOTE**

In the case of circular interpolation, the feedrate is calculated not from the actual amount of movement in the block but from the arc radius.
G93 is a modal G code and belongs to group 05 (includes G95 (feed per revolution) and G94 (feed per minute)).

When an F value is specified in G93 mode and the feedrate exceeds the maximum cutting feedrate, the feedrate is clamped to the maximum cutting feedrate.

In the case of circular interpolation, the feedrate is calculated not from the actual amount of movement in the block but from the arc radius. This means that actual machining time is longer when the arc radius is longer than the arc distance and shorter when the arc radius is shorter than the arc distance. Inverse time feed can also be used for cutting feed in a canned cycle.

Notes

**NOTE**

1. In the G93 mode, an F code is not handled as a modal code and therefore needs to be specified in each block. If an F code is not specified, P/S alarm (No. 11 (indicating that cutting feedrate specification is missing)) is issued.

2. When F0 is specified in G93 mode, P/S alarm (No. 11 (indicating that cutting feedrate specification is missing)) is issued.

3. Inverse time feed cannot be used when PMC axis control is in effect.

4. If the calculated cutting feedrate is smaller than the allowable range, P/S alarm (No. 11 (indicating that cutting feedrate specification is missing)) is issued.
When a one-digit number from 1 to 9 is specified after F, the feedrate set for that number in a parameter (Nos. 1451 to 1459) is used. When F0 is specified, the rapid traverse rate is applied. The feedrate corresponding to the number currently selected can be increased or decreased by turning on the switch for changing F1–digit feedrate on the machine operator’s panel, then by rotating the manual pulse generator.

The increment/decrement, ΔF, in feedrate per scale of the manual pulse generator is as follows:

\[ \Delta F = \frac{F_{\text{max}}}{100X} \]

- \( F_{\text{max}} \): feedrate upper limit for F1–F4 set by parameter (No.1460), or feedrate upper limit for F5–F9 set by parameter (No.1461)
- \( X \): any value of 1–127 set by parameter (No.1450)

The feedrate set or altered is kept even while the power is off. The current feed rate is displayed on the CRT screen.

A common upper limit can be set on the cutting feedrate along each axis with parameter No. 1422. If an actual cutting feedrate (with an override applied) exceeds a specified upper limit, it is clamped to the upper limit. Parameter No. 1430 can be used to specify the maximum cutting feedrate for each axis only for linear interpolation and circular interpolation. When the cutting feedrate along an axis exceeds the maximum feedrate for the axis as a result of interpolation, the cutting feedrate is clamped to the maximum feedrate.

**NOTE**

An upper limit is set in mm/min or inch/min. CNC calculation may involve a feedrate error of ±2% with respect to a specified value. However, this is not true for acceleration/deceleration. To be more specific, this error is calculated with respect to a measurement on the time the tool takes to move 500 mm or more during the steady state:

**Reference**

See Appendix C for range of feedrate command value.
5.4 CUTTING FEEDRATE CONTROL

Cutting feedrate can be controlled, as indicated in Table 5.4 (a).

<table>
<thead>
<tr>
<th>Function name</th>
<th>G code</th>
<th>Validity of G code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exact stop</td>
<td>G09</td>
<td>This function is valid for specified blocks only.</td>
<td></td>
</tr>
<tr>
<td>Exact stop mode</td>
<td>G61</td>
<td>Once specified, this function is valid until G62, G63, or G64 is specified.</td>
<td></td>
</tr>
<tr>
<td>Cutting mode</td>
<td>G64</td>
<td>Once specified, this function is valid until G61, G62, or G63 is specified.</td>
<td></td>
</tr>
<tr>
<td>Tapping mode</td>
<td>G63</td>
<td>Once specified, this function is valid until G61, G62, or G64 is specified.</td>
<td></td>
</tr>
<tr>
<td>Automatic override for inner corners</td>
<td>G62</td>
<td>Once specified, this function is valid until G61, G63, or G64 is specified.</td>
<td></td>
</tr>
<tr>
<td>Internal circular cutting feedrate change</td>
<td>—</td>
<td>This function is valid in the cutter compensation mode, regardless of the G code.</td>
<td></td>
</tr>
</tbody>
</table>

**NOTE**

1. The purpose of in–position check is to check that the servo motor has reached within a specified range (specified with a parameter by the machine tool builder). In–position check is not performed when bit 5 (NCI) of parameter No. 1601 is set to 1.
2. Inner corner angle $\theta$: $2^\circ < \theta \leq \alpha \leq 178^\circ$ ($\alpha$ is a set value)
Format

<table>
<thead>
<tr>
<th>Function</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exact stop</td>
<td>G09 IP_ ;</td>
</tr>
<tr>
<td>Exact stop mode</td>
<td>G61 ;</td>
</tr>
<tr>
<td>Cutting mode</td>
<td>G64 ;</td>
</tr>
<tr>
<td>Tapping mode</td>
<td>G63 ;</td>
</tr>
<tr>
<td>Automatic corner override</td>
<td>G62 ;</td>
</tr>
</tbody>
</table>

5.4.1
Exact Stop (G09, G61)
Cutting Mode (G64)
Tapping Mode (G63)

Explanations

The inter–block paths followed by the tool in the exact stop mode, cutting mode, and tapping mode are different (Fig. 5.4.1 (a)).

Fig. 5.4.1 (a)  Example of Tool Paths from Block (1) to Block (2)

CAUTION
The cutting mode (G64 mode) is set at power–on or system clear.
5.4.2 Automatic Corner Override

When cutter compensation is performed, the movement of the tool is automatically decelerated at an inner corner and internal circular area. This reduces the load on the cutter and produces a smoothly machined surface.

5.4.2.1 Automatic Override for Inner Corners (G62)

Explanations

- Override condition

When G62 is specified, and the tool path with cutter compensation applied forms an inner corner, the feedrate is automatically overridden at both ends of the corner.

There are four types of inner corners (Fig. 5.4.2.1 (a)).

2. $\theta \leq \theta_p \leq 178$, in Fig. 5.4.2.1 (a)

$\theta_p$ is a value set with parameter No. 1711. When $\theta$ is approximately equal to $\theta_p$, the inner corner is determined with an error of 0.001, or less.

![Fig. 5.4.2.1 (a) Inner corner](image-url)
Override range

When a corner is determined to be an inner corner, the feedrate is overridden before and after the inner corner. The distances $L_s$ and $L_e$, where the feedrate is overridden, are distances from points on the cutter center path to the corner (Fig. 5.4.2.1 (b), Fig. 5.4.2.1 (c), Fig. 5.4.2.1 (d)). $L_s$ and $L_e$ are set with parameter Nos. 1713 and 1714.

![Fig. 5.4.2.1 (b) Override Range (Straight Line to Straight Line)](image)

When a programmed path consists of two arcs, the feedrate is overridden if the start and end points are in the same quadrant or in adjacent quadrants (Fig. 5.4.2.1 (c)).

![Fig. 5.4.2.1 (c) Override Range (Arc to Arc)](image)

Regarding program (2) of an arc, the feedrate is overridden from point a to point b and from point c to point d (Fig. 5.4.2.1 (d)).

![Fig. 5.4.2.1 (d) Override Range (Straight Line to Arc, Arc to Straight Line)](image)
Override value

An override value is set with parameter No. 1712. An override value is valid even for dry run and F1-digit specification. In the feed per minute mode, the actual feedrate is as follows:

\[ F \times (\text{automatic override for inner corners}) \times (\text{feedrate override}) \]

Limitations

- **Acceleration/deceleration before interpolation**
  - Override for inner corners is disabled during acceleration/deceleration before interpolation.
- **Start-up/G41, G42**
  - Override for inner corners is disabled if the corner is preceded by a start-up block or followed by a block including G41 or G42.
- **Offset**
  - Override for inner corners is not performed if the offset is zero.

5.4.2.2 Internal Circular Cutting Feedrate Change

For internally offset circular cutting, the feedrate on a programmed path is set to a specified feedrate \( F \) by specifying the circular cutting feedrate with respect to \( F \), as indicated below (Fig. 5.4.2.2). This function is valid in the cutter compensation mode, regardless of the G62 code.

\[ F \times \frac{R_c}{R_p} \]

- \( R_c \): Cutter center path radius
- \( R_p \): Programmed radius

It is also valid for the dry run and the one-digit F command.

![Fig. 5.4.2.2 Internal circular cutting feedrate change](image)

If \( R_c \) is much smaller than \( R_p \), \( R_c/R_p \approx 0 \); the tool stops. A minimum deceleration ratio (MDR) is to be specified with parameter No. 1710. When \( R_c/R_p \leq \text{MDR} \), the feedrate of the tool is \( (F \times \text{MDR}) \).

NOTE

When internal circular cutting must be performed together with override for inner corners, the feedrate of the tool is as follows:

\[ F \times \frac{R_c}{R_p} \times (\text{override for the inner corners}) \times (\text{feedrate override}) \]
5.4.3 Automatic Corner Deceleration

This function automatically controls the feedrate at a corner according to the corner angle between the machining blocks or the feedrate difference between the blocks along each axis.

This function is effective when ACD, bit 6 of parameter No. 1601, is set to 1, the system is in G64 mode (machining mode), and a cutting-feed block (block A) is followed by another cutting-feed block (block B).

The feedrate between machining blocks is controlled according to the corner angle between the blocks or the feedrate difference between the blocks along each axis. These two methods can be switched with CSD, bit 4 of parameter No. 1602.

5.4.3.1 Corner Deceleration According to the Corner Angle

This function decelerates the feedrate when the angle between blocks A and B on the selected plane is smaller than the angle specified in parameter No. 1740. The function executes block B when the feedrates along both the first and second axes are smaller than the feedrate specified in parameter No. 1741. In this case, the function determines that the number of accumulated pulses is zero.

Explanations

- Flowchart for feedrate control

The flowchart for feedrate control is shown below.

```
START

Is the corner angle smaller than the angle specified in parameter (No. 1740)?

Yes

Are the feedrates along the X- and Y-axes smaller than that specified in parameter (No. 1741)?

Yes

The number of accumulated pulses is determined to be zero and block B is executed

No

Further decelerates the feedrate in block A

No

END
```
• **Feedrate and time**
  
  When the corner angle is smaller than the angle specified in the parameter, the relationship between the feedrate and time is as shown below. Although accumulated pulses equivalent to the hatched area remain at time t, the next block is executed because the feedrate of the automatic acceleration/deceleration circuit is smaller than the parameter–set value. This function is effective only for movement on the selected plane.

![Feedrate and time diagram](image)

• **Acceleration/deceleration before interpolation**
  
  When acceleration/deceleration before interpolation is effective, the relationship between the feedrate and time is as shown below. When the angle between blocks A and B on the selected plane is smaller than the angle specified in parameter (No. 1740), and the feedrates specified in blocks A and B are larger than that specified in parameter (No. 1777), the feedrate is decelerated to the parameter–set value in block A, and accelerated to the feedrate specified in block B. The acceleration depends on the parameter for acceleration/deceleration before interpolation.

![Acceleration/deceleration before interpolation diagram](image)

• **Angle between two blocks**
  
  The angle between two blocks (blocks A and B) is assumed to be angle $\theta$, as shown below.

1. **Between linear movements**
2. **Between linear and circular movements** (angle between the linear movement and tangent to the circular movement)
3. **Between circular movements** (angle between the tangents to the circular movements)
• **Selected plane**  
The machining angle is compared with the angle specified in parameter (No. 1740) for movements on the selected plane only. Machining feedrates are compared with that specified in parameter (No. 1741) for movement along the first and second axes on the selected plane only. This means, when movement occurs along three or more axes, only that movement along the first and second axes on the selected plane is considered.

• **Corner roundness**  
Corner roundness is determined by the angle and feedrate specified in parameter (Nos. 1740 and 1741). To always make a sharp corner, set the angle to zero and the feedrate to 180000 (equivalent to 180 degrees).

• **Exact stop**  
When G90 (exact stop) is specified, exact stop is performed irrespective of the angle and feedrate specified in parameter (Nos. 1740 and 1741).

• **Look-ahead control**  
Those parameters related to automatic corner deceleration in look-ahead control mode are shown below.

<table>
<thead>
<tr>
<th>Parameter description</th>
<th>Normal mode</th>
<th>Look-ahead control mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Switching the methods for automatic corner deceleration</td>
<td>No.1602#4</td>
<td>←</td>
</tr>
<tr>
<td>Lower limit of feedrate in automatic corner deceleration</td>
<td>No.1777</td>
<td>No.1778</td>
</tr>
<tr>
<td>Limit angle in corner deceleration</td>
<td>No.1740</td>
<td>No.1779</td>
</tr>
</tbody>
</table>

**Limitations**  
This function cannot be enabled for a single block or during dry run.
5.4.3.2
Corner Deceleration
According to the Feedrate Difference between Blocks Along Each Axis

Explanations

- Flowchart for feedrate control

This function decelerates the feedrate when the difference between the feedrates at the end point of block A and the start point of block B along each axis is larger than the value specified in parameter No. 1781. The function executes block B when the feedrates along all axes are smaller than the feedrate specified in parameter No. 1741. In this case, the function determines that the number of accumulated pulses is zero.

The flowchart for feedrate control is shown below.

![Flowchart for feedrate control](image)

- Feedrate and time

When the feedrate difference between blocks along each axis is larger than the value specified in parameter No. 1781, the relationship between the feedrate and time is as shown below. Although accumulated pulses equivalent to the hatched area remain at time t, the next block is executed because the feedrate of the automatic acceleration/deceleration circuit is smaller than the feedrate specified in parameter No. 1741.

![Feedrate and time](image)
When acceleration/deceleration before interpolation is effective, the relationship between the feedrate and time is as described below.

When the feedrate difference between blocks A and B along each axis is larger than the value specified in parameter No. 1780, the feedrate is decelerated to the corner feedrate calculated from the feedrate difference along each axis.

Let the feedrate be F. Compare the feedrate difference along each axis (Vc[X], Vc[Y], ...) with the value specified in parameter No. 1780, Vmax. When the difference exceeds Vmax, calculate R as shown below.

$$ R = \frac{Vc}{V_{max}} $$

Find the maximum value for R among the calculated values for the axes. Let it be Rmax. Then, the corner feedrate can be obtained as follows:

$$ F_c = F \times \frac{1}{R_{max}} $$

(Example)

![Diagram showing feedrate calculation](image)

When this movement is specified, the feedrate along each axis is as shown in the next figure.

$$ R_{max} = \frac{Vc [X,Y]}{V_{max}} $$

$$ F \times \frac{1}{R_{max}} $$

From the figure, it can be seen that the feedrate differences along the X– and Y–axes (Vc[X] and Vc[Y]) exceed Vmax. Calculate Rmax to get Fc. When the feedrate is decelerated to Fc at the corner, the feedrate difference along each axis do not exceed Vmax.
• Setting the allowable feedrate difference along each axis
  The allowable feedrate difference can be specified for each axis in parameter No. 1783.

• Checking the feedrate difference
  The feedrate difference is also checked during dry-run operation or during deceleration caused by an external signal, using feedrate commands specified in a program.

• Exact stop
  When G90 (exact stop) is specified, exact stop is performed irrespective of the parameter settings.

• Override
  If an override is changed during operation, the feedrate difference will not be checked correctly.
• **Look–ahead control**

Parameters related to automatic corner deceleration in look–ahead control mode are shown below.

<table>
<thead>
<tr>
<th>Parameter description</th>
<th>Normal mode</th>
<th>Look–ahead control mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Switching the methods for automatic corner deceleration</td>
<td>No.1602#4</td>
<td>No.1602#4</td>
</tr>
<tr>
<td>Allowable feedrate difference (for all axis) in automatic corner deceleration based on the feedrate difference</td>
<td>No.1780</td>
<td>No.1780</td>
</tr>
<tr>
<td>Allowable feedrate difference (for each axis) in automatic corner deceleration based on the feedrate difference</td>
<td>No.1783</td>
<td>No.1783</td>
</tr>
</tbody>
</table>

**Limitations**

This function is not effective for feed–per–rotation commands, address–F–with–one–digit commands, rigid tapping, and a single block.
5.5

DWELL (G04)

Format

Dwell G04 X_; or G04 P_;  
X_: Specify a time or spindle speed (decimal point permitted)  
P_: Specify a time or spindle speed (decimal point not permitted)

Explanations

By specifying a dwell, the execution of the next block is delayed by the specified time. In addition, a dwell can be specified to make an exact check in the cutting mode (G64 mode). When neither P nor X is specified, exact stop is performed. Bit 1 (DWL) of parameter No. 3405 can specify dwell for each rotation in feed per rotation mode (G95).

Table 5.5 (a) Command value range of the dwell time
(Command by X)

<table>
<thead>
<tr>
<th>Increment system</th>
<th>Command value range</th>
<th>Dwell time unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>IS–B</td>
<td>0.001 to 99999.999</td>
<td>s or rev</td>
</tr>
<tr>
<td>IS–C</td>
<td>0.0001 to 9999.999</td>
<td>s or rev</td>
</tr>
</tbody>
</table>

Table 5.5 (b) Command value range of the dwell time
(Command by P)

<table>
<thead>
<tr>
<th>Increment system</th>
<th>Command value range</th>
<th>Dwell time unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>IS–B</td>
<td>1 to 99999999</td>
<td>0.001 s or rev</td>
</tr>
<tr>
<td>IS–C</td>
<td>1 to 99999999</td>
<td>0.0001 s or rev</td>
</tr>
</tbody>
</table>
A CNC machine tool has a special position where, generally, the tool is exchanged or the coordinate system is set, as described later. This position is referred to as a reference position.
6.1 REFERENCE POSITION RETURN

General

- Reference position

The reference position is a fixed position on a machine tool to which the tool can easily be moved by the reference position return function. For example, the reference position is used as a position at which tools are automatically changed. Up to four reference positions can be specified by setting coordinates in the machine coordinate system in parameters (No. 1240 to 1243).

Fig. 6.1 (a) Machine zero point and reference positions
Reference position return and movement from the reference position

Tools are automatically moved to the reference position via an intermediate position along a specified axis. Or, tools are automatically moved from the reference position to a specified position via an intermediate position along a specified axis. When reference position return is completed, the lamp for indicating the completion of return goes on.

Reference position return A→B→R  
Return from the reference position R→B→C

Fig. 6.1 (b) Reference position return and return from the reference position

Reference position return check

The reference position return check (G27) is the function which checks whether the tool has correctly returned to the reference position as specified in the program. If the tool has correctly returned to the reference position along a specified axis, the lamp for the axis goes on.

Format

- Reference position return

G28 IP_ ;  Reference position return
G30 P2 IP_ ; 2nd reference position return  (P2 can be omitted.)
G30 P3 IP_ ; 3rd reference position return
G30 P4 IP_ ; 4th reference position return

IP : Command specifying the intermediate position  
(Absolute/incremental command)

- Return from reference position

G29 IP_ ;

IP : Command specifying the destination of return from reference position  
(Absolute/incremental command)

- Reference position return check

G27 IP_ ;

IP : Command specifying the reference position  
(Absolute/incremental command)
Explanations

- **Reference position return (G28)**
  Positioning to the intermediate or reference positions are performed at the rapid traverse rate of each axis. Therefore, for safety, the cutter compensation, and tool length compensation should be cancelled before executing this command. The coordinates for the intermediate position are stored in the CNC only for the axes for which a value is specified in a G28 block. For the other axes, the previously specified coordinates are used.

  Example
  
  N1  G28 X40.0 ; Intermediate position (X40.0)
  
  N2  G28 Y60.0 ; Intermediate position (X40.0, Y60.0)

- **2nd, 3rd, and 4th reference position return (G30)**
  In a system without an absolute–position detector, the first, third, and fourth reference position return functions can be used only after the reference position return (G28) or manual reference position return (see III–3.1) is made. The G30 command is generally used when the automatic tool changer (ATC) position differs from the reference position.

- **Return from the reference position (G29)**
  In general, it is commanded immediately following the G28 command or G30. For incremental programming, the command value specifies the incremental value from the intermediate point.
  Positioning to the intermediate or reference points are performed at the rapid traverse rate of each axis.
  When the workpiece coordinate system is changed after the tool reaches the reference position through the intermediate point by the G28 command, the intermediate point also shifts to a new coordinate system.
  If G29 is then commanded, the tool moves to to the commanded position through the intermediate point which has been shifted to the new coordinate system.
  The same operations are performed also for G30 commands.

- **Reference position return check (G27)**
  G27 command positions the tool at rapid traverse rate. If the tool reaches the reference position, the reference position return lamp lights up. However, if the position reached by the tool is not the reference position, an alarm (No. 092) is displayed.

- **Setting of the reference position return feedrate**
  Before a machine coordinate system is established with the first reference position return after power–on, the manual and automatic reference position return feedrates and automatic rapid traverse rate conform to the setting of parameter No. 1428 for each axis. Even after a machine coordinate system is established upon the completion of reference position return, the manual reference position return feedrate conforms to the setting of the parameter.
NOTE
1 To this feedrate, a rapid traverse override (F0,25,50,100%) is applied, for which the setting is 100%.
2 After a machine coordinate system has been established upon the completion of reference position return, the automatic reference position return feedrate will conform to the ordinary rapid traverse rate.
3 For the manual rapid traverse rate used before a machine coordinate system is established upon the completion of reference position return a jog feedrate or manual rapid traverse rate can be selected using RPD (bit 0 of parameter No. 1401).

<table>
<thead>
<tr>
<th></th>
<th>Before a coordinate system is established</th>
<th>After a coordinate system is established</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automatic reference position return (G28)</td>
<td>No. 1428</td>
<td>No. 1420</td>
</tr>
<tr>
<td>Automatic rapid traverse (G00)</td>
<td>No. 1428</td>
<td>No. 1420</td>
</tr>
<tr>
<td>Manual reference position return</td>
<td>No. 1428</td>
<td>No. 1428</td>
</tr>
<tr>
<td>Manual rapid traverse rate</td>
<td>No. 1423 *1</td>
<td>No. 1424</td>
</tr>
</tbody>
</table>

NOTE
When parameter No. 1428 is set to 0, the feedrates conform to the parameter settings shown below.

<table>
<thead>
<tr>
<th></th>
<th>Before a coordinate system is established</th>
<th>After a coordinate system is established</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automatic reference position return (G28)</td>
<td>No. 1420</td>
<td>No. 1420</td>
</tr>
<tr>
<td>Automatic rapid traverse (G00)</td>
<td>No. 1420</td>
<td>No. 1420</td>
</tr>
<tr>
<td>Manual reference position return</td>
<td>No. 1424</td>
<td>No. 1424</td>
</tr>
<tr>
<td>Manual rapid traverse rate</td>
<td>No. 1423 *1</td>
<td>No. 1424</td>
</tr>
</tbody>
</table>

1420 : Rapid traverse rate
1423 : Jog feedrate
1424 : Manual rapid traverse rate
*1 Setting of parameter No. 1424 when RPD (bit 0 of parameter No. 1401) is set to 1.
6. REFERENCE POSITION

Restrictions

- **Status the machine lock being turned on**
  The lamp for indicating the completion of return does not go on when the machine lock is turned on, even when the tool has automatically returned to the reference position. In this case, it is not checked whether the tool has returned to the reference position even when a G27 command is specified.

- **First return to the reference position after the power has been turned on (without an absolute position detector)**
  When the G28 command is specified when manual return to the reference position has not been performed after the power has been turned on, the movement from the intermediate point is the same as in manual return to the reference position.
  In this case, the tool moves in the direction for reference position return specified in parameter ZMIx (bit 5 of No. 1006). Therefore the specified intermediate position must be a position to which reference position return is possible.

- **Reference position return check in an offset mode**
  In an offset mode, the position to be reached by the tool with the G27 command is the position obtained by adding the offset value. Therefore, if the position with the offset value added is not the reference position, the lamp does not light up, but an alarm is displayed instead. Usually, cancel offsets before G27 is commanded.

- **Lighting the lamp when the programmed position does not coincide with the reference position**
  When the machine tool system is an inch system with metric input, the reference position return lamp may also light up even if the programmed position is shifted from the reference position by the least setting increment. This is because the least setting increment of the machine tool system is smaller than its least command increment.

Reference

**Manual reference position return**
See III–3.1.

Examples

- G28G90X1000.0Y500.0 ; (Programs movement from A to B)
- T1111 ; (Changing the tool at the reference position)
- G29X1300.0Y200.0 ; (Programs movement from B to C)

---

Fig. 6.1 (c) Reference position return and return from the reference position
6.2
FLOATING REFERENCE POSITION RETURN (G30.1)

Format

G30.1 P_;  

P_: Command of the intermediate position of the floating reference position  
(Absolute command/incremental command)

Explanations

Generally speaking, on a machining center or milling machine, cutting tools can be replaced only at specific positions. A position where tools can be replaced is defined as the second or third reference point. Using G30 can easily move the cutting tools back to these points. On some machine tools, the cutting tools can be replaced at any position unless they interfere with the workpiece.

With these machines, the cutting tools should be replaced at a position as close to the workpiece as possible so as to minimize the machine cycle time. For this purpose, the tool change position is to be changed, depending on the figure of the workpiece. This operation can easily be performed using this function. That is, a tool change position suitable for the workpiece is memorized as a floating reference point. Then command G30.1 can easily cause return to the tool change position.

A floating reference point becomes a machine coordinate position memorized by pressing the soft key [SET FRP] on the current positions display screen (see III–11.1.7). The G30.1 block first positions the tool at the intermediate point along the specified axes at rapid traverse rate, then further moves the tool from the intermediate point to the floating reference point at rapid traverse rate.

Before using G30.1, cancel cutter compensation and tool length compensation.

A floating reference point is not lost even if power is turned off. The function for returning from the reference position (G29) can be used for moving the tool from the floating reference position (see II–6.1).

Examples

G30.1 G90 X50.0 Y40.0 ;
By teaching the CNC a desired tool position, the tool can be moved to the position. Such a tool position is represented by coordinates in a coordinate system. Coordinates are specified using program axes. When three program axes, the X-axis, Y-axis, and Z-axis, are used, coordinates are specified as follows:

\[ X \_ Y \_ Z \_ \]

This command is referred to as a dimension word.

Coordinates are specified in one of the following three coordinate systems:

1. Machine coordinate system
2. Workpiece coordinate system
3. Local coordinate system

The number of the axes of a coordinate system varies from one machine to another. So, in this manual, a dimension word is represented as \( IP \_ \).
7. COORDINATE SYSTEM

7.1 MACHINE COORDINATE SYSTEM

The point that is specific to a machine and serves as the reference of the machine is referred to as the machine zero point. A machine tool builder sets a machine zero point for each machine. A coordinate system with a machine zero point set as its origin is referred to as a machine coordinate system. A machine coordinate system is set by performing manual reference position return after power–on (see III–3.1). A machine coordinate system, once set, remains unchanged until the power is turned off.

Format

\[(G90)G53 \ P_\ ;\]
\[P_\;: \text{Absolute dimension word}\]

Explanations

- **Selecting a machine coordinate system (G53)**
  
  When a command is specified the position on a machine coordinate system, the tool moves to the position by rapid traverse. G53, which is used to select a machine coordinate system, is a one–shot G code; that is, it is valid only in the block in which it is specified on a machine coordinate system. Specify an absolute command (G90) for G53. When an incremental command (G91) is specified, the G53 command is ignored. When the tool is to be moved to a machine–specific position such as a tool change position, program the movement in a machine coordinate system based on G53.

Restrictions

- **Cancel of the compensation function**
  
  When the G53 command is specified, cancel the cutter compensation, tool length offset, and tool offset.

- **G53 specification immediately after power–on**
  
  Since the machine coordinate system must be set before the G53 command is specified, at least one manual reference position return or automatic reference position return by the G28 command must be performed after the power is turned on. This is not necessary when an absolute–position detector is attached.

Reference

When manual reference position return is performed after power–on, a machine coordinate system is set so that the reference position is at the coordinate values of \((\alpha, \beta)\) set using parameter No.1240.
7.2 WORKPIECE COORDINATE SYSTEM

A coordinate system used for machining a workpiece is referred to as a workpiece coordinate system. A workpiece coordinate system is to be set with the CNC beforehand (setting a workpiece coordinate system). A machining program sets a workpiece coordinate system (selecting a workpiece coordinate system). A set workpiece coordinate system can be changed by shifting its origin (changing a workpiece coordinate system).

7.2.1 Setting a Workpiece Coordinate System

A workpiece coordinate system can be set using one of three methods:

1. **Method using G92**
   A workpiece coordinate system is set by specifying a value after G92 in the program.

2. **Automatic setting**
   If bit 0 of parameter SPR No. 1201 is set beforehand, a workpiece coordinate system is automatically set when manual reference position return is performed (see Part III–3.1.).

3. **Method using G54 to G59**
   Six workpiece coordinate systems can be set beforehand using the CRT/MDI panel (see Part III–11.4.6.). When using an absolute command, establish the workpiece coordinate system in any of the above ways.

**Format**

- Setting a workpiece coordinate system by G92

\[
\text{(G90) G92 } \_\_
\]

**Explanations**

A workpiece coordinate system is set so that a point on the tool, such as the tool tip, is at specified coordinates. If a coordinate system is set using G92 during tool length offset, a coordinate system in which the position before offset matches the position specified in G92 is set. Cutter compensation is cancelled temporarily with G92.

**Examples**

**Example 1**
Setting the coordinate system by the G92X25.2Z23.0; command
(The tool tip is the start point for the program.)

**Example 2**
Setting the coordinate system by the G92X600.0Z1200.0; command
(The base point on the tool holder is the start point for the program.)

If an absolute command is issued, the base point moves to the commanded position. In order to move the tool tip to the commanded position, the difference from the tool tip to the base point is compensated by tool length offset.
7.2.2 Selecting a Workpiece Coordinate System

The user can choose from set workpiece coordinate systems as described below. (For information about the methods of setting, see II–7.2.1.)

1. Once a workpiece coordinate system is selected by G92 or automatic workpiece coordinate system setting, absolute commands work with the workpiece coordinate system.

2. Choosing from six workpiece coordinate systems set using the MDI panel
   By specifying a G code from G54 to G59, one of the workpiece coordinate systems 1 to 6 can be selected.

   - G54 Workpiece coordinate system 1
   - G55 Workpiece coordinate system 2
   - G56 Workpiece coordinate system 3
   - G57 Workpiece coordinate system 4
   - G58 Workpiece coordinate system 5
   - G59 Workpiece coordinate system 6

   Workpiece coordinate system 1 to 6 are established after reference position return after the power is turned on. When the power is turned on, G54 coordinate system is selected.

Examples

![Diagram of positioning in workpiece coordinate system 2](image)

G90 G55 G00 X40.0 Y100.0 ;

In this example, positioning is made to positions (X=40.0, Y=100.0) in workpiece coordinate system 2.

Fig. 7.2.2
The six workpiece coordinate systems specified with G54 to G59 can be changed by changing an external workpiece zero point offset value or workpiece zero point offset value.

Three methods are available to change an external workpiece zero point offset value or workpiece zero point offset value.

1. Inputting from the MDI panel (see III–11.4.6)
2. Programming by G10 or G92
3. Using the external data input function

An external workpiece zero point offset value can be changed by input signal to CNC. Refer to machine tool builder’s manual for details.

**Fig. 7.2.3 Changing an external workpiece zero point offset value or workpiece zero point offset value**

**Format**

- **Changing by G10**

  \[
  \text{G10 L2 Pp IP } _\_;
  \]

  \( p=0 \) : External workpiece zero point offset value

  \( p=1 \) to \( 6 \) : Workpiece zero point offset value correspond to workpiece coordinate system 1 to 6

  \( \text{IP} \) : For an absolute command (G90), workpiece zero point offset for each axis.

  For an incremental command (G91), value to be added to the set workpiece zero point offset for each axis (the result of addition becomes the new workpiece zero point offset).

- **Changing by G92**

  \[
  \text{G92 IP } _\_;
  \]
Explanations

- **Changing by G10**
  
  With the G10 command, each workpiece coordinate system can be changed separately.

- **Changing by G92**
  
  By specifying G92IP_;, a workpiece coordinate system (selected with a code from G54 to G59) is shifted to set a new workpiece coordinate system so that the current tool position matches the specified coordinates (IP_).
  
  Then, the amount of coordinate system shift is added to all the workpiece zero point offset values. This means that all the workpiece coordinate systems are shifted by the same amount.

**WARNING**

When a coordinate system is set with G92 after an external workpiece zero point offset value is set, the coordinate system is not affected by the external workpiece zero point offset value. When G92X100.0Z80.0; is specified, for example, the coordinate system having its current tool reference position at X = 100.0 and Z = 80.0 is set.
Examples

If G92X100Y100; is commanded when the tool is positioned at (200, 160) in G54 mode, workpiece coordinate system 1 (X′ – Y′) shifted by vector A is created.

Suppose that a G54 workpiece coordinate system is specified. Then, a G55 workpiece coordinate system where the black circle on the tool (figure at the left) is at (600.0, 1200.0) can be set with the following command if the relative relationship between the G54 workpiece coordinate system and G55 workpiece coordinate system is set correctly: G92X600.0Z1200.0; Also, suppose that pallets are loaded at two different positions. If the relative relationship of the coordinate systems of the pallets at the two positions is correctly set by handling the coordinate systems as the G54 workpiece coordinate system and G55 workpiece coordinate system, a coordinate system shift with G92 in one pallet causes the same coordinate system shift in the other pallet. This means that workpieces on two pallets can be machined with the same program just by specifying G54 or G55.
### 7.2.4 Workpiece Coordinate System Preset (G92.1)

The workpiece coordinate system preset function presets a workpiece coordinate system shifted by manual intervention to the pre-shift workpiece coordinate system. The latter system is displaced from the machine zero point by a workpiece zero point offset value.

There are two methods for using the workpiece coordinate system preset function. One method uses a programmed command (G92.1). The other uses MDI operations on the absolute position display screen, relative position display screen, and overall position display screen (III–11.1.4).

#### Format

```
G92.1 IP 0 ;
```

IP 0 : Specifies axis addresses subject to the workpiece coordinate system preset operation. Axes that are not specified are not subject to the preset operation.

#### Explanations

When manual reference position return operation is performed in the reset state, a workpiece coordinate system is shifted by the workpiece zero point offset value from the machine coordinate system zero point. Suppose that the manual reference position return operation is performed when a workpiece coordinate system is selected with G54. In this case, a workpiece coordinate system is automatically set which has its zero point displaced from the machine zero point by the G54 workpiece zero point offset value; the distance from the zero point of the workpiece coordinate system to the reference position represents the current position in the workpiece coordinate system.

If an absolute position detector is provided, the workpiece coordinate system automatically set at power-up has its zero point displaced from the machine zero point by the G54 workpiece zero point offset value. The machine position at the time of power-up is read from the absolute position detector and the current position in the workpiece coordinate system is set by subtracting the G54 workpiece zero point offset value from this machine position. The workpiece coordinate system set by these operations is shifted from the machine coordinate system using the commands and operations listed next page.
(a) Manual intervention performed when the manual absolute signal is off
(b) Move command executed in the machine lock state
(c) Movement by handle interrupt
(d) Operation using the mirror image function
(e) Setting the local coordinate system using G52, or shifting the workpiece coordinate system using G92

In the case of (a) above, the workpiece coordinate system is shifted by the amount of movement during manual intervention.

In the operation above, a workpiece coordinate system once shifted can be preset using G code specification or MDI operation to a workpiece coordinate system displaced by a workpiece zero point offset value from the machine zero point. This is the same as when manual reference position return operation is performed on a workpiece coordinate system that has been shifted. In this example, such G code specification or MDI operation has the effect of returning workpiece coordinate system zero point WZn to the original zero point WZo, and the distance from WZo to Pn is used to represent the current position in the workpiece coordinate system.

Bit 3 (PPD) of parameter No. 3104 specifies whether to preset relative coordinates (RELATIVE) as well as absolute coordinates.

When no workpiece coordinate system option (G54 to G59) is selected, the workpiece coordinate system is preset to the coordinate system set by automatic workpiece coordinate system setting. When automatic workpiece coordinate system setting is not selected, the workpiece coordinate system is preset with its zero point placed at the reference position.

**Limitations**

- **Cutter compensation, tool length compensation, tool offset**
- **Program restart**
- **Prohibited modes**

When using the workpiece coordinate system preset function, cancel compensation modes: cutter compensation, tool length compensation, and tool offset. If the function is executed without cancelling these modes, compensation vectors are temporarily cancelled.

The workpiece coordinate system preset function is not executed during program restart.

Do not use the workpiece coordinate system preset function when the scaling, coordinate system rotation, programmable image, or drawing copy mode is set.
7.2.5 Adding Workpiece Coordinate Systems (G54.1 or G54)

Besides the six workpiece coordinate systems (standard workpiece coordinate systems) selectable with G54 to G59, 48 additional workpiece coordinate systems (additional workpiece coordinate systems) can be used. Alternatively, up to 300 additional workpiece coordinate systems can be used.

Format

- Selecting the additional workpiece coordinate systems

\[ \text{G54.1Pn} \text{ or G54Pn ;} \]
\[ \text{Pn : Codes specifying the additional workpiece coordinate systems} \]
\[ n : 1 \text{ to 48 or 1 to 300} \]

- Setting the workpiece zero point offset value in the additional workpiece coordinate systems

\[ \text{G10L20 Pn IP ;} \]
\[ \text{Pn : Codes specifying the workpiece coordinate system for setting the workpiece zero point offset value} \]
\[ n : 1 \text{ to 48 or 1 to 300} \]
\[ \text{IP : Axis addresses and a value set as the workpiece zero point offset} \]

Explanations

- Selecting the additional workpiece coordinate systems

When a P code is specified together with G54.1 (G54), the corresponding coordinate system is selected from the additional workpiece coordinate systems (1 to 48 or 1 to 300).

A workpiece coordinate system, once selected, is valid until another workpiece coordinate system is selected. Standard workpiece coordinate system 1 (selectable with G54) is selected at power–on.

- Setting the workpiece zero point offset value in the additional workpiece coordinate systems

When an absolute workpiece zero point offset value is specified, the specified value becomes a new offset value. When an incremental workpiece zero point offset value is specified, the specified value is added to the current offset value to produce a new offset value.

As with the standard workpiece coordinate systems, the following operations can be performed for a workpiece zero point offset in an additional workpiece coordinate system:

1. The OFFSET function key can be used to display and set a workpiece zero point offset value.

2. The G10 function enables a workpiece zero point offset value to be set by programming (refer to II–7.2.3).
(3) A custom macro allows a workpiece zero point offset value to be handled as a system variable.
(4) Workpiece zero point offset data can be entered or output as external data.
(5) The PMC window function enables workpiece zero point offset data to be read as program command modal data.

When the workpiece origin offset is specified using an absolute value, the specified value is the new offset. When it is specified using an incremental value, the specified value is added to the current offset to obtain the new offset.

Limitations

Setting the workpiece origin offset in the coordinate system for the added workpiece (G10)

Specifying P codes

A P code must be specified after G54.1 (G54). If G54.1 is not followed by a P code in the same block, additional workpiece coordinate system 1 (G54.1P1) is assumed.

If a value not within the specifiable range is specified in a P code, an P/S alarm (No. 030) is issued.

P codes other than workpiece offset numbers cannot be specified in a G54.1 (G54) block.

Example) G54.1 (G54) G04 P1000 ;
7.3 LOCAL COORDINATE SYSTEM

When a program is created in a workpiece coordinate system, a child workpiece coordinate system can be set for easier programming. Such a child coordinate system is referred to as a local coordinate system.

Format

\[ \text{G52 } \text{IP } _{\_}; \text{ Setting the local coordinate system} \]

\[ \text{G52 } \text{IP } 0; \text{ Canceling of the local coordinate system} \]

\[ \text{IP } _{\_}: \text{Origin of the local coordinate system} \]

Explanations

By specifying G52 \text{IP } _{\_};, a local coordinate system can be set in all the workpiece coordinate systems (G54 to G59). The origin of each local coordinate system is set at the position specified by \text{IP } _{\_} in the workpiece coordinate system.

When a local coordinate system is set, the move commands in absolute mode (G90), which is subsequently commanded, are the coordinate values in the local coordinate system. The local coordinate system can be changed by specifying the G52 command with the zero point of a new local coordinate system in the workpiece coordinate system.

To cancel the local coordinate system and specify the coordinate value in the workpiece coordinate system, match the zero point of the local coordinate system with that of the workpiece coordinate system.

![Fig. 7.3 Setting the local coordinate system](image-url)
WARNING

1 When an axis returns to the reference point by the manual reference point return function, the zero point of the local coordinate system of the axis matches that of the work coordinate system. The same is true when the following command is issued:
   
   G52α0;
   
   α: Axis which returns to the reference point

2 The local coordinate system setting does not change the workpiece and machine coordinate systems.

3 Whether the local coordinate system is canceled at reset depends on the parameter setting. The local coordinate system is canceled when either CLR, bit 6 of parameter No.3402 or RLC, bit 3 of parameter No.1202 is set to 1.

4 If coordinate values are not specified for all axes when setting a workpiece coordinate system with the G92 command, the local coordinate systems of axes for which coordinate values were not specified are not cancelled, but remain unchanged.

5 G52 cancels the offset temporarily in cutter compensation.

6 Command a move command immediately after the G52 block in the absolute mode.
7.4

PLANE SELECTION

Select the planes for circular interpolation, cutter compensation, and drilling by G-code.

The following table lists G-codes and the planes selected by them.

Explanations

<table>
<thead>
<tr>
<th>G code</th>
<th>Selected plane</th>
<th>Xp</th>
<th>Yp</th>
<th>Zp</th>
</tr>
</thead>
<tbody>
<tr>
<td>G17</td>
<td>Xp Yp plane</td>
<td>X-axis or an axis parallel to it</td>
<td>Y-axis or an axis parallel to it</td>
<td>Z-axis or an axis parallel to it</td>
</tr>
<tr>
<td>G18</td>
<td>Zp Xp plane</td>
<td>X-axis or an axis parallel to it</td>
<td>Y-axis or an axis parallel to it</td>
<td>Z-axis or an axis parallel to it</td>
</tr>
<tr>
<td>G19</td>
<td>Yp Zp plane</td>
<td>X-axis or an axis parallel to it</td>
<td>Y-axis or an axis parallel to it</td>
<td>Z-axis or an axis parallel to it</td>
</tr>
</tbody>
</table>

Xp, Yp, Zp are determined by the axis address appeared in the block in which G17, G18 or G19 is commanded.

When an axis address is omitted in G17, G18 or G19 block, it is assumed that the addresses of basic three axes are omitted.

Parameter No. 1022 is used to specify that an optional axis be parallel to the each axis of the X, Y–, and Z–axes as the basic three axes.

The plane is unchanged in the block in which G17, G18 or G19 is not commanded.

When the power is turned on or the CNC is reset, G17 (XY plane), G18 (ZX plane), or G19 (YZ plane) is selected by bits 1 (G18) and 2 (G19) of parameter 3402.

The movement instruction is irrelevant to the plane selection.

Examples

Plane selection when the X–axis is parallel with the U–axis.

G17X_Y_ XY plane,
G17U_Y_ UY plane
G18X_Z_ ZX plane
X_Y_ Plane is unchanged (ZX plane)
G17    XY plane
G18    ZX plane
G17 U_ UY plane
G18Y_ ; ZX plane, Y axis moves regardless without any relation to the plane.
This chapter contains the following topics.

8.1 ABSOLUTE AND INCREMENTAL PROGRAMMING (G90, G91)
8.2 POLAR COORDINATE COMMAND (G15, G16)
8.3 INCH/METRIC CONVERSION (G20, G21)
8.4 DECIMAL POINT PROGRAMMING
8.1 ABSOLUTE AND INCREMENTAL PROGRAMMING (G90, G91)

Format

<table>
<thead>
<tr>
<th>Absolute command</th>
<th>Incremental command</th>
</tr>
</thead>
<tbody>
<tr>
<td>G90 IP ;</td>
<td>G91 IP ;</td>
</tr>
</tbody>
</table>

Examples

There are two ways to command travels of the tool; the absolute command, and the incremental command. In the absolute command, coordinate value of the end position is programmed; in the incremental command, move distance of the position itself is programmed. G90 and G91 are used to command absolute or incremental command, respectively.

- Absolute command: G90 X40.0 Y70.0;
- Incremental command: G91 X–60.0 Y40.0;
8.2 POLAR COORDINATE COMMAND (G15, G16)

The end point coordinate value can be input in polar coordinates (radius and angle). The plus direction of the angle is counterclockwise of the selected plane first axis + direction, and the minus direction is clockwise. Both radius and angle can be commanded in either absolute or incremental command (G90, G91).

Format

```
G... G... G16 ;   Starting the polar coordinate command (polar coordinate mode)
G... P_ ;         Polar coordinate command
  ;                
G15 ;             Canceling the polar coordinate command (polar coordinate mode)
G16               Polar coordinate command
G15               Polar coordinate command cancel
G...              Plane selection of the polar coordinate command (G17, G18 or G19)
G...              G90 specifies the zero point of the work coordinate system as the origin of the polar coordinate system, from which a radius is measured. G91 specifies the current position as the origin of the polar coordinate system, from which a radius is measured.
P_                Specifying the addresses of axes constituting the plane selected for the polar coordinate system, and their values First axis : radius of polar coordinate Second axis : angle of polar coordinate
```

- **Setting the zero point of the workpiece coordinate system as the origin of the polar coordinate system**

Specify the radius (the distance between the zero point and the point) to be programmed with an absolute command. The zero point of the work coordinate system is set as the origin of the polar coordinate system. When a local coordinate system (G52) is used, the origin of the local coordinate system becomes the center of the polar coordinates.
**Setting the current position as the origin of the polar coordinate system**

Specify the radius (the distance between the current position and the point) to be programmed with an incremental command. The current position is set as the origin of the polar coordinate system.

**Examples**

Bolt hole circle

- The zero point of the work coordinate system is set as the origin of the polar coordinate system.
- The XY plane is selected.

**Specifying angles and a radius with absolute commands**

- N1 G17 G90 G16;
  Setting the polar coordinate command and selecting the XY plane
- N2 G81 X100.0 Y30.0 Z–20.0 R–5.0 F200.0;
  Specifying a distance of 100 mm and an angle of 30 degrees
- N3 Y150.0;
  Specifying a distance of 100 mm and an angle of 150 degrees
- N4 Y270.0;
  Specifying a distance of 100 mm and an angle of 270 degrees
- N5 G15 G80;
  Canceling the polar coordinate command

**Specifying angles with incremental commands and a radius with absolute commands**

- N1 G17 G90 G16;
  Setting the polar coordinate command and selecting the XY plane
- N2 G81 X100.0 Y30.0 Z–20.0 R–5.0 F200.0;
  Specifying a distance of 100 mm and an angle of 30 degrees
- N3 G91 Y120.0;
  Specifying a distance of 100 mm and an angle of +120 degrees
- N4 Y120.0;
  Specifying a distance of 100 mm and an angle of +120 degrees
N5 G15 G80 ;
  Canceling the polar coordinate command

## Limitations

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Specifying a radius in the polar coordinate mode</strong></td>
<td>In the polar coordinate mode, specify a radius for circular interpolation or helical cutting (G02, G03) with R.</td>
</tr>
<tr>
<td><strong>Axes that are not considered part of a polar coordinate command in the polar coordinate mode</strong></td>
<td>Axes specified for the following commands are not considered part of the polar coordinate command:</td>
</tr>
<tr>
<td></td>
<td>- Dwell (G04)</td>
</tr>
<tr>
<td></td>
<td>- Programmable data input (G10)</td>
</tr>
<tr>
<td></td>
<td>- Setting the local coordinate system (G52)</td>
</tr>
<tr>
<td></td>
<td>- Converting the workpiece coordinate system (G92)</td>
</tr>
<tr>
<td></td>
<td>- Selecting the machine coordinate system (G53)</td>
</tr>
<tr>
<td></td>
<td>- Stored stroke check (G22)</td>
</tr>
<tr>
<td></td>
<td>- Coordinate system rotation (G68)</td>
</tr>
<tr>
<td></td>
<td>- Scaling (G51)</td>
</tr>
<tr>
<td><strong>Arbitrary angle chamfering and corner rounding</strong></td>
<td>Arbitrary angle chamfering and corner rounding cannot be specified in polar coordinate mode.</td>
</tr>
</tbody>
</table>
Either inch or metric input can be selected by G code.

This G code must be specified in an independent block before setting the coordinate system at the beginning of the program. After the G code for inch/metric conversion is specified, the unit of input data is switched to the least inch or metric input increment of increment system IS−B or IS−C (II−2.3). The unit of data input for degrees remains unchanged. The unit systems for the following values are changed after inch/metric conversion:

- Feedrate commanded by F code
- Positional command
- Work zero point offset value
- Tool compensation value
- Unit of scale for manual pulse generator
- Movement distance in incremental feed
- Some parameters

When the power is turned on, the G code is the same as that held before the power was turned off.

**WARNING**

1. G20 and G21 must not be switched during a program.
2. When switching inch input (G20) to metric input (G21) and vice versa, the tool compensation value must be re-set according to the least input increment. However, when bit 0 (OIM) of parameter 5006 is 1, tool compensation values are automatically converted and need not be re-set.

**CAUTION**

For the first G28 command after switching inch input to metric input or vice versa, operation from the intermediate point is the same as that for manual reference position return. The tool moves from the intermediate point in the direction for reference position return, specified with bit 5 (ZMI) of parameter No. 1006.

**NOTE**

1. When the least input increment and the least command increment systems are different, the maximum error is half of the least command increment. This error is not accumulated.
2. The inch and metric input can also be switched using settings (see III−11.4.3).
8.4 DECIMAL POINT PROGRAMMING

Numerical values can be entered with a decimal point. A decimal point can be used when entering a distance, time, or speed. Decimal points can be specified with the following addresses:

Explanations

There are two types of decimal point notation: calculator-type notation and standard notation.

When calculator-type decimal notation is used, a value without decimal point is considered to be specified in millimeters inch, or deg. When standard decimal notation is used, such a value is considered to be specified in least input increments. Select either calculator-type or standard decimal notation by using the DPI bit (bit 0 of parameter 3401). Values can be specified both with and without decimal point in a single program.

Examples

<table>
<thead>
<tr>
<th>Program command</th>
<th>Pocket calculator type decimal point programming</th>
<th>Standard type decimal point programming</th>
</tr>
</thead>
<tbody>
<tr>
<td>X1000</td>
<td>1000mm Unit : mm</td>
<td>1mm Unit : Least input increment (0.001 mm)</td>
</tr>
<tr>
<td>X1000.0</td>
<td>1000mm Unit : mm</td>
<td>1000mm Unit : mm</td>
</tr>
</tbody>
</table>

WARNING

In a single block, specify a G code before entering a value. The position of decimal point may depend on the command.

Examples:
- **G20;** Input in inches
- **X1.0 G04;** X1.0 is considered to be a distance and processed as X10000. This command is equivalent to G04 X10000. The tool dwells for 10 seconds.
- **G04 X1.0;** Equivalent to G04 X1000. The tool dwells for one second.

NOTE

1. Fractions less than the least input increment are truncated.
   **Examples:**
   - **X1.23456;** Truncated to X1.234 when the least input increment is 0.001 mm. Processed as X1.2345 when the least input increment is 0.0001 inch.
2. When more than eight digits are specified, an alarm occurs. If a value is entered with a decimal point, the number of digits is also checked after the value is converted to an integer according to the least input increment.
   **Examples:**
   - **X1.23456789;** P/S alarm 0.003 occurs because more than eight digits are specified.
   - **X123456.7;** If the least input increment is 0.001 mm, the value is converted to integer 123456700. Because the integer has more than eight digits, an alarm occurs.
The spindle speed can be controlled by specifying a value following address S.

This chapter contains the following topics.

9.1 SPECIFYING THE SPINDLE SPEED WITH A CODE
9.2 SPECIFYING THE SPINDLE SPEED VALUE DIRECTLY (S5–DIGIT COMMAND)
9.3 CONSTANT SURFACE SPEED CONTROL (G96, G97)
9.4 SPINDLE SPEED FLUCTUATION DETECTION FUNCTION (G25, G26)
9. SPINDLE SPEED FUNCTION (S FUNCTION)

9.1 SPECIFYING THE SPINDLE SPEED WITH A CODE

When a value is specified after address S, the code signal and strobe signal are sent to the machine to control the spindle rotation speed. A block can contain only one S code. Refer to the appropriate manual provided by the machine tool builder for details such as the number of digits in an S code or the execution order when a move command and an S code command are in the same block.

9.2 SPECIFYING THE SPINDLE SPEED VALUE DIRECTLY (S5–DIGIT COMMAND)

The spindle speed can be specified directly by address S followed by a max.five-digit value (min\(^{-1}\)). The unit for specifying the spindle speed may vary depending on the machine tool builder. Refer to the appropriate manual provided by the machine tool builder for details.
9.3 CONSTANT SURFACE SPEED CONTROL (G96, G97)

Specify the surface speed (relative speed between the tool and workpiece) following S. The spindle is rotated so that the surface speed is constant regardless of the position of the tool.

Format

- Constant surface speed control command

\[
\text{G96 } \text{S} \quad \text{Surface speed (m/min or feet/min)}
\]

Note: This surface speed unit may change according to machine tool builder's specification.

- Constant surface speed control cancel command

\[
\text{G97 } \text{S} \quad \text{Spindle speed (min}^{-1})
\]

Note: This surface speed unit may change according to machine tool builder's specification.

- Constant surface speed controlled axis command

\[
\text{G96 } \text{P} \quad \text{P0 : Axis set in the parameter (No. 3770)}
\]

P1 : X axis, P2 : Y axis, P3 : Z axis, P4 : 4th axis
P5 : 5th axis, P6 : 6th axis, P7 : 7th axis, P8 : 8th axis

- Clamp of maximum spindle speed

\[
\text{G92 } \text{S} \quad \text{The maximum spindle speed (min}^{-1}) \text{ follows S.}
\]
G96 (constant surface speed control command) is a modal G code. After a G96 command is specified, the program enters the constant surface speed control mode (G96 mode) and specified S values are assumed as a surface speed. A G96 command must specify the axis along which constant surface speed control is applied. A G97 command cancels the G96 mode. When constant surface speed control is applied, a spindle speed higher than the value specified in G92S_ (maximum spindle speed) is clamped at the maximum spindle speed. When the power is turned on, the maximum spindle speed is not yet set and the speed is not clamped. S (surface speed) commands in the G96 mode are assumed as S = 0 (the surface speed is 0) until M03 (rotating the spindle in the positive direction) or M04 (rotating the spindle in the negative direction) appears in the program.

The spindle speed (min⁻¹) almost coincides with the surface speed (m/min) at approx. 160 mm (radius). S is 600 m/min.

To execute the constant surface speed control, it is necessary to set the work coordinate system, and so the coordinate value at the center of the rotary axis, for example, Z axis, (axis to which the constant surface speed control applies) becomes zero.
9. SPINDLE SPEED FUNCTION (S FUNCTION)

- **Surface speed specified in the G96 mode**

<table>
<thead>
<tr>
<th>G96 mode</th>
<th>G97 mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specify the surface speed in m/min (or feet/min)</td>
<td>Command for the spindle speed</td>
</tr>
<tr>
<td>G97 command</td>
<td>The specified spindle speed (rpm) is used</td>
</tr>
<tr>
<td>Store the surface speed in m/min (or feet/min)</td>
<td>Not specified</td>
</tr>
<tr>
<td></td>
<td>The surface speed (m/min or feet/min) is converted to the spindle speed (rpm)</td>
</tr>
<tr>
<td></td>
<td>Commands other than G96</td>
</tr>
<tr>
<td></td>
<td>G96 command</td>
</tr>
<tr>
<td></td>
<td>Specified</td>
</tr>
<tr>
<td></td>
<td>The specified surface speed is used</td>
</tr>
<tr>
<td></td>
<td>Not specified</td>
</tr>
<tr>
<td></td>
<td>The stored surface speed (m/min or feet/min) is used. If no surface speed is stored, 0 is assumed.</td>
</tr>
</tbody>
</table>

**Restrictions**

- **Constant surface speed control for threading**

  The constant surface speed control is also effective during threading. Accordingly, it is recommended that the constant surface speed control be invalidated with G97 command before starting the scroll threading and taper threading, because the response problem in the servo system may not be considered when the spindle speed changes.

- **Constant surface speed control for rapid traverse (G00)**

  In a rapid traverse block specified by G00, the constant surface speed control is not made by calculating the surface speed to a transient change of the tool position, but is made by calculating the surface speed based on the position at the end point of the rapid traverse block, on the condition that cutting is not executed at rapid traverse.
9.4 SPINDLE SPEED FLUCTUATION DETECTION FUNCTION (G25, G26)

With this function, an overheat alarm (No. 704) is raised when the spindle speed deviates from the specified speed due to machine conditions. This function is useful, for example, for preventing the seizure of the guide bushing.

G26 enables spindle speed fluctuation detection. G25 disables spindle speed fluctuation detection.

Format

G26 Pp Qq Rr ;  Spindle fluctuation detection on
G25 ;  Spindle fluctuation detection off

p : Time (in ms) from the issue of a new spindle rotation command (S command) to the start of checking whether the actual spindle speed is so fast that an overheat can occur. When a specified speed is reached within the time period of P, a check is started at that time.

q : Tolerance (%) of a specified spindle speed

\[ q = \left( \frac{1 - \text{actual spindle speed}}{\text{specified spindle speed}} \right) \times 100 \]

If a specified spindle speed lies within this range, it is regarded as having reached the specified value. Then, the checking of an actual spindle speed is started.

r : Spindle speed fluctuation (%) at which the actual spindle speed is so fast that an overheat can occur

\[ r = \left( \frac{1 - \text{speed that can cause overheat}}{\text{specified spindle speed}} \right) \times 100 \]

G26 enables the spindle speed fluctuation detection function, and G25 disables the spindle speed fluctuation detection. Even if G25 is specified, p, q, and r are not cleared.
Explanations

The fluctuation of the spindle speed is detected as follows:

1. When an alarm is issued after a specified spindle speed is reached

   ![Diagram of spindle speed fluctuation after specified speed is reached]

   Specified speed:
   (Speed specified by address S and five-digit value) \times \text{(spindle override)}

   Actual speed: Speed detected with a position coder

   \( p \): Time elapses since the specified speed changes until a check starts.
   \( q \): (Percentage tolerance for a check to start) \times \text{(specified speed)}
   \( r \): (Percentage fluctuation detected as an alarm condition) \times \text{(specified speed)}
   \( d \): Fluctuation detected as an alarm (specified in parameter (No.4913))

   An alarm is issued when the difference between the specified speed and the actual speed exceeds both \( r \) and \( d \).

2. When an alarm is issued before a specified spindle speed is reached

   ![Diagram of spindle speed fluctuation before specified speed is reached]

   Specified speed:
   (Speed specified by address S and five-digit value) \times \text{(spindle override)}

   Actual speed: Speed detected with a position coder

   \( p \): Time elapses since the specified speed changes until a check starts.
   \( q \): (Percentage tolerance for a check to start) \times \text{(specified speed)}
   \( r \): (Percentage fluctuation detected as an alarm condition) \times \text{(specified speed)}
   \( d \): Fluctuation detected as an alarm (specified in parameter (No.4913))

   An alarm is issued when the difference between the specified speed and the actual speed exceeds both \( r \) and \( d \).
NOTE
1 When an alarm is issued in automatic operation, a single block stop occurs. The spindle overheat alarm is indicated on the screen, and the alarm signal “SPAL” is output (set to 1 for the presence of an alarm). This signal is cleared by resetting.
2 Even when reset operation is performed after an alarm occurs, the alarm is issued again unless the cause of the alarm is corrected.
3 No check is made during spindle stop state (*SSTP = 0).
4 By setting the parameter (No. 4913), an allowable range of speed fluctuations can be set which suppresses the occurrence of an alarm. However, an alarm is issued one second later if the actual speed is found to be 0 rpm.
Two tool functions are available. One is the tool selection function, and the other is the tool life management function.
10.1 TOOL SELECTION FUNCTION

By specifying an up to 8-digit numerical value following address T, tools can be selected on the machine. One T code can be commanded in a block. Refer to the machine tool builder’s manual for the number of digits commandable with address T and the correspondence between the T codes and machine operations. When a move command and a T code are specified in the same block, the commands are executed in one of the following two ways:

(i) Simultaneous execution of the move command and T function commands.

(ii) Executing T function commands upon completion of move command execution.

The selection of either (i) or (ii) depends on the machine tool builder’s specifications. Refer to the manual issued by the machine tool builder for details.
10.2 TOOL LIFE MANAGEMENT FUNCTION

Tools are classified into various groups, with the tool life (time or frequency of use) for each group being specified. The function of accumulating the tool life of each group in use and selecting and using the next tool previously sequenced in the same group, is called the tool life management function.

![Fig. 10.2 (a) Tool life management data (number of n tools)](image)

By choosing a tool from a tool group specified by a machining program, the tool life can be managed.

![Fig. 10.2 (b) Tool Selection by Machining Program](image)

For two-path control, tool life management is applied independently for each path. Tool life management data is also set for each path.
10.2.1 Tool Life Management Data

Explanations

• Tool group number

Tool life management data consists of tool group numbers, tool numbers, codes specifying tool compensation values, and tool life value.

The Max. number of groups and the number of tools per group that can be registered are set by parameter (GS1,GS2 No. 6800#0, #1) (Table 10.2.1 (a)).

Table 10.2.1 (a) The Max. number of groups and tools that can be registered

<table>
<thead>
<tr>
<th>GS1 (No. 6800#0)</th>
<th>GS2 (No. 6800#1)</th>
<th>The Max. number of groups and tools without optional function of 512 tool pairs</th>
<th>The Max. number of groups and tools with optional function of 512 tool pairs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Number of group</td>
<td>Number of tool</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>32</td>
<td>8</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>64</td>
<td>4</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>128</td>
<td>2</td>
</tr>
</tbody>
</table>

WARNING

When bits 0 or 1 of parameter GS1,GS2 No.6800 is changed, re-register tool life management data with the G10L3 command (for registering and deleting data for all groups). Otherwise, new data pairs cannot be set.

• Tool number

Specify a four-digit number after T.

• Code specifying tool compensation value

Codes specifying tool offset values are classified into H codes (for tool length offset) and D codes (cutter compensation). The maximum number of the tool compensation value specification code which can be registered is 255 when there are 400 tool compensation values (even if the option for 512 tool life management sets is supported). The maximum number is 32, 64, 99, 200, 499, or 999 when there are 32, 64, 99, 200, 499, or 999 tool compensation values.

NOTE

When codes specifying tool offset values are not used, registration can be omitted.

• Tool life value

Refer to II–10.2.2 and II–10.2.4.
### 10.2.2
**Register, Change and Delete of Tool Life Management Data**

<table>
<thead>
<tr>
<th>Description</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Register with deleting all groups</strong></td>
<td>A different program format is used for each of the four types of operations described below.</td>
</tr>
<tr>
<td><strong>Addition and change of tool life management data</strong></td>
<td>After all registered tool life management data is deleted, programmed tool life management data is registered.</td>
</tr>
<tr>
<td><strong>Deletion of tool life management data</strong></td>
<td>Programmed tool life management data for a group can be added or changed.</td>
</tr>
<tr>
<td><strong>Register of tool life count type</strong></td>
<td>Programmed tool life management data for a group can be deleted.</td>
</tr>
<tr>
<td><strong>Life value</strong></td>
<td>Count types (time or frequency can be registered for individual groups.</td>
</tr>
</tbody>
</table>

In a program, tool life management data can be registered in the CNC unit, and registered tool life management data can be changed or deleted.

Whether tool life is to be indicated by time (minutes) or by frequency, it is set by a parameter LTM (No. 6800 #2).

- Maximum value of tool life is as follows.
  - In case of minute: 4300 (minutes)
  - In case of frequency: 9999 (times)
10. TOOL FUNCTION
(T FUNCTION)

### Format

- Register with deleting all groups

<table>
<thead>
<tr>
<th>Format</th>
<th>Meaning of command</th>
</tr>
</thead>
<tbody>
<tr>
<td>G10L3 ;</td>
<td>G10L3 : Register with deleting all groups</td>
</tr>
<tr>
<td>P_L ;</td>
<td>P_ : Group number</td>
</tr>
<tr>
<td>T_H_D ;</td>
<td>L_ : Life value</td>
</tr>
<tr>
<td>T_H_D ;</td>
<td>T_ : Tool number</td>
</tr>
<tr>
<td>P_L ;</td>
<td>H_ : Code specifying tool offset value</td>
</tr>
<tr>
<td>T_H_D ;</td>
<td>(H code)</td>
</tr>
<tr>
<td>T_H_D ;</td>
<td>D_ : Code specifying tool offset value</td>
</tr>
<tr>
<td>G11 ;</td>
<td>(D code)</td>
</tr>
<tr>
<td>M02 (M30) ;</td>
<td>G11 : End of registration</td>
</tr>
</tbody>
</table>

- Addition and change of tool life management data

<table>
<thead>
<tr>
<th>Format</th>
<th>Meaning of command</th>
</tr>
</thead>
<tbody>
<tr>
<td>G10L3P1 ;</td>
<td>G10L3P1 : Addition and change of group</td>
</tr>
<tr>
<td>P_L ;</td>
<td>P_ : Group number</td>
</tr>
<tr>
<td>T_H_D ;</td>
<td>L_ : Life value</td>
</tr>
<tr>
<td>T_H_D ;</td>
<td>T_ : Tool number</td>
</tr>
<tr>
<td>P_L ;</td>
<td>H_ : Code specifying tool offset value</td>
</tr>
<tr>
<td>T_H_D ;</td>
<td>(H code)</td>
</tr>
<tr>
<td>T_H_D ;</td>
<td>D_ : Code specifying tool offset value</td>
</tr>
<tr>
<td>G11 ;</td>
<td>(D code)</td>
</tr>
<tr>
<td>M02 (M30) ;</td>
<td>G11 : End of addition and change of group</td>
</tr>
</tbody>
</table>

- Deletion of tool life management data

<table>
<thead>
<tr>
<th>Format</th>
<th>Meaning of command</th>
</tr>
</thead>
<tbody>
<tr>
<td>G10L3P2 ;</td>
<td>G10L3P2 : Deletion of group</td>
</tr>
<tr>
<td>P_ ;</td>
<td>P_ : Group number</td>
</tr>
<tr>
<td>P_ ;</td>
<td>G11 : End of deletion of group</td>
</tr>
<tr>
<td>P_ ;</td>
<td></td>
</tr>
<tr>
<td>G11 ;</td>
<td></td>
</tr>
<tr>
<td>M02 (M30) ;</td>
<td></td>
</tr>
</tbody>
</table>

---

---
### Setting a tool life count type for groups

<table>
<thead>
<tr>
<th>Format</th>
<th>Meaning of command</th>
</tr>
</thead>
<tbody>
<tr>
<td>G10L3 or G10L3P1; P_L_Q_; T_H_D_; T_H_D_;</td>
<td>Q_ : Life count type (1:Frequency, 2:Time)</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>.</td>
<td></td>
</tr>
<tr>
<td>P_L_Q_; T_H_D_; T_H_D_;</td>
<td></td>
</tr>
<tr>
<td>.</td>
<td></td>
</tr>
<tr>
<td>G11 ; M02 (M30) ;</td>
<td></td>
</tr>
</tbody>
</table>

#### CAUTION

1. When the Q command is omitted, the value set in bit 7 (LTM) of parameter No.6800 is used as the life count type.
2. G10L3P1 and G10L3P2 can be specified only when the extended tool life management function is enabled. (Parameter EXT (No.6801#6) = 1)
10.2.3 Tool Life Management Command in a Machining Program

Explanations

- Command

The following command is used for tool life management:
T▼▼▼▼;—specifies a tool group number.

The tool life management function selects, from a specified group, a tool whose life has not expired, and outputs its T code. In ▼▼▼▼, specify a number calculated by adding the tool life management cancel number specified in parameter 6810 to a group number. For example, to set tool group 1 when the tool life management cancel number is 100, specify T101;.

NOTE
When ▼▼▼▼ is less than a tool life management cancel number, the T code is treated as an ordinary T code.

M06;——terminates life management for the previously used tools, and begins counting the life of the new tools selected with the T code.

WARNING
When an option for specifying multiple M codes is selected, specify this code by itself or as the first M code.

H99;——selects the H code of tool life management data for the tool currently being used.
H00;——cancels tool length offset
D99;——selects the D code of tool life management data for the tool currently being used.
D00;——cancels cutter compensation

WARNING
H99 or D99 must be specified after the M06 command. When a code other than H99 or D99 is specified after the M06 command, the H code and D code of tool life management data are not selected.
• Types

For tool life management, the four tool change types indicated below are available. The type used varies from one machine to another. For details, refer to the appropriate manual of each machine tool builder.

<table>
<thead>
<tr>
<th>Tool change type</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tool group number specified in the same block as the tool change command (M06)</td>
<td>Previously used tools</td>
<td>Tools to be used next</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tool life count timing</td>
<td>Life counting is performed for a tool in the specified tool group when M06 is specified next.</td>
<td>Life counting is performed when a tool in the tool group specified in the same block as M06 is specified.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Remarks</td>
<td>Normally, when a tool group number is specified by itself, type B is used. However, no alarm is raised even if the tool group number is specified by itself as type C.</td>
<td>When only M06 is specified, P/S alarm No. 153 is issued.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parameter</td>
<td>No. 6800#7 (M6T)=0 No.6801#7 (M6E)=0</td>
<td>No. 6800#7 (M6T)=1 No. 6801#7 (M6E)=0</td>
<td>No.6801#7 (M6E)=1</td>
<td></td>
</tr>
</tbody>
</table>

NOTE
When a tool group number is specified and a new tool is selected, the new tool selection signal is output.

Examples

• Tool change type A

Suppose that the tool life management cancel number is 100.

T101;  A tool whose life has not expired is selected from group 1.  
      (Suppose that tool number 010 is selected.)
M06;  Tool life counting is performed for the tool in group 1.  
      (The life of tool number 010 is counted.)
T102;  A tool whose life has not expired is selected from group 2.  
      (Suppose that tool number 100 is selected.)
M06T101; Tool life counting is performed for the tool in group 2.  
         (The life of tool number 100 is counted.)
      The number of the tool currently used (in group 1) is output with a T code signal. (Tool number 010 is output.)
• Tool change type B and C

Suppose that the tool life management ignore number is 100.

T101; A tool whose life has not expired is selected from group 1.
    ; (Suppose that tool number 010 is selected.)
M06T102; Tool life counting is performed for the tool in group 1.
    ; (The life of tool number 010 is counted.)
    ; A tool whose life has not expired is selected from group 2.
    ; (Suppose that tool number 100 is selected.)
M06T103; Tool life counting is performed for the tool in group 2.
    ; (The life of tool number 100 is counted.)
    ; A tool whose life has not expired is selected from group 3.
    ; (Suppose that tool number 200 is selected.)

• Tool change type D

Suppose that the tool life management ignore number is 100.

T101M06; A tool whose life has not expired is selected from group 1.
    ; (Suppose that tool number 010 is selected.)
    ; Tool life counting is performed for the tool in group 1.
    ;
T102M06; A tool whose life has not expired is selected from group 2.
    ; (Suppose that tool number 100 is selected.)
    ; Tool life counting is performed for the tool in group 2.
    ; (The life of tool number 100 is counted.)
10.2.4 Tool Life

The life of a tool is specified by a usage frequency (count) or usage time (in minutes).

Explanations

• Usage count

The usage count is incremented by 1 for each tool used in a program. In other words, the usage count is incremented by 1 only when the first tool group number and tool change command are specified after the CNC unit enters the automatic operation state from the reset state.

CAUTION

Even if the same tool group number is specified more than once in a program, the usage count is only incremented by 1 and no new tools are selected.

• Usage time

When a tool change is specified (M06), tool life management is started for the tools specified by the tool group number. In tool life management, the time during which a tool is used in the cutting mode is counted in four second increments. If the tool group is changed before the incremental time of four seconds elapses, the time is not counted. The time a tool is used for single block stop, feed hold, rapid traverse, dwell, machine lock, and interlock is not counted.

NOTE

1 When a tool is selected from available tools, tools are searched starting from the current tool towards the last tool to find a tool whose life has not expired. When the last tool is reached during this search, the search restarts from the first tool. When it has been determined that there are no tools whose life has not expired, the last tool is selected. When the tool currently being used is changed by tool skip signal, the next new tool is selected using the method described here.

2 When tool life is counted by time, the life counting can be overridden using the tool life count override signal. An override from 0 to 99.9 can be applied. When 0 is specified, time is not counted. Before the override capability can be used, bit 2 of parameter LFV No.6801 must be set.

3 When tool life counting indicates that the life of the last tool in a group has expired, the tool change signal is output. When tool life is managed by time, the signal is output when the life of the last tool in the group has expired. When tool life is managed by usage frequency (count), the signal is output when the CNC unit is reset or the tool life count restart M code is specified.
There are two types of auxiliary functions; miscellaneous function (M code) for specifying spindle start, spindle stop, program end, and so on, and secondary auxiliary function (B code) for specifying index table positioning.

When a move command and miscellaneous function are specified in the same block, the commands are executed in one of the following two ways:

i) Simultaneous execution of the move command and miscellaneous function commands.

ii) Executing miscellaneous function commands upon completion of move command execution.

The selection of either sequence depends on the machine tool builder’s specification. Refer to the manual issued by the machine tool builder for details.
11.1 AUXILIARY FUNCTION (M FUNCTION)

When a numeral is specified following address M, code signal and a strobe signal are sent to the machine. The machine uses these signals to turn on or off its functions.

Usually, only one M code can be specified in one block. In some cases, however, up to three M codes can be specified for some types of machine tools.

Which M code corresponds to which machine function is determined by the machine tool builder.

The machine processes all operations specified by M codes except those specified by M98, M99, M198 or called subprogram (Parameter No. 6071 to 6079), or called custom macro (Parameter No. 6080 to 6089). Refer to the machine tool builder’s instruction manual for details.

The following M codes have special meanings.

- **M02, M03 (End of program)**
  - This indicates the end of the main program.
  - Automatic operation is stopped and the CNC unit is reset.
  - This differs with the machine tool builder.
  - After a block specifying the end of the program is executed, control returns to the start of the program.
  - Bit 5 of parameter 3404 (M02) or bit 4 of parameter 3404 (M30) can be used to disable M02, M30 from returning control to the start of the program.

- **M00 (Program stop)**
  - Automatic operation is stopped after a block containing M00 is executed.
  - When the program is stopped, all existing modal information remains unchanged. The automatic operation can be restarted by actuating the cycle operation. This differs with the machine tool builder.

- **M01 (Optional stop)**
  - Similarly to M00, automatic operation is stopped after a block containing M01 is executed. This code is only effective when the Optional Stop switch on the machine operator’s panel has been pressed.

- **M98 (Calling of sub-program)**
  - This code is used to call a subprogram. The code and strobe signals are not sent. See the subprogram section 12.3 for details.

- **M99 (End of subprogram)**
  - This code indicates the end of a subprogram.
  - M99 execution returns control to the main program. The code and strobe signals are not sent. See the subprogram section 12.3 for details.

- **M198 (Calling a subprogram)**
  - This code is used to call a subprogram of a file in the external input/output function. See the description of the subprogram call function (III–4.7) for details.

**NOTE**

The block following M00, M01, M02, or M30 is not pre–read (buffered). Similarly, ten M codes which do not buffer can be set by parameters (Nos. 3411 to 3420). Refer to the machine tool builder’s instruction manual for these M codes.
11.2 MULTIPLE M COMMANDS IN A SINGLE BLOCK

In general, only one M code can be specified in a block. However, up to three M codes can be specified at once in a block by setting bit 7 (M3B) of parameter No. 3404 to 1. Up to three M codes specified in a block are simultaneously output to the machine. This means that compared with the conventional method of a single M command in a single block, a shorter cycle time can be realized in machining.

CNC allows up to three M codes to be specified in one block. However, some M codes cannot be specified at the same time due to mechanical operation restrictions. For detailed information about the mechanical operation restrictions on simultaneous specification of multiple M codes in one block, refer to the manual of each machine tool builder.

M00, M01, M02, M30, M98, M99, or M198 must not be specified together with another M code.

Some M codes other than M00, M01, M02, M30, M98, M99, and M198 cannot be specified together with other M codes; each of those M codes must be specified in a single block.

Such M codes include those which direct the CNC to perform internal operations in addition to sending the M codes themselves to the machine. To be specified, such M codes are M codes for calling program numbers 9001 to 9009 and M codes for disabling advance reading (buffering) of subsequent blocks. Meanwhile, multiple of M codes that direct the CNC only to send the M codes themselves (without performing internal operations) can be specified in a single block.

**Examples**

<table>
<thead>
<tr>
<th>One M command in a single block</th>
<th>Multiple M commands in a single block</th>
</tr>
</thead>
<tbody>
<tr>
<td>M40 ; M50 ; M60 ; G28G91X0Y0Z0 ;</td>
<td>M40M50M60 ; G28G91X0Y0Z0 ;</td>
</tr>
<tr>
<td>:</td>
<td>:</td>
</tr>
<tr>
<td>:</td>
<td>:</td>
</tr>
<tr>
<td>:</td>
<td>:</td>
</tr>
</tbody>
</table>

---

---
The M code group check function checks if a combination of multiple M codes (up to three M codes) contained in a block is correct. This function has two purposes. One is to detect if any of the multiple M codes specified in a block include an M code that must be specified alone. The other purpose is to detect if any of the multiple M codes specified in a block include M codes that belong to the same group. In either of these cases, P/S alarm No. 5016 is issued.

For details on group data setting, refer to the manual available from the machine tool builder.

Explanations

- **M code setting**
  Up to 500 M codes can be specified. In general, M0 to M99 are always specified. M codes from M100 and up are optional.

- **Group numbers**
  Group numbers can be set from 0 to 127. Note, however, that 0 and 1 have special meanings. Group number 0 represents M codes that need not be checked. Group number 1 represents M codes that must be specified alone.
Indexing of the table is performed by address B and a following 8-digit number. The relationship between B codes and the corresponding indexing differs between machine tool builders. Refer to the manual issued by the machine tool builder for details.

1. To enable the use of a decimal point, set bit 0 (AUP) of parameter No. 3450 to 1.

<table>
<thead>
<tr>
<th>Command</th>
<th>Output value</th>
</tr>
</thead>
<tbody>
<tr>
<td>B10. 10000</td>
<td></td>
</tr>
<tr>
<td>B10 10</td>
<td></td>
</tr>
</tbody>
</table>

2. Use bit 0 (DPI) of parameter No. 3401 to specify whether the magnification for B output will be \times 1000 or \times 1 when a decimal point is omitted.

<table>
<thead>
<tr>
<th>Command</th>
<th>Output value</th>
</tr>
</thead>
<tbody>
<tr>
<td>DPI=1 B1 1000</td>
<td></td>
</tr>
<tr>
<td>DPI=0 B1 1</td>
<td></td>
</tr>
</tbody>
</table>

3. Use bit 0 (AUX) of parameter No. 3405 to specify whether the magnification for B output will be \times 1000 or \times 10000 when a decimal point is omitted for the inch Input system (only when DPI=1).

<table>
<thead>
<tr>
<th>Command</th>
<th>Output value</th>
</tr>
</thead>
<tbody>
<tr>
<td>AUX=1 B1 10000</td>
<td></td>
</tr>
<tr>
<td>AUX=0 B1 1000</td>
<td></td>
</tr>
</tbody>
</table>

Addresses used for the second auxiliary functions (addresses specified with B or parameter No. 3460) cannot be used as controlled axis names (parameter No. 1020).
There are two program types, main program and subprogram. Normally, the CNC operates according to the main program. However, when a command calling a subprogram is encountered in the main program, control is passed to the subprogram. When a command specifying a return to the main program is encountered in a subprogram, control is returned to the main program.

The CNC memory can hold up to 400 main programs and subprograms (63 as standard). A main program can be selected from the stored main programs to operate the machine. See III–9.3 or III–10 in OPERATION for the methods of registering and selecting programs.
• **Program components**

A program consists of the following components:

*Table 12 Program components*

<table>
<thead>
<tr>
<th>Components</th>
<th>Descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tape start</td>
<td>Symbol indicating the start of a program file</td>
</tr>
<tr>
<td>Leader section</td>
<td>Used for the title of a program file, etc.</td>
</tr>
<tr>
<td>Program start</td>
<td>Symbol indicating the start of a program</td>
</tr>
<tr>
<td>Program section</td>
<td>Commands for machining</td>
</tr>
<tr>
<td>Comment section</td>
<td>Comments or directions for the operator</td>
</tr>
<tr>
<td>Tape end</td>
<td>Symbol indicating the end of a program file</td>
</tr>
</tbody>
</table>

*Fig. 12 (b) Program configuration*

• **Program section configuration**

A program section consists of several blocks. A program section starts with a program number and ends with a program end code.

*Program section configuration*

<table>
<thead>
<tr>
<th>Program number</th>
<th>O0001 ;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block 1</td>
<td>N1 G91 G00 X120.0 Y80.0 ;</td>
</tr>
<tr>
<td>Block 2</td>
<td>N2 G43 Z–32.0 H01 ;</td>
</tr>
<tr>
<td>Block n</td>
<td>Nn Z0 ;</td>
</tr>
<tr>
<td>Program end</td>
<td>M30 ;</td>
</tr>
</tbody>
</table>

A block contains information necessary for machining, such as a move command or coolant on/off command. Specifying a slash (/) at the start of a block disables the execution of some blocks (see “optional block skip” in II–12.2).
12.1 PROGRAM COMPONENTS OTHER THAN PROGRAM SECTIONS

This section describes program components other than program sections. See II–12.2 for a program section.

Explanations

- **Tape start**
  The tape start indicates the start of a file that contains NC programs. The mark is not required when programs are entered using SYSTEM P or ordinary personal computers. The mark is not displayed on the screen. However, if the file is output, the mark is automatically output at the start of the file.

<table>
<thead>
<tr>
<th>Name</th>
<th>ISO code</th>
<th>EIA code</th>
<th>Notation in this manual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tape start</td>
<td>%</td>
<td>ER</td>
<td>%</td>
</tr>
</tbody>
</table>

- **Leader section**
  Data entered before the programs in a file constitutes a leader section. When machining is started, the label skip state is usually set by turning on the power or resetting the system. In the label skip state, all information is ignored until the first end-of-block code is read. When a file is read into the CNC unit from an I/O device, leader sections are skipped by the label skip function. A leader section generally contains information such as a file header. When a leader section is skipped, even a TV parity check is not made. So a leader section can contain any codes except the EOB code.

- **Program start**
  The program start code is to be entered immediately after a leader section, that is, immediately before a program section. This code indicates the start of a program, and is always required to disable the label skip function.
  With SYSTEM P or ordinary personal computers, this code can be entered by pressing the return key.

<table>
<thead>
<tr>
<th>Name</th>
<th>ISO code</th>
<th>EIA code</th>
<th>Notation in this manual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Program start</td>
<td>LF</td>
<td>CR</td>
<td>;</td>
</tr>
</tbody>
</table>
### Comment section

Any information enclosed by the control–out and control–in codes is regarded as a comment. The user can enter a header, comments, directions to the operator, etc. in a comment section.

<table>
<thead>
<tr>
<th>Name</th>
<th>ISO code</th>
<th>EIA code</th>
<th>Notation in this manual</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control–out</td>
<td>(</td>
<td>2–4–5</td>
<td>(</td>
<td>Start of comment section</td>
</tr>
<tr>
<td>Control–in</td>
<td>)</td>
<td>2–4–7</td>
<td>)</td>
<td>End of comment section</td>
</tr>
</tbody>
</table>

When a program is read into memory for memory operation, comment sections, if any, are not ignored but are also read into memory. Note, however, that codes other than those listed in the code table in Appendix A are ignored, and thus are not read into memory.

When data in memory is output on external I/O device (See III–8), the comment sections are also output.

When a program is displayed on the screen, its comment sections are also displayed. However, those codes that were ignored when read into memory are not output or displayed.

During memory operation or DNC operation, all comment sections are ignored.

The TV check function can be used for a comment section by setting parameter CTV (bit 1 of No. 0100).

### CAUTION

If a long comment section appears in the middle of a program section, a move along an axis may be suspended for a long time because of such a comment section. So a comment section should be placed where movement suspension may occur or no movement is involved.

### NOTE

1. If only a control–in code is read with no matching control–out code, the read control–in code is ignored.
2. The EOB code cannot be used in a comment.
• **Tape end**

A tape end is to be placed at the end of a file containing NC programs. If programs are entered using the automatic programming system, the mark need not be entered. The mark is not displayed on the screen. However, when a file is output, the mark is automatically output at the end of the file. If an attempt is made to execute % when M02 or M03 is not placed at the end of the program, the P/S alarm (No. 5010) is occurred.

<table>
<thead>
<tr>
<th>Name</th>
<th>ISO code</th>
<th>EIA code</th>
<th>Notation in this manual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tape end</td>
<td>%</td>
<td>ER</td>
<td>%</td>
</tr>
</tbody>
</table>
This section describes elements of a program section. See II–12.1 for program components other than program sections.

**12.2 PROGRAM SECTION CONFIGURATION**

- **Program number**

  A program number consisting of address O followed by a four-digit number is assigned to each program at the beginning registered in memory to identify the program.

  In ISO code, the colon (:) can be used instead of O.

  When no program number is specified at the start of a program, the sequence number (N....) at the start of the program is regarded as its program number. If a five-digit sequence number is used, the lower four digits are registered as a program number. If the lower four digits are all 0, the program number registered immediately before added to 1 is registered as a program number. Note, however, that N0 cannot be used for a program number.

  If there is no program number or sequence number at the start of a program, a program number must be specified using the MDI panel when the program is stored in memory (See III–8.4 or III–10.1)

**NOTE**

Program numbers 8000 to 9999 may be used by machine tool builders, and the user may not be able to use these numbers.
**Sequence number and block**

A program consists of several commands. One command unit is called a block. One block is separated from another with an EOB of end of block code.

<table>
<thead>
<tr>
<th>Name</th>
<th>ISO code</th>
<th>EIA code</th>
<th>Notation in this manual</th>
</tr>
</thead>
<tbody>
<tr>
<td>End of block (EOB)</td>
<td>LF</td>
<td>CR</td>
<td>;</td>
</tr>
</tbody>
</table>

At the head of a block, a sequence number consisting of address N followed by a number not longer than five digits (1 to 99999) can be placed. Sequence numbers can be specified in a random order, and any numbers can be skipped. Sequence numbers may be specified for all blocks or only for desired blocks of the program. In general, however, it is convenient to assign sequence numbers in ascending order in phase with the machining steps (for example, when a new tool is used by tool replacement, and machining proceeds to a new surface with table indexing.)

```
N300 X200.0 Z300.0 ; A sequence number is underlined.
```

**Fig. 12.2 (b) Sequence number and block (example)**

**NOTE**

N0 must not be used for the reason of file compatibility with other CNC systems.

Program number 0 cannot be used. So 0 must not be used for a sequence number regarded as a program number.

**TV check (Vertical parity check along tape)**

A parity check is made for a block on input tape vertically. If the number of characters in one block (starting with the code immediately after an EOB and ending with the next EOB) is odd, an P/S alarm (No.002) is output. No TV check is made only for those parts that are skipped by the label skip function. Bit 1 (CTV) of parameter No. 0100 is used to specify whether comments enclosed in parentheses are counted as characters during TV check. The TV check function can be enabled or disabled by setting on the MDI unit (See III－11.4.3.).
A block consists of one or more words. A word consists of an address followed by a number some digits long. (The plus sign (+) or minus sign (−) may be prefixed to a number.)

Word = Address + number (Example: X−1000)

For an address, one of the letters (A to Z) is used; an address defines the meaning of a number that follows the address. Table 12.2 (b) indicates the usable addresses and their meanings.

The same address may have different meanings, depending on the preparatory function specification.

<table>
<thead>
<tr>
<th>Function</th>
<th>Address</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Program number</td>
<td>O (*1)</td>
<td>Program number</td>
</tr>
<tr>
<td>Sequence number</td>
<td>N</td>
<td>Sequence number</td>
</tr>
<tr>
<td>Preparatory function</td>
<td>G</td>
<td>Specifies a motion mode (linear, arc, etc.)</td>
</tr>
<tr>
<td>Dimension word</td>
<td>X, Y, Z, U, V, W, A, B, C</td>
<td>Coordinate axis move command</td>
</tr>
<tr>
<td></td>
<td>I, J, K</td>
<td>Coordinate of the arc center</td>
</tr>
<tr>
<td></td>
<td>R</td>
<td>Arc radius</td>
</tr>
<tr>
<td>Feed function</td>
<td>F</td>
<td>Rate of feed per minute, Rate of feed per revolution</td>
</tr>
<tr>
<td>Spindle speed function</td>
<td>S</td>
<td>Spindle speed</td>
</tr>
<tr>
<td>Tool function</td>
<td>T</td>
<td>Tool number</td>
</tr>
<tr>
<td>Auxiliary function</td>
<td>M</td>
<td>On/off control on the machine tool</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Table indexing, etc.</td>
</tr>
<tr>
<td>Offset number</td>
<td>D, H</td>
<td>Offset number</td>
</tr>
<tr>
<td>Dwell</td>
<td>P, X</td>
<td>Dwell time</td>
</tr>
<tr>
<td>Program number</td>
<td>P</td>
<td>Subprogram number</td>
</tr>
<tr>
<td>designation</td>
<td>P</td>
<td>Number of subprogram repetitions</td>
</tr>
<tr>
<td>Number of repetitions</td>
<td>P</td>
<td>Number of subprogram repetitions</td>
</tr>
<tr>
<td>Parameter</td>
<td>P, Q</td>
<td>Canned cycle parameter</td>
</tr>
</tbody>
</table>

**NOTE**

(*1) In ISO code, the colon (:) can also be used as the address of a program number.

---

*Fig. 12.2 (c) 1 block (example)*
Major addresses and the ranges of values specified for the addresses are shown below. Note that these figures represent limits on the CNC side, which are totally different from limits on the machine tool side. For example, the CNC allows a tool to traverse up to about 100 m (in millimeter input) along the X axis. However, an actual stroke along the X axis may be limited to 2 m for a specific machine tool.

Similarly, the CNC may be able to control a cutting federate of up to 240 m/min, but the machine tool may not allow more than 3 m/min. When developing a program, the user should carefully read the manuals of the machine tool as well as this manual to be familiar with the restrictions on programming.

Table 12.2 (c) Major addresses and ranges of command values

<table>
<thead>
<tr>
<th>Function</th>
<th>Address</th>
<th>Input in mm</th>
<th>Input in inch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Program number</td>
<td>O (1)</td>
<td>1–9999</td>
<td>1–9999</td>
</tr>
<tr>
<td>Sequence number</td>
<td>N</td>
<td>1–99999</td>
<td>1–99999</td>
</tr>
<tr>
<td>Preparatory function</td>
<td>G</td>
<td>0–99</td>
<td>0–99</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>±9999.9999mm</td>
<td>±99999999inch</td>
</tr>
<tr>
<td>Feed per minute</td>
<td>F</td>
<td>1–240000mm/min</td>
<td>0.01–9600.00 inch/min</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1–100000mm/min</td>
<td>0.01–4000.00 inch/min</td>
</tr>
<tr>
<td>Feed per revolution</td>
<td>F</td>
<td>0.001–500.00 mm/rev</td>
<td>0.0001–9.9999 inch/rev</td>
</tr>
<tr>
<td>Spindle speed function</td>
<td>S</td>
<td>0–20000</td>
<td>0–20000</td>
</tr>
<tr>
<td>Tool function</td>
<td>T</td>
<td>0–99999999999</td>
<td>0–9999999999</td>
</tr>
<tr>
<td>Auxiliary function</td>
<td>M</td>
<td>0–99999999999</td>
<td>0–99999999999</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>0–99999999999</td>
<td>0–99999999999</td>
</tr>
<tr>
<td>Offset number</td>
<td>H, D</td>
<td>0–400</td>
<td>0–400</td>
</tr>
<tr>
<td>Dwell</td>
<td>X, P</td>
<td>0–999999.9999s</td>
<td>0–999999.9999s</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0–999999.9999s</td>
<td>0–999999.99999</td>
</tr>
<tr>
<td>Designation of a program</td>
<td>P</td>
<td>1–9999</td>
<td>1–9999</td>
</tr>
<tr>
<td>Number of subprogram</td>
<td>P</td>
<td>1–999</td>
<td>1–999</td>
</tr>
</tbody>
</table>

NOTE

(*1) In ISO code, the colon (:) can also be used as the address of a program number.
• Optional block skip

When a slash followed by a number (/n (n=1 to 9)) is specified at the head of a block, and optional block skip switch n on the machine operator panel is set to on, the information contained in the block for which /n corresponding to switch number n is specified is ignored in DNC operation or memory operation.

When optional block skip switch n is set to off, the information contained in the block for which /n is specified is valid. This means that the operator can determine whether to skip the block containing /n.

Number 1 for /1 can be omitted. However, when two or more optional block skip switches are used for one block, number 1 for /1 cannot be omitted.

**Example**

Incorrect) (Correct)

```
//3 G00X10.0; /1/3 G00X10.0;
```

This function is ignored when programs are loaded into memory. Blocks containing /n are also stored in memory, regardless of how the optional block skip switch is set.

Programs held in memory can be output, regardless of how the optional block skip switches are set.

Optional block skip is effective even during sequence number search operation.

Depending on the machine tool, all optional block skip switches (1 to 9) may not be usable. Refer to manuals of the machine tool builder to find which switches are usable.

---

**WARNING**

1. **Position of a slash**

   A slash (/) must be specified at the head of a block. If a slash is placed elsewhere, the information from the slash to immediately before the EOB code is ignored.

2. **Disabling an optional block skip switch**

   Optional block skip operation is processed when blocks are read from memory or tape into a buffer. Even if a switch is set to on after blocks are read into a buffer, the blocks already read are not ignored.

---

**NOTE**

**TV and TH check**

When an optional block skip switch is on, TH and TV checks are made for the skipped portions in the same way as when the optional block skip switch is off.
The end of a program is indicated by programming one of the following codes at the end of the program:

**Table 12.2 (d) Code of a program end**

<table>
<thead>
<tr>
<th>Code</th>
<th>Meaning usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>M02</td>
<td>For main program</td>
</tr>
<tr>
<td>M30</td>
<td></td>
</tr>
<tr>
<td>M99</td>
<td>For subprogram</td>
</tr>
</tbody>
</table>

If one of the program end codes is executed in program execution, the CNC terminates the execution of the program, and the reset state is set. When the subprogram end code is executed, control returns to the program that called the subprogram.

**WARNING**

A block containing an optional block skip code such as /M02 ; , /M30 ; , or /M99 ; is not regarded as the end of a program, if the optional block skip switch on the machine operator’s panel is set to on.

(See “Optional block skip”.)
12.3 SUBPROGRAM (M98, M99)

If a program contains a fixed sequence or frequently repeated pattern, such a sequence or pattern can be stored as a subprogram in memory to simplify the program.

A subprogram can be called from the main program.

A called subprogram can also call another subprogram.

**Format**

- **Subprogram configuration**

  One subprogram

  
  ![Subprogram configuration diagram]

  - Subprogram number
  - (or the colon (:) optionally in the case of ISO)
  - Program end

  M99 need not constitute a separate block as indicated below.

  Example) X100.0 Y100.0 M99 ;

- **Subprogram call**

  ![Subprogram call diagram]

  - M98 P
  - Number of times the subprogram is called repeatedly

  When no repetition data is specified, the subprogram is called just once.

**Explanations**

When the main program calls a subprogram, it is regarded as a one–level subprogram call. Thus, subprogram calls can be nested up to four levels as shown below.

<table>
<thead>
<tr>
<th>Main program</th>
<th>Subprogram</th>
<th>Subprogram</th>
<th>Subprogram</th>
<th>Subprogram</th>
</tr>
</thead>
<tbody>
<tr>
<td>O0001 ;</td>
<td>O1000 ;</td>
<td>O2000 ;</td>
<td>O3000 ;</td>
<td>O4000 ;</td>
</tr>
<tr>
<td>M98P1000 ;</td>
<td>M98P2000 ;</td>
<td>M98P3000 ;</td>
<td>M98P4000 ;</td>
<td></td>
</tr>
<tr>
<td>M30 ;</td>
<td>M99 ;</td>
<td>M99 ;</td>
<td>M99 ;</td>
<td>M99 ;</td>
</tr>
</tbody>
</table>

A single call command can repeatedly call a subprogram up to 999 times.

For compatibility with automatic programming systems, in the first block, Nxxxx can be used instead of a subprogram number that follows O (or :). A sequence number after N is registered as a subprogram number.

**Reference**

See III–10 for the method of registering a subprogram.
NOTE

1. The M98 and M99 code signal and strobe signal are not output to the machine tool.
2. If the subprogram number specified by address P cannot be found, an alarm (No. 078) is output.

Examples

☆ M98 P51002 ;
This command specifies "Call the subprogram (number 1002) five times in succession." A subprogram call command (M98P_) can be specified in the same block as a move command.

☆ X1000.0 M98 P1200 ;
This example calls the subprogram (number 1200) after an X movement.

☆ Execution sequence of subprograms called from a main program

<table>
<thead>
<tr>
<th>Main program</th>
<th>Subprogram</th>
</tr>
</thead>
<tbody>
<tr>
<td>N0010 ... ;</td>
<td>O1010 ... ;</td>
</tr>
<tr>
<td>N0020 ... ;</td>
<td>N1020 ... ;</td>
</tr>
<tr>
<td>N0030 M98 P21010 ;</td>
<td>N1030 ... ;</td>
</tr>
<tr>
<td>N0040 ... ;</td>
<td>N1040 ... ;</td>
</tr>
<tr>
<td>N0050 M98 P1010 ;</td>
<td>N1050 ... ;</td>
</tr>
<tr>
<td>N0060 ... ;</td>
<td>N1060 ... M99 ;</td>
</tr>
</tbody>
</table>

A subprogram can call another subprogram in the same way as a main program calls a subprogram.
Special Usage

- **Specifying the sequence number for the return destination in the main program**

If P is used to specify a sequence number when a subprogram is terminated, control does not return to the block after the calling block, but returns to the block with the sequence number specified by P. Note, however, that P is ignored if the main program is operating in a mode other than memory operation mode.

This method consumes a much longer time than the normal return method to return to the main program.

- **Using M99 in the main program**

If M99 is executed in a main program, control returns to the start of the main program. For example, M99 can be executed by placing /M99 ; at an appropriate location of the main program and setting the optional block skip function to off when executing the main program. When M99 is executed, control returns to the start of the main program, then execution is repeated starting at the head of the main program.

Execution is repeated while the optional block skip function is set to off. If the optional block skip function is set to on, the /M99 ; block is skipped; control is passed to the next block for continued execution.

If /M99Pn ; is specified, control returns not to the start of the main program, but to sequence number n. In this case, a longer time is required to return to sequence number n.
● Using a subprogram only

A subprogram can be executed just like a main program by searching for the start of the subprogram with the MDI.

(See III–9.3 for information about search operation.)

In this case, if a block containing M99 is executed, control returns to the start of the subprogram for repeated execution. If a block containing M99Pn is executed, control returns to the block with sequence number n in the subprogram for repeated execution. To terminate this program, a block containing /M02 ; or /M30 ; must be placed at an appropriate location, and the optional block switch must be set to off ; this switch is to be set to on first.

```
N1010 ... ;
N1020 ... ;
N1030 ... ;
/ N1040 M02 ;
N1050 M99 P1020 ;
```

Optional block skip
ON
12. PROGRAM CONFIGURATION

12.4 8–DIGIT PROGRAM NUMBER

Explanations

• Disabling editing of programs

Editing of subprograms O00008000 to O00008999, O00009000 to O00009999, O80000000 to O89999999, and O90000000 to O99999999 can be disabled.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Program numbers for which editing is disabled</th>
</tr>
</thead>
<tbody>
<tr>
<td>NE8(No.3202#0)</td>
<td>O00008000 to O00008999</td>
</tr>
<tr>
<td>NE9(No.3202#4)</td>
<td>O00009000 to O00009999</td>
</tr>
<tr>
<td>PRG8E(No.3204#3)</td>
<td>O80000000 to O89999999</td>
</tr>
<tr>
<td>PRG9E(No.3204#4)</td>
<td>O90000000 to O99999999</td>
</tr>
</tbody>
</table>

NOTE
When a wrong password has been specified for the password function (see III–9.9), the settings of NE9 (bit 3 of parameter No. 3202) and PRG9E (bit 4 of parameter No. 3204) cannot be changed.

• File name

For program punch by specifying a range, files are named as follows:
When punching by specifying O00000001 and O00123456: “O00000001–G”
When punching by specifying O12345678 and O45678900: “O12345678–G”
When 2–path control is being applied, the file name for the first path is suffixed with “–1” and that for the second path is suffixed with “–2.”

• Special programs

Special subprogram numbers can be changed by using bit 5 (SPR) of parameter No. 3204.

1) Macro call using G code

<table>
<thead>
<tr>
<th>Parameter used to specify G code</th>
<th>Program number</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>When SPR = 0</td>
</tr>
<tr>
<td>No.6050</td>
<td>O00009010</td>
</tr>
<tr>
<td>No.6051</td>
<td>O00009011</td>
</tr>
<tr>
<td>No.6052</td>
<td>O00009012</td>
</tr>
<tr>
<td>No.6053</td>
<td>O00009013</td>
</tr>
<tr>
<td>No.6054</td>
<td>O00009014</td>
</tr>
<tr>
<td>No.6055</td>
<td>O00009015</td>
</tr>
<tr>
<td>No.6056</td>
<td>O00009016</td>
</tr>
<tr>
<td>No.6057</td>
<td>O00009017</td>
</tr>
<tr>
<td>No.6058</td>
<td>O00009018</td>
</tr>
<tr>
<td>No.6059</td>
<td>O00009019</td>
</tr>
</tbody>
</table>
2) Macro call using M code

<table>
<thead>
<tr>
<th>Parameter used to specify M code</th>
<th>Program number</th>
<th>Program number</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>When SPR = 0</td>
<td>When SPR = 1</td>
</tr>
<tr>
<td>No.6080</td>
<td>O00009020</td>
<td>O90009020</td>
</tr>
<tr>
<td>No.6081</td>
<td>O00009021</td>
<td>O90009021</td>
</tr>
<tr>
<td>No.6082</td>
<td>O00009022</td>
<td>O90009022</td>
</tr>
<tr>
<td>No.6083</td>
<td>O00009023</td>
<td>O90009023</td>
</tr>
<tr>
<td>No.6084</td>
<td>O00009024</td>
<td>O90009024</td>
</tr>
<tr>
<td>No.6085</td>
<td>O00009025</td>
<td>O90009025</td>
</tr>
<tr>
<td>No.6086</td>
<td>O00009026</td>
<td>O90009026</td>
</tr>
<tr>
<td>No.6087</td>
<td>O00009027</td>
<td>O90009027</td>
</tr>
<tr>
<td>No.6088</td>
<td>O00009028</td>
<td>O90009028</td>
</tr>
<tr>
<td>No.6089</td>
<td>O00009029</td>
<td>O90009029</td>
</tr>
</tbody>
</table>

3) Subprogram call using M code

<table>
<thead>
<tr>
<th>Parameter used to specify M code</th>
<th>Program number</th>
<th>Program number</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>When SPR = 0</td>
<td>When SPR = 1</td>
</tr>
<tr>
<td>No.6071</td>
<td>O00009001</td>
<td>O90009001</td>
</tr>
<tr>
<td>No.6072</td>
<td>O00009002</td>
<td>O90009002</td>
</tr>
<tr>
<td>No.6073</td>
<td>O00009003</td>
<td>O90009003</td>
</tr>
<tr>
<td>No.6074</td>
<td>O00009004</td>
<td>O90009004</td>
</tr>
<tr>
<td>No.6075</td>
<td>O00009005</td>
<td>O90009005</td>
</tr>
<tr>
<td>No.6076</td>
<td>O00009006</td>
<td>O90009006</td>
</tr>
<tr>
<td>No.6077</td>
<td>O00009007</td>
<td>O90009007</td>
</tr>
<tr>
<td>No.6078</td>
<td>O00009008</td>
<td>O90009008</td>
</tr>
<tr>
<td>No.6079</td>
<td>O00009009</td>
<td>O90009009</td>
</tr>
</tbody>
</table>

4) Macro call using T code

<table>
<thead>
<tr>
<th>Parameter used to specify T code</th>
<th>Program number</th>
<th>Program number</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>When SPR = 0</td>
<td>When SPR = 1</td>
</tr>
<tr>
<td>TCS(No.6001#5)</td>
<td>O00009000</td>
<td>O90009000</td>
</tr>
</tbody>
</table>

5) Macro call using ASCII code

<table>
<thead>
<tr>
<th>Parameter used to specify ASCII code</th>
<th>Program number</th>
<th>Program number</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.6090</td>
<td>O00009004</td>
<td>O90009004</td>
</tr>
<tr>
<td>No.6091</td>
<td>O00009005</td>
<td>O90009005</td>
</tr>
</tbody>
</table>
6) Pattern data function

<table>
<thead>
<tr>
<th>Program number</th>
<th>When SPR = 0</th>
<th>When SPR = 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>O00009500</td>
<td>O00009500</td>
<td></td>
</tr>
<tr>
<td>O00009501</td>
<td>O00009501</td>
<td></td>
</tr>
<tr>
<td>O00009502</td>
<td>O00009502</td>
<td></td>
</tr>
<tr>
<td>O00009503</td>
<td>O00009503</td>
<td></td>
</tr>
<tr>
<td>O00009504</td>
<td>O00009504</td>
<td></td>
</tr>
<tr>
<td>O00009505</td>
<td>O00009505</td>
<td></td>
</tr>
<tr>
<td>O00009506</td>
<td>O00009506</td>
<td></td>
</tr>
<tr>
<td>O00009507</td>
<td>O00009507</td>
<td></td>
</tr>
<tr>
<td>O00009508</td>
<td>O00009508</td>
<td></td>
</tr>
<tr>
<td>O00009509</td>
<td>O00009509</td>
<td></td>
</tr>
<tr>
<td>O00009510</td>
<td>O00009510</td>
<td></td>
</tr>
</tbody>
</table>

- **External program number search**

External input signals can be used to search for a program number. A program stored in CNC memory can be selected by externally inputting a program number, between 1 and 99999999, to the CNC. For details, refer to the appropriate manual supplied from the machine tool builder.

- **Limitations**

- **Subprogram call**

This function disables subprogram call unless FS15 tape format (see II–18) is used. This restriction also applies to calling a program in external I/O devices (M198).

(Example)

```
M98 P12345678 ;
```

Subprogram number only. The repetition count is not included.

- **DNC**

The eight-digit program number cannot be used in DNC1, DNC2, Ethernet, data server, open CNC, and graphic conversation functions.
13 FUNCTIONS TO SIMPLIFY PROGRAMMING

General

This chapter explains the following items:

13.1 CANNED CYCLE
13.2 RIGID TAPPING
13.3 CANNED GRINDING CYCLE (FOR GRINDING MACHINE)
13.4 GRINDING WHEEL WEAR COMPENSATION BY CONTINUOUS DRESSING (FOR GRINDING MACHINE)
13.5 AUTOMATIC GRINDING WHEEL DIAMETER COMPENSATION AFTER DRESSING
13.6 IN–FEED GRINDING ALONG THE Y AND Z AXES AT THE END OF TABLE SWING (FOR GRINDING MACHINE)
13.7 OPTIONAL ANGLE CHAMFERING AND CORNER Rounding
13.8 EXTERNAL MOTION FUNCTION
13.9 FIGURE COPY (G72.1, G72.2)
13.10 THREE–DIMENSIONAL COORDINATE CONVERSION (G68, G69)
13.11 INDEX TABLE INDEXING FUNCTION
13. FUNCTIONS TO SIMPLIFY PROGRAMMING

13.1 CANNED CYCLE

Canned cycles make it easier for the programmer to create programs. With a canned cycle, a frequently-used machining operation can be specified in a single block with a G function; without canned cycles, normally more than one block is required. In addition, the use of canned cycles can shorten the program to save memory.

Table 13.1 (a) lists canned cycles.

<table>
<thead>
<tr>
<th>G code</th>
<th>Drilling(–Z direction)</th>
<th>Operation at the bottom of a hole</th>
<th>Retraction(+Z direction)</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>G73</td>
<td>Intermittent feed</td>
<td>–</td>
<td>Rapid traverse</td>
<td>High-speed peck drilling cycle</td>
</tr>
<tr>
<td>G74</td>
<td>Feed</td>
<td>Dwell→Spindle CW</td>
<td>Feed</td>
<td>Left-hand tapping cycle</td>
</tr>
<tr>
<td>G76</td>
<td>Feed</td>
<td>Oriented spindle stop</td>
<td>Rapid traverse</td>
<td>Fine boring cycle</td>
</tr>
<tr>
<td>G80</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>Cancel</td>
</tr>
<tr>
<td>G81</td>
<td>Feed</td>
<td>–</td>
<td>Rapid traverse</td>
<td>Drilling cycle, spot drilling cycle</td>
</tr>
<tr>
<td>G82</td>
<td>Feed</td>
<td>Dwell</td>
<td>Rapid traverse</td>
<td>Drilling cycle, counter boring cycle</td>
</tr>
<tr>
<td>G83</td>
<td>Intermittent feed</td>
<td>–</td>
<td>Rapid traverse</td>
<td>Peck drilling cycle</td>
</tr>
<tr>
<td>G84</td>
<td>Feed</td>
<td>Dwell→Spindle CCW</td>
<td>Feed</td>
<td>Tapping cycle</td>
</tr>
<tr>
<td>G85</td>
<td>Feed</td>
<td>–</td>
<td>Feed</td>
<td>Boring cycle</td>
</tr>
<tr>
<td>G86</td>
<td>Feed</td>
<td>Spindle stop</td>
<td>Rapid traverse</td>
<td>Boring cycle</td>
</tr>
<tr>
<td>G87</td>
<td>Feed</td>
<td>Spindle CW</td>
<td>Rapid traverse</td>
<td>Back boring cycle</td>
</tr>
<tr>
<td>G88</td>
<td>Feed</td>
<td>Dwell⇒spindle stop</td>
<td>Manual</td>
<td>Boring cycle</td>
</tr>
<tr>
<td>G89</td>
<td>Feed</td>
<td>Dwell</td>
<td>Feed</td>
<td>Boring cycle</td>
</tr>
</tbody>
</table>
A canned cycle consists of a sequence of six operations (Fig. 13.1 (a))

Operation 1  Positioning of axes X and Y  
(including also another axis)
Operation 2  Rapid traverse up to point R level
Operation 3  Hole machining
Operation 4  Operation at the bottom of a hole
Operation 5  Retraction to point R level
Operation 6  Rapid traverse up to the initial point

Fig. 13.1  Canned cycle operation sequence

- **Positioning plane**

  The positioning plane is determined by plane selection code G17, G18, or G19.

  The positioning axis is an axis other than the drilling axis.

- **Drilling axis**

  Although canned cycles include tapping and boring cycles as well as drilling cycles, in this chapter, only the term drilling will be used to refer to operations implemented with canned cycles.

  The drilling axis is a basic axis (X, Y, or Z) not used to define the positioning plane, or any axis parallel to that basic axis.

  The axis (basic axis or parallel axis) used as the drilling axis is determined according to the axis address for the drilling axis specified in the same block as G codes G73 to G89.

  If no axis address is specified for the drilling axis, the basic axis is assumed to be the drilling axis.

<table>
<thead>
<tr>
<th>G code</th>
<th>Positioning plane</th>
<th>Drilling axis</th>
</tr>
</thead>
<tbody>
<tr>
<td>G17</td>
<td>Xp–Yp plane</td>
<td>Zp</td>
</tr>
<tr>
<td>G18</td>
<td>Zp–Xp plane</td>
<td>Yp</td>
</tr>
<tr>
<td>G19</td>
<td>Yp–Zp plane</td>
<td>Xp</td>
</tr>
</tbody>
</table>

Xp : X axis or an axis parallel to the X axis
Yp : Y axis or an axis parallel to the Y axis
Zp : Z axis or an axis parallel to the Z axis
Assume that the U, V and W axes be parallel to the X, Y, and Z axes respectively. This condition is specified by parameter No. 1022.

```
G17 G81 ........Z _ _ : The Z axis is used for drilling.
G17 G81 ........W _ _ : The W axis is used for drilling.
G18 G81 ........Y _ _ : The Y axis is used for drilling.
G18 G81 ........V _ _ : The V axis is used for drilling.
G19 G81 ........X _ _ : The X axis is used for drilling.
G19 G81 ........U _ _ : The U axis is used for drilling.
```

G17 to G19 may be specified in a block in which any of G73 to G89 is not specified.

**WARNING**
Switch the drilling axis after canceling a canned cycle.

**NOTE**
A parameter FXY (No. 6200 #0) can be set to the Z axis always used as the drilling axis. When FXY=0, the Z axis is always the drilling axis.

**Travel distance along the drilling axis G90/G91**

The travel distance along the drilling axis varies for G90 and G91 as follows:

<table>
<thead>
<tr>
<th>G90 (Absolute Command)</th>
<th>G91 (Incremental Command)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Diagram" /></td>
<td><img src="image" alt="Diagram" /></td>
</tr>
</tbody>
</table>

**Drilling mode**

G73, G74, G76, and G81 to G89 are modal G codes and remain in effect until canceled. When in effect, the current state is the drilling mode. Once drilling data is specified in the drilling mode, the data is retained until modified or canceled. Specify all necessary drilling data at the beginning of canned cycles; when canned cycles are being performed, specify data modifications only.
When the tool reaches the bottom of a hole, the tool may be returned to point R or to the initial level. These operations are specified with G98 and G99. The following illustrates how the tool moves when G98 or G99 is specified. Generally, G99 is used for the first drilling operation and G98 is used for the last drilling operation. The initial level does not change even when drilling is performed in the G99 mode.

<table>
<thead>
<tr>
<th>G98 (Return to initial level)</th>
<th>G99 (Return to point R level)</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Diagram of G98]</td>
<td>![Diagram of G99]</td>
</tr>
</tbody>
</table>

To repeat drilling for equally-spaced holes, specify the number of repeats in K_. K is effective only within the block where it is specified. Specify the first hole position in incremental mode (G91). If it is specified in absolute mode (G90), drilling is repeated at the same position.

Number of repeats K  The maximum command value = 9999

If K0 is specified, drilling data is stored, but drilling is not performed.

To cancel a canned cycle, use G80 or a group 01 G code.

**Group 01 G codes**

- **G00**: Positioning (rapid traverse)
- **G01**: Linear interpolation
- **G02**: Circular interpolation or helical interpolation (CW)
- **G03**: Circular interpolation or helical interpolation (CCW)
- **G60**: Single direction positioning (when the MDL bit (bit 0 of parameter 5431) is set to 1)

**Symbols in figures**

Subsequent sections explain the individual canned cycles. Figures in these explanations use the following symbols:

- Positioning (rapid traverse G00)
- Cutting feed (linear interpolation G01)
- Manual feed
- Oriented spindle stop (The spindle stops at a fixed rotation position)
- Shift (rapid traverse G00)
- Dwell
13.1.1 High-Speed Peck Drilling Cycle (G73)

This cycle performs high-speed peck drilling. It performs intermittent cutting feed to the bottom of a hole while removing chips from the hole.

Format

\[
\text{G73 X_ Y_ Z_ R_ Q_ F_ K_ ;}
\]

- \(X_\): Hole position data
- \(Y_\): The distance from point R to the bottom of the hole
- \(Z_\): The distance from the initial level to point R level
- \(R_\): Depth of cut for each cutting feed
- \(Q_\): Cutting feedrate
- \(K_\): Number of repeats (if required)

<table>
<thead>
<tr>
<th>G73 (G98)</th>
<th>G73 (G99)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Diagram G73 (G98)" /></td>
<td><img src="image2" alt="Diagram G73 (G99)" /></td>
</tr>
</tbody>
</table>
The high-speed peck drilling cycle performs intermittent feeding along the Z-axis. When this cycle is used, chips can be removed from the hole easily, and a smaller value can be set for retraction. This allows, drilling to be performed efficiently. Set the clearance, \(d\), in parameter 5114. The tool is retracted in rapid traverse.

Before specifying G73, rotate the spindle using a miscellaneous function (M code).

When the G73 code and an M code are specified in the same block, the M code is executed at the time of the first positioning operation. The system then proceeds to the next drilling operation.

When K is used to specify the number of repeats, the M code is executed for the first hole only; for the second and subsequent holes, the M code is not executed.

When a tool length offset (G43, G44, or G49) is specified in the canned cycle, the offset is applied at the time of positioning to point R.

Limitations

- **Axis switching**
  
  Before the drilling axis can be changed, the canned cycle must be canceled.

- **Drilling**

  In a block that does not contain X, Y, Z, R, or any other axes, drilling is not performed.

- **Q**

  Specify Q in blocks that perform drilling. If they are specified in a block that does not perform drilling, they cannot be stored as modal data.

- **Cancel**

  Do not specify a G code of the 01 group (G00 to G03 or G60 (when the MDL bit (bit 0 of parameter 5431) is set to 1)) and G73 in a single block. Otherwise, G73 will be canceled.

- **Tool offset**

  In the canned cycle mode, tool offsets are ignored.

**Examples**

```
M3 S2000 ;
  Position, drill hole 1, then return to point R.
Y–550. ;
  Position, drill hole 2, then return to point R.
Y–750. ;
  Position, drill hole 3, then return to point R.
X1000. ;
  Position, drill hole 4, then return to point R.
Y–550. ;
  Position, drill hole 5, then return to point R.
G98 Y–750. ;
  Position, drill hole 6, then return to the initial level.
G80 G28 G91 X0 Y0 Z0 ;
  Return to the reference position return
M5 ;
  Cause the spindle to stop rotating.
```
This cycle performs left–handed tapping. In the left–handed tapping cycle, when the bottom of the hole has been reached, the spindle rotates clockwise.

**Format**

```
G74 X_ Y_ Z_ R_ P_ F_ K_ ;
```

- **X_ Y_**: Hole position data
- **Z_**: The distance from point R to the bottom of the hole
- **R_**: The distance from the initial level to point R level
- **P_**: Dwell time
- **F_**: Cutting feedrate
- **K_**: Number of repeats (if required)

---

**Explanations**

Tapping is performed by turning the spindle counterclockwise. When the bottom of the hole has been reached, the spindle is rotated clockwise for retraction. This creates a reverse thread.

Feedrate overrides are ignored during left–handed tapping. A feed hold does not stop the machine until the return operation is completed.

Before specifying G74, use a miscellaneous function (M code) to rotate the spindle counterclockwise.

When the G74 command and an M code are specified in the same block, the M code is executed at the time of the first positioning operation. The system then proceeds to the next drilling operation.

When K is used to specify the number of repeats, the M code is executed for the first hole only; for the second and subsequent holes, the M code is not executed.

When a tool length offset (G43, G44, or G49) is specified in the canned cycle, the offset is applied at the time of positioning to point R.
13. FUNCTIONS TO SIMPLIFY PROGRAMMING

Limitations

- **Axis switching**
  Before the drilling axis can be changed, the canned cycle must be canceled.

- **Drilling**
  In a block that does not contain X, Y, Z, R, or any other axes, drilling is not performed.

- **P**
  Specify P in blocks that perform drilling. If it is specified in a block that does not perform drilling, it cannot be stored as modal data.

- **Cancel**
  Do not specify a G code of the 01 group (G00 to G03 or G60 (when the MDL bit (bit 0 of parameter 5431) is set to 1)) and G74 in a single block. Otherwise, G74 will be canceled.

- **Tool offset**
  In the canned cycle mode, tool offsets are ignored.

- **Subprogram call**
  In the canned cycle mode, specify the subprogram call command M98P_in an independent block.

**Examples**

```
M4 S100 ;
G90 Y–550. ;
G90 Y–750. ;
G90 X1000. ;
G90 Y–550. ;
G98 Y–750. ;
G80 G28 G91 X0 Y0 Z0 ;
M5 ;
```

- Cause the spindle to start rotating.
- Position, tapping hole 1, then return to point R.
- Position, tapping hole 2, then return to point R.
- Position, tapping hole 3, then return to point R.
- Position, tapping hole 4, then return to point R.
- Position, tapping hole 5, then return to point R.
- Position, tapping hole 6, then return to the initial level.
- Return to the reference position return
- Cause the spindle to stop rotating.
The fine boring cycle bores a hole precisely. When the bottom of the hole has been reached, the spindle stops, and the tool is moved away from the machined surface of the workpiece and retracted.

**13.1.3 Fine Boring Cycle (G76)**

**Format**

G76 X_ Y_ Z_ R_ Q_ P_ F_ K_;  
X_ Y_: Hole position data  
Z_: The distance from point R to the bottom of the hole  
R_: The distance from the initial level to point R level  
Q_: Shift amount at the bottom of a hole  
P_: Dwell time at the bottom of a hole  
F_: Cutting feedrate  
K_: Number of repeats (if required)

**WARNING**  
Q (shift at the bottom of a hole) is a modal value retained within canned cycles. It must be specified carefully because it is also used as the depth of cut for G73 and G83.
Explanations

When the bottom of the hole has been reached, the spindle is stopped at the fixed rotation position, and the tool is moved in the direction opposite to the tool tip and retracted. This ensures that the machined surface is not damaged and enables precise and efficient boring to be performed.

Before specifying G76, use a miscellaneous function (M code) to rotate the spindle.

When the G76 command and an M code are specified in the same block, the M code is executed at the time of the first positioning operation. The system then proceeds to the next operation.

When K is used to specify the number of repeats, the M code is executed for the first hole only; for the second and subsequent holes, the M code is not executed.

When a tool length offset (G43, G44, or G49) is specified in the canned cycle, the offset is applied at the time of positioning to point R.

Limitations

• **Axis switching**

  Before the drilling axis can be changed, the canned cycle must be canceled.

• **Boring**

  In a block that does not contain X, Y, Z, R, or any additional axes, boring is not performed.

• **P/Q**

  Be sure to specify a positive value in Q. If Q is specified with a negative value, the sign is ignored. Set the direction of shift in bits 4 (RD1) and 5 (RD2) of parameter 5101. Specify P and Q in a block that performs boring. If they are specified in a block that does not perform boring, they are not stored as modal data.

• **Cancel**

  Do not specify a G code of the 01 group (G00 to G03 or G60 (when the MDL bit (bit 0 of parameter 5431) is set to 1)) and G76 in a single block. Otherwise, G76 will be canceled.

• **Tool offset**

  In the canned cycle mode, tool offsets are ignored.

• **Subprogram call**

  In the canned cycle mode, specify the subprogram call command M98P_in an independent block.

Examples

```
M3 S500 ;
P1000 F120. ;
Y–550. ;
Y–750. ;
X1000. ;
Y–550. ;
G98 Y–750. ;
G80 G28 G91 X0 Y0 Z0 ;
M5 ;
```

Cause the spindle to start rotating.

Position, bore hole 1, then return to point R.

Orient at the bottom of the hole, then shift by 5 mm.

Stop at the bottom of the hole for 1 s.

Position, drill hole 2, then return to point R.

Position, drill hole 3, then return to point R.

Position, drill hole 4, then return to point R.

Position, drill hole 5, then return to point R.

Position, drill hole 6, then return to the initial level.

Return to the reference position return

Cause the spindle to stop rotating.
13. FUNCTIONS TO SIMPLIFY
PROGRAMMING

13.1.4 Drilling Cycle, Spot Drilling (G81)

This cycle is used for normal drilling. Cutting feed is performed to the bottom of the hole. The tool is then retracted from the bottom of the hole in rapid traverse.

Format

G81 X_ Y_ Z_ R_ F_ K_ ;

X_: Hole position data
Y_: The distance from point R to the bottom of the hole
Z_: The distance from the initial level to point R level
R_: Cutting feedrate
K_: Number of repeats (if required)

<table>
<thead>
<tr>
<th>G81 (G98)</th>
<th>G81 (G99)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Diagram" /></td>
<td><img src="image2.png" alt="Diagram" /></td>
</tr>
</tbody>
</table>

Explanations

After positioning along the X- and Y-axes, rapid traverse is performed to point R.
Drilling is performed from point R to point Z.
The tool is then retracted in rapid traverse.
Before specifying G81, use a miscellaneous function (M code) to rotate the spindle.
When the G81 command and an M code are specified in the same block, the M code is executed at the time of the first positioning operation. The system then proceeds to the next drilling operation.
When K is used to specify the number of repeats, the M code is performed for the first hole only; for the second and subsequent holes, the M code is not executed.
When a tool length offset (G43, G44, or G49) is specified in the canned cycle, the offset is applied at the time of positioning to point R.
13. FUNCTIONS TO SIMPLIFY PROGRAMMING

Restrictions

- **Axis switching**
  Before the drilling axis can be changed, the canned cycle must be canceled.

- **Drilling**
  In a block that does not contain X, Y, Z, R, or any other axes, drilling is not performed.

- **Cancel**
  Do not specify a G code of the 01 group (G00 to G03 or G60 (when the MDL bit (bit 0 of parameter 5431) is set to 1)) and G81 in a single block. Otherwise, G81 will be canceled.

- **Tool offset**
  In the canned cycle mode, tool offsets are ignored.

Examples

```gcode
M3 S2000 ;
G98 Y–750. ;
G80 G28 G91 X0 Y0 Z0 ;
M5 ;
```

- Cause the spindle to start rotating.
- Position, drill hole 1, then return to point R.
- Position, drill hole 2, then return to point R.
- Position, drill hole 3, then return to point R.
- Position, drill hole 4, then return to point R.
- Position, drill hole 5, then return to point R.
- Position, drill hole 6, then return to the initial level.
- Return to the reference position return
- Cause the spindle to stop rotating.
13.1.5 Drilling Cycle Counter
Boring Cycle (G82)

This cycle is used for normal drilling. Cutting feed is performed to the bottom of the hole. At the bottom, a dwell is performed, then the tool is retracted in rapid traverse. This cycle is used to drill holes more accurately with respect to depth.

Format

```
G82 X_ Y_ Z_ R_ P_ F_ K_;
```

- \( X_ \): Hole position data
- \( Z_ \): The distance from point R to the bottom of the hole
- \( R_ \): The distance from the initial level to point R level
- \( P_ \): Dwell time at the bottom of a hole
- \( F_ \): Cutting feed rate
- \( K_ \): Number of repeats (if required)

<table>
<thead>
<tr>
<th>Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>G82 (G98)</td>
<td></td>
</tr>
<tr>
<td>![Diagram showing cycle]</td>
<td>![Diagram showing cycle]</td>
</tr>
</tbody>
</table>

- Point R: Initial level
- Point R level: Point Z

Explanations

After positioning along the X- and Y-axes, rapid traverse is performed to point R. Drilling is then performed from point R to point Z. When the bottom of the hole has been reached, a dwell is performed. The tool is then retracted in rapid traverse.

Before specifying G82, use a miscellaneous function (M code) to rotate the spindle.

When the G82 command and an M code are specified in the same block, the M code is executed at the time of the first positioning operation. The system then proceeds to the next drilling operation.

When \( K \) is used to specify the number of repeats, the M code is executed for the first hole only; for the second and subsequent holes, the M code is not executed.

When a tool length offset (G43, G44, or G49) is specified in the canned cycle, the offset is applied at the time of positioning to point R.
Restrictions

- **Axis switching**
  Before the drilling axis can be changed, the canned cycle must be canceled.

- **Drilling**
  In a block that does not contain X, Y, Z, R, or any other axes, drilling is not performed.

- **P**
  Specify P in blocks that perform drilling. If it is specified in a block that does not perform drilling, it cannot be stored as modal data.

- **Cancel**
  Do not specify a G code of the 01 group (G00 to G03 or G60 (when the MDL bit (bit 0 of parameter 5431) is set to 1)) and G81 in a single block. Otherwise, G81 will be canceled.

- **Tool offset**
  In the canned cycle mode, tool offsets are ignored.

- **Subprogram call**
  In the canned cycle mode, specify the subprogram call command M98P_in an independent block.

Examples

```
M3 S2000 ;  Cause the spindle to start rotating.
G90 G99 G82 X300. Y–250. Z–150. R–100. P1000 F120. ;  Position, drill hole 2, and dwell for 1 s at the bottom of the hole, then return to point R.
Y–550. ;  Position, drill hole 2, then return to point R.
Y–750. ;  Position, drill hole 3, then return to point R.
X1000. ;  Position, drill hole 4, then return to point R.
Y–550. ;  Position, drill hole 5, then return to point R.
G98 Y–750. ;  Position, drill hole 6, then return to the initial level.
G80 G28 G91 X0 Y0 Z0 ;  Return to the reference position return
M5 ;  Cause the spindle to stop rotating.
```

---

---
13.1.6 Peck Drilling Cycle (G83)

This cycle performs peck drilling. It performs intermittent cutting feed to the bottom of a hole while removing shavings from the hole.

Format

```
G83 X_ Y_ Z_ R_ Q_ F_ K_ ;
```

- **X_ Y_**: Hole position data
- **Z_**: The distance from point R to the bottom of the hole
- **R_**: The distance from the initial level to point R level
- **Q_**: Depth of cut for each cutting feed
- **F_**: Cutting feedrate
- **K_**: Number of repeats (if required)

Explanations

Q represents the depth of cut for each cutting feed. It must always be specified as an incremental value.

In the second and subsequent cutting feeds, rapid traverse is performed up to a d point just before where the last drilling ended, and cutting feed is performed again. d is set in parameter (No.5115).

Be sure to specify a positive value in Q. Negative values are ignored.

Before specifying G83, use a miscellaneous function (M code) to rotate the spindle.

When the G83 command and an M code are specified in the same block, the M code is executed at the time of the first positioning operation. The system then proceeds to the next drilling operation.

When K is used to specify the number of repeats, the M code is executed for the first hole only; for the second and subsequent holes, the M code is not executed.

When a tool length offset (G43, G44, or G49) is specified in the canned cycle, the offset is applied at the time of positioning to point R.
Limitations

- **Axis switching**
  Before the drilling axis can be changed, the canned cycle must be canceled.

- **Drilling**
  In a block that does not contain X, Y, Z, R, or any other axes, drilling is not performed.

- **Q**
  Specify Q in blocks that perform drilling. If they are specified in a block that does not perform drilling, they cannot be stored as modal data.

- **Cancel**
  Do not specify a G code of the 01 group (G00 to G03 or G60 (when the MDL bit (bit 0 of parameter 5431) is set to 1)) and G82 in a single block. Otherwise, G82 will be canceled.

- **Tool offset**
  In the canned cycle mode, tool offsets are ignored.

Examples

```plaintext
M3 S2000 ;  Cause the spindle to start rotating.
  Position, drill hole 1, then return to point R.
Y–550. ;
  Position, drill hole 2, then return to point R.
Y–750. ;
  Position, drill hole 3, then return to point R.
X1000. ;
  Position, drill hole 4, then return to point R.
Y–550. ;
  Position, drill hole 5, then return to point R.
G98 Y–750. ;
  Position, drill hole 6, then return to the initial level.

G80 G28 G91 X0 Y0 Z0 ;  Return to the reference position return
M5 ;  Cause the spindle to stop rotating.
```
An arbor with the overload torque detection function is used to retract the tool when the overload torque detection signal (skip signal) is detected during drilling. Drilling is resumed after the spindle speed and cutting feedrate are changed. These steps are repeated in this peck drilling cycle.

The mode for the small–hole peck drilling cycle is selected when the M code in parameter 5163 is specified. The cycle can be started by specifying G83 in this mode. This mode is canceled when G80 is specified or when a reset occurs.

### Format

G83 X_ Y_ Z_ R_ Q_ F_ I_ K_ P_ ;

- **X_ Y_**: Hole position data
- **Z_**: Distance from point R to the bottom of the hole
- **R_**: Distance from the initial level to point R
- **Q_**: Depth of each cut
- **F_**: Cutting feedrate
- **I_**: Forward or backward traveling speed (same format as F above)
  - (If this is omitted, the values in parameters No.5172 and No.5173 are assumed as defaults.)
- **K_**: Number of times the operation is repeated (if required)
- **P_**: Dwell time at the bottom of the hole
  - (If this is omitted, P0 is assumed as the default.)

<table>
<thead>
<tr>
<th>G83(G98)</th>
<th>G83(G99)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Diagram" /></td>
<td><img src="image2.png" alt="Diagram" /></td>
</tr>
</tbody>
</table>

- **Δ**: Initial clearance when the tool is retracted to point R and the clearance from the bottom of the hole in the second or subsequent drilling (parameter 5174)
- **Q**: Depth of each cut
- **Path along which the tool travels at the rapid traverse rate**
- **Path along which the tool travels (forward or backward) at the rapid traverse rate during the cycle specified with parameters**
- **Path along which the tool travels at the programmed cutting feedrate**
Explanations

• Component operations of the cycle

*Positioning along the X–axis and Y–axis
*Positioning at point R along the Z–axis
*Drilling along the Z–axis (first drilling, depth of cut Q, incremental)
  Retraction (bottom of the hole → point R)
  Advance (point R → point at a height of clearance \( \Delta \) from the bottom of the hole)
Drilling (second or subsequent drilling, depth of cut \( Q + \Delta \), incremental)
*Dwell
*Return to point R (or initial level) along the Z–axis, cycle end

Acceleration/deceleration during advancing and retraction is controlled according to the cutting feed acceleration/deceleration time constant. When retraction is performed, the position is checked at point R.

• Specifying an M code

When the M code in parameter 5163 is specified, the system enters the mode for the small–hole peck drilling cycle. This M code does not wait for FIN. Care must be taken when this M code is specified with another M code in the same block.

(Example) \( M\square\square M03 \); → Waits for FIN.
\( M03 M\square\square \); → Does not wait for FIN.

• Specifying a G code

When G83 is specified in the mode for the small–hole peck drilling cycle, the cycle is started. This continuous–state G code remains unchanged until another canned cycle is specified or until the G code for cancelling the canned cycle is specified. This eliminates the need for specifying drilling data in each block when identical drilling is repeated.

• Signal indicating that the cycle is in progress

In this cycle, the signal indicating that the small–hole peck drilling cycle is in progress is output after the tool is positioned at the hole position along the axes not used for drilling. Signal output continues during positioning to point R along the drilling axis and terminates upon a return to point R or the initial level. For details, refer to the manual of the machine tool builder.

• Overload torque detection signal

A skip signal is used as the overload torque detection signal. The skip signal is effective while the tool is advancing or drilling and the tool tip is between points R and Z. (The signal causes a retraction). For details, refer to the manual of the machine tool builder.
In a single G83 cycle, drilling conditions are changed for each drilling operation (advance → drilling → retraction). Bits 1 and 2 of parameter OLS, NOL No. 5160 can be specified to suppress the change in drilling conditions.

1. Changing the cutting feedrate
   The cutting feedrate programmed with the F code is changed for each of the second and subsequent drilling operations. In parameters No.5166 and No.5167, specify the respective rates of change applied when the skip signal is detected and when it is not detected in the previous drilling operation.

   Cutting feedrate = \( F \times \alpha \)

   - \( \alpha=1.0 \) when the skip signal is not detected
   - \( \alpha=\alpha \times \beta \div 100 \), where \( \beta \) is the rate of change for each drilling operation

   When the skip signal is detected during the previous drilling operation:
   - \( \beta=b1\% \) (parameter No. 5166)
   - When the skip signal is not detected during the previous drilling operation:
   - \( \beta=b2\% \) (parameter No. 5167)

   If the rate of change in cutting feedrate becomes smaller than the rate specified in parameter 5168, the cutting feedrate is not changed. The cutting feedrate can be increased up to the maximum cutting feedrate.

2. Changing the spindle speed
   The spindle speed programmed with the S code is changed for each of the second and subsequent advances. In parameters 5164 and 5165, specify the rates of change applied when the skip signal is detected and when it is not detected in the previous drilling operation.

   Spindle speed = \( S \times \gamma \)

   - \( \gamma=1.0 \) when the skip signal is not detected
   - \( \gamma=\gamma \times \delta \div 100 \), where \( \delta \) is the rate of change for each drilling operation

   When the skip signal is detected during the previous drilling operation:
   - \( \delta=b1\% \) (parameter No. 5164)
   - When the skip signal is not detected during the previous drilling operation:
   - \( \delta=b2\% \) (parameter No. 5165)

   When the cutting feedrate reaches the minimum rate, the spindle speed is not changed. The spindle speed can be increased up to a value corresponding to the maximum value of S analog data.

- Advance and retraction

Advancing and retraction of the tool are not executed in the same manner as rapid–traverse positioning. Like cutting feed, the two operations are carried out as interpolated operations. The speed is subjected to exponential acceleration/deceleration. Note that the tool life management function excludes advancing and retraction from the calculation of the tool life.
• Specifying address I

The forward or backward traveling speed can be specified with address I in the same format as address F, as shown below:

- G83 11000 : (without decimal point)
- G83 11000. : (with decimal point)

Both commands indicate a speed of 1000 mm/min.

Address I specified with G83 in the continuous–state mode continues to be valid until G80 is specified or until a reset occurs.

• Functions that can be specified

In this canned cycle mode, the following functions can be specified:

- Hole position on the X–axis, Y–axis, and additional axis
- Operation and branch by custom macro
- Subprogram (hole position group, etc.) calling
- Switching between absolute and incremental modes
- Coordinate system rotation
- Scaling (This command will not affect depth of cut Q or small clearance d1.)
- Dry run
- Feed hold

• Single block

When single–block operation is enabled, drilling is stopped after each retraction.

• Feedrate override

The feedrate override function works during cutting, retraction, and advancing in the cycle.

• Custom macro interface

The number of retractions made during cutting and the number of retractions made in response to the overload signal received during cutting can be output to custom macro common variables (#100 to #149) specified in parameters No.5170 and No.5171. Parameters No.5170 and No.5171 can specify variable numbers within the range of #100 to #149.

Parameter No.5170 : Specifies the number of the common variable to which the number of retractions made during cutting is output.

Parameter No.5171 : Specifies the number of the common variable to which the number of retractions made in response to the overload signal received during cutting is output.

Restrictions

• Subprogram call

In the canned cycle mode, specify the subprogram call command M98P_ in an independent block.
13. FUNCTIONS TO SIMPLIFY
PROGRAMMING

Examples

N01 M03 S___;
N02 M__ ;
N03 G83 X_ Y_ Z_ R_ Q_ F_ I_ K_ P_ ;
N04 X_ Y_ ;
  :
  :
N10 G80 ;

>Description of each block>
N01: Specifies forward spindle rotation and spindle speed.
N02: Specifies the M code to execute G83 as the small–hole peck drilling cycle.
The M code is specified in parameter No.5163.
N03: Specifies the small–hole peck drilling cycle. Drilling data (except K and P)
is stored and drilling is started.
N04: Drills a small, deep hole at another position with the same drilling data as
for N03.
N10: Cancels the small–hole peck drilling cycle. The M code specified in N02
is also canceled.

13.1.8
Tapping Cycle
(G84)

This cycle performs tapping.
In this tapping cycle, when the bottom of the hole has been reached, the
spindle is rotated in the reverse direction.

Format

G84 X_ Y_ Z_ R_ P_ F_ K_ ;

X_ Y_: Hole position data
Z_: The distance from point R to the bottom of the hole
R_: The distance from the initial level to point R level
P_: Dwell time
F_: Cutting feedrate
K_: Number of repents (if required)

G84 (G98)          G84 (G99)

Initial level
Point R
Point Z
Spindle CW
Spindle CCW                Spindle CW
Spindle CCW

Point R
Point R level
Tapping is performed by rotating the spindle clockwise. When the bottom of the hole has been reached, the spindle is rotated in the reverse direction for retraction. This operation creates threads.

Feedrate overrides are ignored during tapping. A feed hold does not stop the machine until the return operation is completed.

Before specifying G84, use a miscellaneous function (M code) to rotate the spindle.

When the G84 command and an M code are specified in the same block, the M code is executed at the time of the first positioning operation. The system then proceeds to the next drilling operation.

When the K is used to specify number of repeats, the M code is executed for the first hole only; for the second and subsequent holes, the M code is not executed.

When a tool length offset (G43, G44, or G49) is specified in the canned cycle, the offset is applied at the time of positioning to point R.

Before the drilling axis can be changed, the canned cycle must be canceled.

In a block that does not contain X, Y, Z, R, or any other axes, drilling is not performed.

Specify P in blocks that perform drilling. If it is specified in a block that does not perform drilling, it cannot be stored as modal data.

Do not specify a G code of the 01 group (G00 to G03 or G60 (when the MDL bit (bit 0 of parameter 5431) is set to 1)) and G84 in a single block. Otherwise, G84 will be canceled.

In the canned cycle mode, tool offsets are ignored.

In the canned cycle mode, specify the subprogram call command M98P_ in an independent block.

Examples

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>M3 S100 ;</td>
<td>Cause the spindle to start rotating.</td>
</tr>
<tr>
<td>G90 G99 G84 X300. Y–250. Z–150. R–120. P300 F120. ;</td>
<td>Position, drill hole 1, then return to point R.</td>
</tr>
<tr>
<td>Y–550. ;</td>
<td>Position, drill hole 2, then return to point R.</td>
</tr>
<tr>
<td>Y–750. ;</td>
<td>Position, drill hole 3, then return to point R.</td>
</tr>
<tr>
<td>X1000. ;</td>
<td>Position, drill hole 4, then return to point R.</td>
</tr>
<tr>
<td>Y–550. ;</td>
<td>Position, drill hole 5, then return to point R.</td>
</tr>
<tr>
<td>G98 Y–750. ;</td>
<td>Position, drill hole 6, then return to the initial level.</td>
</tr>
<tr>
<td>G80 G28 G91 X0 Y0 Z0 ;</td>
<td>Return to the reference position return</td>
</tr>
<tr>
<td>M5 ;</td>
<td>Cause the spindle to stop rotating.</td>
</tr>
</tbody>
</table>
13.1.9 Boring Cycle (G85)

This cycle is used to bore a hole.

**Format**

```
G85 X_ Y_ Z_ R_ F_ K_ ;
```

- **X_ Y_**: Hole position data
- **Z_**: The distance from point R to the bottom of the hole
- **R_**: The distance from the initial level to point R level
- **F_**: Cutting feed rate
- **K_**: Number of repeats (if required)

<table>
<thead>
<tr>
<th>G85 (G98)</th>
<th>G85 (G99)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Diagram" /></td>
<td><img src="image2" alt="Diagram" /></td>
</tr>
</tbody>
</table>

**Explanations**

After positioning along the X– and Y– axes, rapid traverse is performed to point R.
Drilling is performed from point R to point Z.
When point Z has been reached, cutting feed is performed to return to point R.
Before specifying G85, use a miscellaneous function (M code) to rotate the spindle.
When the G85 command and an M code are specified in the same block, the M code is executed at the time of the first positioning operation. The system then proceeds to the next drilling operation.
When K is used to specify the number of repeats, the M code is executed for the first hole only; for the second and subsequent holes, the M code is not executed.
When a tool length offset (G43, G44, or G49) is specified in the canned cycle, the offset is applied at the time of positioning to point R.
Limitations

- **Axis switching**
  Before the drilling axis can be changed, the canned cycle must be canceled.

- **Drilling**
  In a block that does not contain X, Y, Z, R, or any other axes, drilling is not performed.

- **Cancel**
  Do not specify a G code of the 01 group (G00 to G03 or G60 (when the MDL bit (bit 0 of parameter 5431) is set to 1)) and G85 in a single block. Otherwise, G85 will be canceled.

- **Tool offset**
  In the canned cycle mode, tool offsets are ignored.

### Examples

```plaintext
M3 S100;  // Cause the spindle to start rotating.
G90 G99 G85 X300. Y–250. Z–150. R–120. F120.;  // Position, drill hole 1, then return to point R.
Y–550.;   // Position, drill hole 2, then return to point R.
Y–750.;   // Position, drill hole 3, then return to point R.
X1000.;   // Position, drill hole 4, then return to point R.
Y–550.;   // Position, drill hole 5, then return to point R.
G98 Y–750.;  // Position, drill hole 6, then return to the initial level.
G80 G28 G91 X0 Y0 Z0 ;  // Return to the reference position return
M5 ;  // Cause the spindle to stop rotating.
```
This cycle is used to bore a hole.

### Format

```
G86 X_ Y_ Z_ R_ F_ K_;  
```

- **X_ Y_**: Hole position data
- **Z_**: The distance from point R to the bottom of the hole
- **R_**: The distance from the initial level to point R level
- **F_**: Cutting feed rate
- **K_**: Number of repeats (if required)

<table>
<thead>
<tr>
<th>G86 (G98)</th>
<th>G86 (G99)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Diagram" /></td>
<td><img src="image2" alt="Diagram" /></td>
</tr>
</tbody>
</table>

### Explanations

After positioning along the X– and Y–axes, rapid traverse is performed to point R.

Drilling is performed from point R to point Z.

When the spindle is stopped at the bottom of the hole, the tool is retracted in rapid traverse.

Before specifying G86, use a miscellaneous function (M code) to rotate the spindle.

When the G86 command and an M code are specified in the same block, the M code is executed at the time of the first positioning operation.

The system then proceeds to the next drilling operation.

When K is used to specify the number of repeats, the M code is executed for the first hole only; for the second and subsequent holes, the M code is not executed.

When a tool length offset (G43, G44, or G49) is specified in the canned cycle, the offset is applied at the time of positioning to point R.
13. FUNCTIONS TO SIMPLIFY

Limitations

- **Axis switching**
  Before the drilling axis can be changed, the canned cycle must be canceled.

- **Drilling**
  In a block that does not contain X, Y, Z, R, or any other axes, drilling is not performed.

- **Cancel**
  Do not specify a G code of the 01 group (G00 to G03 or G60 (when the MDL bit (bit 0 of parameter 5431) is set to 1)) and G86 in a single block. Otherwise, G86 will be canceled.

- **Tool offset**
  In the canned cycle mode, tool offsets are ignored.

Examples

M3 S2000 ;
  Position, drill hole 1, then return to point R.
Y–550. ;
  Position, drill hole 2, then return to point R.
Y–750. ;
  Position, drill hole 3, then return to point R.
X1000. ;
  Position, drill hole 4, then return to point R.
Y–550. ;
  Position, drill hole 5, then return to point R.
G98 Y–750. ;
  Position, drill hole 6, then return to the initial level.
G80 G28 G91 X0 Y0 Z0 ;
  Return to the reference position return
M5 ;
  Cause the spindle to stop rotating.
13.1.11 Back Boring Cycle (G87)

This cycle performs accurate boring.

Format

G87 X_ Y_ Z_ R_ Q_ P_ F_ K_ ;

X_ Y_ : Hole position data
Z_ : The distance from the bottom of the hole to point Z
R_ : The distance from the initial level to point R (the bottom of the hole) level
Q_ : Tool shift amount
P_ : Dwell time
F_ : Cutting feed rate
K_ : Number of repeats (if required)

<table>
<thead>
<tr>
<th>G87 (G98)</th>
<th>G87 (G99)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Diagram" /></td>
<td><img src="image2" alt="Diagram" /></td>
</tr>
</tbody>
</table>

WARNING

Q (shift at the bottom of a hole) is a modal value retained in canned cycles. It must be specified carefully because it is also used as the depth of cut for G73 and G83.
After positioning along the X– and Y–axes, the spindle is stopped at the fixed rotation position. The tool is moved in the direction opposite to the tool tip, positioning (rapid traverse) is performed to the bottom of the hole (point R).

The tool is then shifted in the direction of the tool tip and the spindle is rotated clockwise. Boring is performed in the positive direction along the Z–axis until point Z is reached.

At point Z, the spindle is stopped at the fixed rotation position again, the tool is shifted in the direction opposite to the tool tip, then the tool is returned to the initial level. The tool is then shifted in the direction of the tool tip and the spindle is rotated clockwise to proceed to the next block operation.

Before specifying G87, use a miscellaneous function (M code) to rotate the spindle.

When the G87 command and an M code are specified in the same block, the M code is executed at the time of the first positioning operation. The system then proceeds to the next drilling operation. When K is used to specify the number of repeats, the M code is executed for the first hole only; for the second and subsequent holes, the M code is not executed. When a tool length offset (G43, G44, or G49) is specified in the canned cycle, the offset is applied at the time of positioning to point R.

Before the drilling axis can be changed, the canned cycle must be canceled.

In a block that does not contain X, Y, Z, R, or any additional axes, boring is not performed.

Be sure to specify a positive value in Q. If Q is specified with a negative value, the sign is ignored. Set the direction of shift in bits 4 (RD1) and 5 (RD2) of parameter No.5101. Specify P and Q in a block that performs boring. If they are specified in a block that does not perform boring, they are not stored as modal data.

Do not specify a G code of the 01 group (G00 to G03 or G60 (when the MDL bit (bit 0 of parameter 5431) is set to 1)) and G87 in a single block. Otherwise, G87 will be canceled.

In the canned cycle mode, tool offsets are ignored.

In the canned cycle mode, specify the subprogram call command M98P_ in an independent block.

M3 S500 ;
G90 G87 X300. Y–250.
P1000 F120. ;
Y–550. ;
Y–750. ;
X1000. ;
Y–550. ;
Y–750. ;
G80 G28 G91 X0 Y0 Z0 ;
M5 ;
13.1.12 Boring Cycle (G88)

Format

G88 X_ Y_ Z_ R_ P_ F_ K_; 

- X_ Y_: Hole position data
- Z_: The distance from point R to the bottom of the hole
- R_: The distance from the initial level to point R level
- P_: Dwell time at the bottom of a hole
- F_: Cutting feed rate
- K_: Number of repeats (if required)

<table>
<thead>
<tr>
<th>G88 (G98)</th>
<th>G88 (G99)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Diagram" /></td>
<td><img src="image2" alt="Diagram" /></td>
</tr>
</tbody>
</table>

Explanations

This cycle is used to bore a hole.

After positioning along the X– and Y–axes, rapid traverse is performed to point R. Boring is performed from point R to point Z. When boring is completed, a dwell is performed, then the spindle is stopped. The tool is manually retracted from the bottom of the hole (point Z) to point R. At point R, the spindle is rotated clockwise, and rapid traverse is performed to the initial level.

Before specifying G88, use a miscellaneous function (M code) to rotate the spindle.

When the G88 command and an M code are specified in the same block, the M code is executed at the time of the first positioning operation. The system then proceeds to the next drilling operation.

When K is used to specify the number of repeats, the M code is executed for the first hole only; for the second and subsequent holes, the M code is not executed.

When a tool length offset (G43, G44, or G49) is specified in the canned cycle, the offset is applied at the time of positioning to point R.
Limitations

- **Axis switching**
  Before the drilling axis can be changed, the canned cycle must be canceled.

- **Drilling**
  In a block that does not contain X, Y, Z, R, or any other axes, drilling is not performed.

- **P**
  Specify P in blocks that perform drilling. If it is specified in a block that does not perform drilling, it cannot be stored as modal data.

- **Cancel**
  Do not specify a G code of the 01 group (G00 to G03 or G60 (when the MDL bit (bit 0 of parameter 5431) is set to 1)) and G88 in a single block. Otherwise, G88 will be canceled.

- **Tool offset**
  In the canned cycle mode, tool offsets are ignored.

- **Subprogram call**
  In the canned cycle mode, specify the subprogram call command M98P_ in an independent block.

Examples

```
M3 S2000 ; Cause the spindle to start rotating.
  Position, drill hole 1, return to point R
  then stop at the bottom of the hole for 1 s.
Y–550. ;
  Position, drill hole 2, then return to point R.
Y–750. ;
  Position, drill hole 3, then return to point R.
X1000. ;
  Position, drill hole 4, then return to point R.
Y–550. ;
  Position, drill hole 5, then return to point R.
G98 Y–750. ;
  Position, drill hole 6, then return to the initial level.
G80 G28 G91 X0 Y0 Z0 ; Return to the reference position return
M5 ; Cause the spindle to stop rotating.
```
This cycle is used to bore a hole.

Boring Cycle (G89)

Format

\[
\text{G89 X_ Y_ Z_ R_ P_ F_ K_ ;}
\]

- **X_ Y_**: Hole position data
- **Z_**: The distance from point R to the bottom of the hole
- **R_**: The distance from the initial level to point R level
- **P_**: Dwell time at the bottom of a hole
- **F_**: Cutting feed rate
- **K_**: Number of repeats (if required)

This cycle is almost the same as G85. The difference is that this cycle performs a dwell at the bottom of the hole.

Before specifying G89, use a miscellaneous function (M code) to rotate the spindle.

When the G89 command and an M code are specified in the same block, the M code is executed at the time of the first positioning operation. The system then proceeds to the next drilling operation.

When K is used to specify the number of repeats, the M code is executed for the first hole only; for the second and subsequent holes, the M code is not executed.

When a tool length offset (G43, G44, or G49) is specified in the canned cycle, the offset is applied at the time of positioning to point R.
Before the drilling axis can be changed, the canned cycle must be canceled.

In a block that does not contain X, Y, Z, R, or any other axes, drilling is not performed.

Specify P in blocks that perform drilling. If it is specified in a block that does not perform drilling, it cannot be stored as modal data.

Do not specify a G code of the 01 group (G00 to G03 or G60 (when the MDL bit (bit 0 of parameter 5431) is set to 1)) and G89 in a single block. Otherwise, G89 will be canceled.

In the canned cycle mode, tool offsets are ignored.

In the canned cycle mode, specify the subprogram call command M98P in an independent block.

Examples

M3 S100 ; Cause the spindle to start rotating.
Position, drill hole 1, return to point R then stop at the bottom of the hole for 1 s.
Y–550. ;
Position, drill hole 2, then return to point R.
Y–750. ;
Position, drill hole 3, then return to point R.
X1000. ;
Position, drill hole 4, then return to point R.
Y–550. ;
Position, drill hole 5, then return to point R.
G98 Y–750. ;
Position, drill hole 6, then return to the initial level.
G80 G28 G91 X0 Y0 Z0 ; Return to the reference position return
M5 ; Cause the spindle to stop rotating.
13.1.14  Canned Cycle Cancel (G80)

G80 cancels canned cycles.

Format

G80 ;

Explanations

All canned cycles are canceled to perform normal operation. Point R and point Z are cleared. This means that \( R = 0 \) and \( Z = 0 \) in incremental mode. Other drilling data is also canceled (cleared).

Examples

- \textbf{M3 S100 ;}  Cause the spindle to start rotating.
- \textbf{G90 G99 G88 X300. Y–250. Z–150. R–120. F120. ;}  Position, drill hole 1, then return to point R.
- \textbf{Y–550. ;}  Position, drill hole 2, then return to point R.
- \textbf{Y–750. ;}  Position, drill hole 3, then return to point R.
- \textbf{X1000. ;}  Position, drill hole 4, then return to point R.
- \textbf{Y–550. ;}  Position, drill hole 5, then return to point R.
- \textbf{G98 Y–750. ;}  Position, drill hole 6, then return to the initial level.
- \textbf{G80 G28 G91 X0 Y0 Z0 ;}  Return to the reference position return, canned cycle cancel
- \textbf{M5 ;}  Cause the spindle to stop rotating.
Program example using tool length offset and canned cycles

# 1 to 6 Drilling of a 10mm diameter hole
# 7 to 10 Drilling of a 20mm diameter hole
# 11 to 13 Boring of a 95mm diameter hole (depth 50 mm)
Offset value +200.0 is set in offset No.11, +190.0 is set in offset No.15, and +150.0 is set in offset No.31

**Program example**

```
N001 G92X0Y0Z0; Coordinate setting at reference position
N002 G90 G00 Z250.0 T11 M6; Tool change
N003 G43 Z0 H11; Initial level, tool length offset
N004 S30 M3 Spindle start
N005 G99 G81X400.0 R Y–350.0 Z–153.0 R–97.0 F120; Positioning, then #1 drilling
N006 Y–550.0; Positioning, then #2 drilling and point R level return
N007 G98Y–750.0; Positioning, then #3 drilling and initial level return
N008 G99X1200.0; Positioning, then #4 drilling and point R level return
N009 Y–550.0; Positioning, then #5 drilling and point R level return
N010 G98Y–350.0; Positioning, then #6 drilling and initial level return
N011 G00X0Y0M5; Reference position return, spindle stop
N012 G49Z250.0T15M6; Tool length offset cancel, tool change
N013 G43Z0H15; Initial level, tool length offset
N014 S20M3; Spindle start
N015 G99G82X550.0Y–450.0 Z–130.0 R–97.0 P300F70; Positioning, then #7 drilling, point R level return
N016 G98Y–650.0; Positioning, then #8 drilling, initial level return
N017 G99X1050.0; Positioning, then #9 drilling, point R level return
N018 G98Y–450.0; Positioning, then #10 drilling, initial level return
N019 G00X0Y0M5; Reference position return, spindle stop
N020 G49Z250.0T31M6; Tool length offset cancel, tool change
N021 G43Z0H31; Initial level, tool length offset
N022 S10M3; Spindle start
N023 G85G99X800.0Y–350.0 Z–153.0 R47.0 F50; Positioning, then #11 drilling, point R level return
N024 G91Y–200.0K2; Positioning, then #12, 13 drilling, point R level return
N025 G28X0Y0M5; Reference position return, spindle stop
N026 G49Z0; Tool length offset cancel
N027 M0; Program stop
```
13.2 RIGID TAPPING

The tapping cycle (G84) and left-handed tapping cycle (G74) may be performed in standard mode or rigid tapping mode.
In standard mode, the spindle is rotated and stopped along with a movement along the tapping axis using miscellaneous functions M03 (rotating the spindle clockwise), M04 (rotating the spindle counterclockwise), and M05 (stopping the spindle) to perform tapping. In rigid mode, tapping is performed by controlling the spindle motor as if it were a servo motor and by interpolating between the tapping axis and spindle.
When tapping is performed in rigid mode, the spindle rotates one turn every time a certain feed (thread lead) which takes place along the tapping axis. This operation does not vary even during acceleration or deceleration.
Rigid mode eliminates the need to use a floating tap required in the standard tapping mode, thus allowing faster and more precise tapping.
13.2.1 Rigid Tapping (G84)

When the spindle motor is controlled in rigid mode as if it were a servo motor, a tapping cycle can be sped up.

**Format**

```
G84 X_ Y_ Z_ R_ P_ F_ K_;  
X_ Y_: Hole position data 
Z_: The distance from point R to the bottom of the hole and the position of the bottom of the hole 
R_: The distance from the initial level to point R level 
P_: Dwell time at the bottom of the hole and at point R when a return is made 
F_: Cutting feedrate 
K_: Number of repeats (Only for necessity of repeat) 
```

```
G84.2 X_ Y_ Z_ R_ P_ F_ L_;   (FS15 format)  
L_: Number of repeats (only for necessity of repeat) 
```

**Explanations**

After positioning along the X– and Y–axes, rapid traverse is performed to point R.

Tapping is performed from point R to point Z. When tapping is completed, the spindle is stopped and a dwell is performed. The spindle is then rotated in the reverse direction, the tool is retracted to point R, then the spindle is stopped. Rapid traverse to initial level is then performed. While tapping is being performed, the feedrate override and spindle override are assumed to be 100%.

However, the speed for extraction (operation 5) can be overridden by up to 2000% depending on the setting at bit 4 (DOV) of parameter No.5200, bit 3 (OVU) of parameter (No.5201), and parameter No.5211.

- **Rigid mode**

  Rigid mode can be specified using any of the following methods:
  - Specify M29 S***** before a tapping command.
  - Specify M29 S***** in a block which contains a tapping command.
  - Specify G84 for rigid tapping (parameter G84 No. 5200 #0 set to 1).
• **Thread lead**  
In feed–per–minute mode, the thread lead is obtained from the expression, feedrate \( \times \) spindle speed. In feed–per–revolution mode, the thread lead equals the feedrate speed.

• **Tool length compensation**  
If a tool length compensation (G43, G44, or G49) is specified in the canned cycle, the offset is applied at the time of positioning to point R.

• **FS15–format command**  
Rigid tapping can be performed using FS15–format commands. The rigid tapping sequence (including data transfer to and from the PMC), restrictions, and the like are the same as described for the 16i/18i.

**Limitations**

• **Axis switching**  
Before the drilling axis can be changed, the canned cycle must be canceled. If the drilling axis is changed in rigid mode, P/S alarm (No. 206) is issued.

• **S command**  
  - If a speed higher than the maximum speed for the gear being used is specified, P/S alarm (No. 200) is issued.
  - When the rigid tapping canned cycle is cancelled, the S command used for rigid tapping is cleared to S0.

• **Distribution amount for the spindle**  
For an analog spindle control circuit:
Upon specifying a speed command requiring more than 4096 pulses, in detection units, within 8 ms, a P/S alarm (No.202) is issued because the result of such an operation is unpredictable.

For a serial spindle:
Upon specifying a speed command requiring more than 32767 pulses, in detection units, within 8 ms, a P/S alarm (No.202) is issued because the result of such an operation is unpredictable.

• **F command**  
If a value exceeding the upper limit of cutting feedrate is specified, P/S alarm (No. 011) is issued.

• **Unit of F command**

<table>
<thead>
<tr>
<th></th>
<th>Metric input</th>
<th>Inch input</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>G94</td>
<td>1 mm/min</td>
<td>0.01 inch/min</td>
<td>Decimal point programming allowed</td>
</tr>
<tr>
<td>G95</td>
<td>0.01 mm/rev</td>
<td>0.0001 inch/rev</td>
<td>Decimal point programming allowed</td>
</tr>
</tbody>
</table>

• **M29**  
If an S command and axis movement are specified between M29 and G84, P/S alarm (No. 203) is issued. If M29 is specified in a tapping cycle, P/S alarm (No. 204) is issued.

• **P**  
Specify P in a block that performs drilling. If R is specified in a non–drilling block, it is not stored as modal data.

• **Cancel**  
Do not specify a G code of the 01 group (G00 to G03 or G60 when the MDL bit (bit 0 of parameter 5431) is set to 1) and G84 in a single block. Otherwise, G84 will be canceled.

• **Tool offset**  
In the canned cycle mode, tool offsets are ignored.

• **Program restart**  
A program cannot be restarted during rigid tapping.
• **Subprogram call**

In the canned cycle mode, specify the subprogram call command M98P_ in an independent block.

**Examples**

- **Z–axis feedrate** 1000 mm/min
- **Spindle speed** 1000 min⁻¹
- **Thread lead** 1.0 mm

**<Programming of feed per minute>**
- G94 ; Specify a feed–per–minute command.
- G00 X120.0 Y100.0 ; Positioning
- M29 S1000 ; Rigid mode specification
- G84 Z–100.0 R–20.0 F1000 ; Rigid tapping

**<Programming of feed per revolution>**
- G95 ; Specify a feed–per–revolution command.
- G00 X120.0 Y100.0 ; Positioning
- M29 S1000 ; Rigid mode specification
- G84 Z–100.0 R–20.0 F1.0 ; Rigid tapping
When the spindle motor is controlled in rigid mode as if it were a servo motor, tapping cycles can be speed up.

13.2.2 Left-Handed Rigid Tapping Cycle (G74)

Format

G74 X_ Y_ Z_ R_ P_ F_ K_;  
X_ Y_: Hole position data  
Z_: The distance from point R to the bottom of the hole and the position of the bottom of the hole  
R_: The distance from the initial level to point R level  
P_: Dwell time at the bottom of the hole and at point R when return is made.  
F_: Cutting feedrate  
K_: Number of repeats (Only for necessity of repeat)

G84.3 X_ Y_ Z_ R_ P_ F_ L_; (FS15 format)  
L_: Number of repeats (Only for necessity of repeat)

<table>
<thead>
<tr>
<th>G74 (G98)</th>
<th>G74 (G99)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image.png" alt="Diagram" /></td>
<td><img src="image.png" alt="Diagram" /></td>
</tr>
</tbody>
</table>

Explanations

After positioning along the X– and Y–axes, rapid traverse is performed to point R. Tapping is performed from point R to point Z. When tapping is completed, the spindle is stopped and a dwell is performed. The spindle is then rotated in the normal direction, the tool is retracted to point R, then the spindle is stopped. Rapid traverse to initial level is then performed. While tapping is being performed, the feedrate override and spindle override are assumed to be 100%.

However, the speed for extraction (operation 5) can be overridden by up to 2000% depending on the setting at bit 4 (DOV) of parameter 5200, bit 3 (OVU) of parameter (No.5201), and parameter 5211.

- **Rigid mode**

  Rigid mode can be specified using any of the following methods:
  - Specify M29 S***** before a tapping command.
  - Specify M29 S***** in a block which contains a tapping command.
  - Specify G84 for rigid tapping. (parameter G84 No. 5200#0 set to1).
• Thread lead
  In feed-per-minute mode, the thread lead is obtained from the expression, feedrate × spindle speed. In feed-per-revolution mode, the thread lead equals the feedrate.

• Tool length compensation
  If a tool length offset (G43, G44, or G49) is specified in the canned cycle, the offset is applied at the time of positioning to point R.

• FS15–format command
  Rigid tapping can be performed using FS15–format commands. The rigid tapping sequence (including data transfer to and from the PMC), restrictions, and the like are the same as described for the 16i/18i.

Limitations
• Axis switching
  Before the drilling axis can be changed, the canned cycle must be canceled. If the drilling axis is changed in rigid mode, P/S alarm (No. 206) is issued.

• S command
  • Specifying a rotation speed exceeding the maximum speed for the gear used causes P/S alarm (No. 200).
  • When the rigid tapping canned cycle is cancelled, the S command used for rigid tapping is cleared to S0.

• Distribution amount for the spindle
  For an analog spindle control circuit:
  Upon specifying a speed command requiring more than 4096 pulses, in detection units, within 8 ms, a P/S alarm (No.202) is issued because the result of such an operation is unpredictable.
  For a serial spindle:
  Upon specifying a speed command requiring more than 32767 pulses, in detection units, within 8 ms, a P/S alarm (No.202) is issued because the result of such an operation is unpredictable.

• F command
  Specifying a value that exceeds the upper limit of cutting feedrate causes P/S alarm (No. 011).

• Unit of F command

<table>
<thead>
<tr>
<th></th>
<th>Metric input</th>
<th>Inch input</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>G94</td>
<td>1 mm/min</td>
<td>0.01 inch/min</td>
<td>Decimal point programming allowed</td>
</tr>
<tr>
<td>G95</td>
<td>0.01 mm/rev</td>
<td>0.0001 inch/rev</td>
<td>Decimal point programming allowed</td>
</tr>
</tbody>
</table>

• M29
  Specifying an S command or axis movement between M29 and G74 causes P/S alarm (No. 203). Then, specifying M29 in the tapping cycle causes P/S alarm (No. 204).

• P
  Specify P in a block that performs drilling. If R is specified in a non-drilling block, it is not stored as modal data.

• Cancel
  Do not specify a G code of the 01 group (G00 to G03 or G60 when the MDL bit (bit 0 of parameter 5431) is set to 1) and G74 in a single block. Otherwise, G74 will be canceled.

• Tool offset
  In the canned cycle mode, tool offsets are ignored.

• Subprogram call
  In the canned cycle mode, specify the subprogram call command M98P_ in an independent block.
Examples

Z-axis feedrate 1000 mm/min
Spindle speed 1000 min⁻¹
Thread lead 1.0 mm

<Programming for feed per minute>
G94 ; Specify a feed–per–minute command.
G00 X120.0 Y100.0 ; Positioning
M29 S1000 ; Rigid mode specification
G84 Z–100.0 R–20.0 F1000 ; Rigid tapping

<Programming for feed per revolution>
G95 ; Specify a feed–per–revolution command.
G00 X120.0 Y100.0 ; Positioning
M29 S1000 ; Rigid mode specification
G74 Z–100.0 R–20.0 F1.0 ; Rigid tapping
13. FUNCTIONS TO SIMPLIFY PROGRAMMING

13.2.3 Peck Rigid Tapping Cycle (G84 or G74)

Tapping a deep hole in rigid tapping mode may be difficult due to chips sticking to the tool or increased cutting resistance. In such cases, the peck rigid tapping cycle is useful. In this cycle, cutting is performed several times until the bottom of the hole is reached. Two peck tapping cycles are available: High-speed peck tapping cycle and standard peck tapping cycle. These cycles are selected using the PCP bit (bit 5) of parameter 5200.

Format

<table>
<thead>
<tr>
<th>G84, G74 (G98)</th>
<th>G84, G74 (G99)</th>
</tr>
</thead>
<tbody>
<tr>
<td>X: Hole position data</td>
<td>X: Hole position data</td>
</tr>
<tr>
<td>Z: The distance from point R to the bottom of the hole and the position of the bottom of the hole</td>
<td>Z: The distance from point R to the bottom of the hole and the position of the bottom of the hole</td>
</tr>
<tr>
<td>R: The distance from the initial level to point R level</td>
<td>R: The distance from the initial level to point R level</td>
</tr>
<tr>
<td>P: Dwell time at the bottom of the hole and at point R when a return is made</td>
<td>P: Dwell time at the bottom of the hole and at point R when a return is made</td>
</tr>
<tr>
<td>Q: Depth of cut for each cutting feed</td>
<td>Q: Depth of cut for each cutting feed</td>
</tr>
<tr>
<td>F: The cutting feedrate</td>
<td>F: The cutting feedrate</td>
</tr>
<tr>
<td>K: Number of repeats (if required)</td>
<td>K: Number of repeats (if required)</td>
</tr>
</tbody>
</table>

High-speed peck tapping cycle (Parameter PCP(No.5200#5=0))

1) The tool operates at a normal cutting feedrate. The normal time constant is used.
2) Retraction can be overridden. The retraction time constant is used.

Peck tapping cycle (Parameter PCP(No.5200#5=1))

1) The tool operates at a normal cutting feedrate. The normal time constant is used.
2) Retraction can be overridden. The retraction time constant is used.
3) Retraction can be overridden. The normal time constant is used.

During a rigid tapping cycle, in-position check is performed at the end of each operation of (1) and (2) in the peck tapping cycle.
13. FUNCTIONS TO SIMPLIFY PROGRAMMING

Explanations

- **High-speed peck tapping cycle**
  After positioning along the X- and Y-axes, rapid traverse is performed to point R. From point R, cutting is performed with depth Q (depth of cut for each cutting feed), then the tool is retracted by distance d. The DOV bit (bit 4) of parameter 5200 specifies whether retraction can be overridden or not. When point Z has been reached, the spindle is stopped, then rotated in the reverse direction for retraction.
  Set the retraction distance, d, in parameter 5213.

- **Peck tapping cycle**
  After positioning along the X- and Y-axes, rapid traverse is performed to point R level. From point R, cutting is performed with depth Q (depth of cut for each cutting feed), then a return is performed to point R. The DOV bit (bit 4) of parameter 5200 specifies whether the retraction can be overridden or not. The moving of cutting feedrate F is performed from point R to a position distance d from the end point of the last cutting, which is where cutting is restarted. For this moving of cutting feedrate F, the specification of the DOV bit (bit 4) of parameter 5200 is also valid.
  When point Z has been reached, the spindle is stopped, then rotated in the reverse direction for retraction.
  Set d (distance to the point at which cutting is started) in parameter 5213.

**Limitations**

- **Axis switching**
  Before the drilling axis can be changed, the canned cycle must be canceled. If the drilling axis is changed in rigid mode, P/S alarm (No. 206) is issued.

- **S command**
  - Specifying a rotation speed exceeding the maximum speed for the gear used causes P/S alarm (No. 200).
  - When the rigid tapping canned cycle is cancelled, the S command used for rigid tapping is cleared to S0.

- **Distribution amount for the spindle**
  For an analog spindle control circuit:
  Upon specifying a speed command requiring more than 4096 pulses, in detection units, within 8 ms, a P/S alarm (No.202) is issued because the result of such an operation is unpredictable.

  For a serial spindle:
  Upon specifying a speed command requiring more than 32767 pulses, in detection units, within 8 ms, a P/S alarm (No.202) is issued because the result of such an operation is unpredictable.

- **F command**
  Specifying a value that exceeds the upper limit of cutting feedrate causes alarm (No. 011).

<table>
<thead>
<tr>
<th></th>
<th>Metric input</th>
<th>Inch input</th>
<th>Remarks</th>
</tr>
</thead>
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<td>1 mm/min</td>
<td>0.01 inch/min</td>
<td>Decimal point programming allowed</td>
</tr>
<tr>
<td>G95</td>
<td>0.01 mm/rev</td>
<td>0.0001 inch/rev</td>
<td>Decimal point programming allowed</td>
</tr>
</tbody>
</table>

- **M29**
  Specifying an S command or axis movement between M29 and G84 causes P/S alarm (No. 203).
  Then, specifying M29 in the tapping cycle causes P/S alarm (No. 204).
• **P/Q**

Specify P and Q in a block that performs drilling. If they are specified in a block that does not perform drilling, they are not stored as modal data. When Q0 is specified, the peck rigid tapping cycle is not performed.

• **Cancel**

Do not specify a group 01 G code (G00 to G03) and G73 in the same block. If they are specified together, G73 is canceled.

• **Tool offset**

In the canned cycle mode, tool offsets are ignored.

• **Subprogram call**

In the canned cycle mode, specify the subprogram call command M98P_ in an independent block.

<table>
<thead>
<tr>
<th>13.2.4 Canned Cycle Cancel (G80)</th>
</tr>
</thead>
</table>

The rigid tapping canned cycle is canceled. For how to cancel this cycle, see II–13.1.14.

**NOTE**

When the rigid tapping canned cycle is cancelled, the S value used for rigid tapping is also cleared (as if S0 is specified). Accordingly, the S command specified for rigid tapping cannot be used in a subsequent part of the program after the cancellation of the rigid tapping canned cycle. After canceling the rigid tapping canned cycle, specify a new S command as required.
13.3 Canned Grinding Cycle (FOR GRINDING MACHINE)

Canned grinding cycles make it easier for the programmer to create programs that include grinding. With a canned grinding cycle, repetitive operation peculiar to grinding can be specified in a single block with a G function; without canned grinding cycles, normally more than one block is required. In addition, the use of canned grinding cycles shortens the program to save memory. The following four canned grinding cycles are available:

- Plunge grinding cycle (G75)
- Direct constant–dimension plunge grinding cycle (G77)
- Continuous–feed surface grinding cycle (G78)
- Intermittent–feed surface grinding cycle (G79)
A plunge grinding cycle is performed.

### Format

```
G75 I_ J_ K_ X(Z)_ R_ F_ P_ L_;  
I_: Depth–of–cut 1 (A sign in the command specifies the direction of cutting.)
J_: Depth–of–cut 2 (A sign in the command specifies the direction of cutting.)
K_: Total depth of cut (A sign in the command specifies the direction of cutting.)
X(Z)_: Range of grinding (A sign in the command specifies the direction of grinding.)
R_ : Feedrate for I and J
F_ : Feedrate for X (Z)
P_ : Dwell time
L_ : Grinding–wheel wear compensation (Only for continuous dressing)
```

### Explanations

The plunge grinding cycle consists of six operation sequences. Operations (1) to (6) are repeated until the depth reaches the total depth of cut specified at address K. In the single block stop mode, operations (1) to (6) are performed every cycle start.

- **Grinding wheel cutting**
  - (1) Cutting is performed along the Y–axis in cutting feed mode for the amount specified by I (depth of cut 1). The feedrate is specified by R.

- **Dwell**
  - (2) Dwell is performed for the time specified by P.

- **Grinding**
  - (3) Cutting feed is performed for the amount specified by X (or Z). The feedrate is specified by F.

- **Grinding wheel cutting**
  - (4) Cutting is performed along the Y–axis in cutting feed mode for the amount specified by J (depth of cut 2). The feedrate is specified by R.

- **Dwell**
  - (5) Dwell is performed for the time specified by P.

- **Grinding (return direction)**
  - (6) Feeding is performed in the reverse direction for the amount specified by X (or Z) at a feedrate specified by F.
Limitations

- **X(Z), I, J, K**
  
  X, (Z), I, J, and K must all be specified in incremental mode.

- **Clear**
  
  I, J, X, and Z in canned cycles are modal data common to G75, G77, G78, and G79. They remain valid until new data is specified. They are cleared when a group 00 G code other than G04 or a group 01 G code other than G75, G77, G78, and G79 is specified.

- **Operation performed when the total depth of cut is reached**
  
  When the total depth of cut is reached during cutting using I or J, the subsequent operation sequences (up to 6) are executed, then the cycle terminates. In this case, no further cutting is performed after the total depth of cut is reached.

  - **Chart of operation in which the total depth of cut is reached by cutting specified by I and J:**

    ![Diagram](image1)

    ![Diagram](image2)

    ![Diagram](image3)
A direct constant-dimension plunge grinding cycle is performed.

**Direct Constant-Dimension Plunge Grinding Cycle (G77)**

**Format**

\[
G77 \_J\_K\_X(Z)\_R\_F\_P\_L\_;
\]

- **I**: Depth of cut 1 (A sign in the command specifies the direction of cutting.)
- **J**: Depth of cut 2 (A sign in the command specifies the direction of cutting.)
- **K**: Total depth of cut (A sign in the command specifies the direction of cutting.)
- **X(Z)**: Range of grinding (A sign in the command specifies the direction of grinding.)
- **R**: Feedrate for I and J
- **F**: Feedrate for X (Z)
- **P**: Dwell time
- **L**: Grinding wheel wear compensation (Only for continuous dressing)

**Explanations**

The constant-dimension plunge grinding cycle consists of six operation sequences. Operations 1 to 6 are repeated until the depth reaches the total depth of cut specified at address K.

- **Grinding wheel cutting**
  1. Cutting is performed along the Y-axis in cutting feed mode for the amount specified by I (depth of cut 1). The feedrate is specified by R.

- **Dwell**
  2. Dwell is performed for the time specified by P.

- **Grinding**
  3. Cutting feed is performed for the amount specified by X (or Z). The feedrate is specified by F.

- **Grinding wheel cutting**
  4. Cutting is performed along the Y-axis in cutting feed mode for the amount specified by J (depth of cut 2). The feedrate is specified by R.

- **Dwell**
  5. Dwell is performed for the time specified by P.

- **Grinding (return direction)**
  6. Feeding is performed in the reverse direction for the amount specified by X (or Z) at a feedrate specified by F.
13. FUNCTIONS TO SIMPLIFY PROGRAMMING

- **Skip signal**

  When the cycle is performed using G77, a skip signal can be input to terminate the cycle. When a skip signal is input, the current operation sequence is interrupted or completed, then the cycle is terminated. The following shows how the system operates when the skip signal is input during each operation sequence.

  - When the skip signal is input during operation sequence 1 or 4 (cutting feed specified by I or J), cutting is stopped immediately and the tool returns to the X (Z) coordinate at which the cycle started.

```
/C0068
```

- When the skip signal is input during operation sequence 2 or 5 (dwell), dwell is stopped immediately and the tool returns to the X (Z) coordinate at which the cycle started.

- When the skip signal is input during operation sequence 3 or 6 (movement), the tool returns to the X (Z) coordinate at which the cycle started after the movement specified by X (Z) is completed.

```
/C0068
```

**Limitations**

- **X(Z), I, J, K**

  X, (Z), I, J, and K must all be specified in incremental mode.

- **Clear**

  I, J, X, and Z in canned cycles are modal data common to G75, G77, G78, and G79. They remain valid until new data is specified. They are cleared when a group 00 G code other than G04 or a group 01 G code other than G75, G77, G78, and G79 is specified.
A continuous-feed surface grinding cycle is performed.

**Format**

```plaintext
G78 I_ (J_) K_ X_ F_ P_ L_;  
I_ : Depth-of-cut 1 (A sign in the command specifies the direction of cutting.)  
J_ : Depth-of-cut 2 (A sign in the command specifies the direction of cutting.)  
K_ : Total depth of cut (A sign in the command specifies the direction of cutting.)  
X_ : Range of grinding (A sign in the command specifies the direction of grinding.)  
F_ : Feed rate  
P_ : Dwell time  
L_ : Grinding-wheel wear compensation (Only for continuous dressing)
```

**Explanations**

The continuous-feed surface grinding cycle consists of four operation sequences. Operations 1 to 4 are repeated until the depth reaches the total depth of cut specified in address K. In the single block stop mode, operations 1 to 4 are performed every cycle start.

1. Dwell  
2. Grinding  
3. Dwell  
4. Grinding (in reverse direction)
Restrictions

- **J**
  When J is omitted, it is assumed to be 1. J is valid only in the block where it is specified.

- **I, J, K, X**
  X, I, J, and K must all be specified in incremental mode.

- **Clear**
  I, J, X, and Z in canned cycles are modal data common to G75, G77, G78, and G79. They remain valid until new data is specified. They are cleared when a group 00 G code other than G04 or a group 01 G code other than G75, G77, G78, and G79 is specified.

- **Operation performed when the total depth of cut is reached**
  When the total depth of cut is reached during cutting using I or J, the subsequent operation sequences (up to \(2\)) are executed, then the cycle terminates. In this case, no further cutting is performed after the total depth of cut is reached.

  - Chart of operation in which the total depth of cut is reached by cutting specified by I and J:

  
  ![Chart of operation in which the total depth of cut is reached by cutting specified by I and J](image)

  - Chart of operation in which the total depth of cut is reached during cutting specified by I and J:

  
  ![Chart of operation in which the total depth of cut is reached during cutting specified by I and J](image)
13.3.4
Intermittent–Feed
Surface Grinding Cycle
(G79)

Format

G79 I_ J_ K_ X_ R_ F_ P_ L_ ;

I_: Depth–of–cut 1 (A sign in the command specifies the direction of cutting.)
J_: Depth–of–cut 2 (A sign in the command specifies the direction of cutting.)
K_: Total depth of cut (A sign in the command specifies the direction of cutting.)
X_: Range of grinding (A sign in the command specifies the direction of grinding.)
R_: Feedrate for I and J
F_: Feedrate for X
P_: Dwell time
L_: Grinding–wheel wear compensation (Only for continuous dressing)

Explanations

The intermittent–feed surface grinding cycle consists of six operation sequences. Operations 1 to 6 are repeated until the depth reaches the total depth of cut specified at address K. In the single block stop mode, operations 1 to 6 are performed every cycle start.

- **Grinding wheel cutting**
  1 Cutting is performed along the Z–axis in cutting feed mode for the amount specified by I (depth of cut 1). The feedrate is specified by R.

- **Dwell**
  2 Dwell is performed for the time specified by P.

- **Grinding**
  3 Cutting feed is performed for the amount specified by X. The feedrate is specified by F.

- **Grinding wheel cutting**
  4 Cutting is performed along the Z–axis in cutting feed mode for the amount specified by J (depth of cut 2). The feedrate is specified by R.

- **Dwell**
  5 Dwell is performed for the time specified by P.

- **Grinding**
  6 Feeding is performed in the reverse direction for the amount specified by X at a feedrate specified by F.

An intermittent–feed surface grinding cycle is performed.
Restrictions

- **X, I, J, K**
  X, I, J, and K must all be specified in incremental mode.

- **Clear**
  I, J, X, and Z in canned cycles are modal data common to G75, G77, G78, and G79. They remain valid until new data is specified. They are cleared when a group 00 G code other than G04 or a group 01 G code other than G75, G77, G78, and G79 is specified.
This function enables continuous dressing. When G75, G77, G78, or G79 is specified, grinding wheel cutting and dresser cutting are compensated continuously according to the amount of continuous dressing during grinding.

Specify an offset number (grinding wheel wear compensation number) at address L in the block containing G75. The compensation amount set in the offset memory area corresponding to the specified number is used as the amount of dressing.

Up to 400 offset numbers (L1 to L400) can be specified. Compensation amounts must be set beforehand in offset memory corresponding to offset numbers from the MDI panel.

When L is omitted or L0 is specified in a surface grinding canned cycle block, compensation is not performed.

Compensation is performed for every grinding operation (every movement along the X–axis) in the operation sequences of a canned grinding cycle. While the tool moves along the X–axis, compensation is performed along the Y–axis (grinding wheel cutting) and the V–axis (dresser cutting) for simultaneous three–axis interpolation.

The travel distance (compensation amount) along the Y–axis is the same as specified dressing amount, and the travel distance along the V–axis is twice as long (diameter).
13.5
AUTOMATIC
GRINDING WHEEL
DIAMETER
COMPENSATION
AFTER DRESSING

13.5.1
Checking the Minimum
Grinding Wheel
Diameter
(For Grinding Machine)

Compensation amounts set in offset memory can be modified by using the
external tool compensation function or programming (by changing
offsets using custom macro variables).
With these functions, the compensation amount for the diameter of the
dressed grinding wheel can be changed.
If the compensation amount associated with the offset number specified
in the H code is smaller than the minimum grinding wheel diameter
specified in parameter 5030 when programmed compensation (using G43
or G44) is performed, a signal is output to the PMC.
13.6 IN–FEED GRINDING ALONG THE Y AND Z AXES AT THE END OF TABLE SWING (FOR GRINDING MACHINE)

Format

```
G161 R_;
profile program
G160;
```

Explanations

- **G161 R_**
  - Specify the start of an operation mode and profile program. Also specify the depth of cut in R.

- **Profile program**
  - Program a workpiece figure in the Y–Z plane using linear interpolation (G01) and/or circular interpolation (G02 or G03). One or more blocks can be specified.

- **G160**
  - Cancel the operation mode (end of the profile program).

Restrictions

- **Profile program**
  - Do not specify codes other than G01, G02, and G03 within the profile program.

Examples

```
O0001 ;
  :
N0 G161 R10.0 ;
N1 G91 G01 Z–70.0 F100 ;
N2 G19 G02 Z–80.0 R67.0 ;
N3 G01 Z–70.0 ;
N4 G160 ;
  :
```

In the above program, every time the in–feed cutting start signal is input, the tool is moved by 10.000 along the machining profile shown above. 
\( \alpha \) = Travel distance for each in–feed control cutting start signal input
The feedrate is programmed with an F code.
13.7
OPTIONAL ANGLE
CHAMFERING AND CORNER ROUNDOING

Chamfering and corner rounding blocks can be inserted automatically between the following:
- Between linear interpolation and linear interpolation blocks
- Between linear interpolation and circular interpolation blocks
- Between circular interpolation and linear interpolation blocks
- Between circular interpolation and circular interpolation blocks

Format

\[
\begin{array}{ll}
, C_ & \text{Chamfering} \\
, R_ & \text{Corner R}
\end{array}
\]

Explanations

When the above specification is added to the end of a block that specifies linear interpolation (G01) or circular interpolation (G02 or G03), a chamfering or corner rounding block is inserted. Blocks specifying chamfering and corner rounding can be specified consecutively.

- Chamfering

After C, specify the distance from the virtual corner point to the start and end points. The virtual corner point is the corner point that would exist if chamfering were not performed.

\[
\begin{align*}
(1) & \ G91 \ G01 \ X100.0 ,C10.0 ; \\
(2) & \ X100.0 \ Y100.0 ;
\end{align*}
\]

- Corner R

After R, specify the radius for corner rounding.

\[
\begin{align*}
(1) & \ G91 \ G01 \ X100.0 ,R10.0 ; \\
(2) & \ X100.0 \ Y100.0 ;
\end{align*}
\]
Examples

N001 G92 G90 X0 Y0 ;
N002 G00 X10.0 Y10.0 ;
N003 G01 X50.0 F10.0 ,C5.0 ;
N004 Y25.0 ,R8.0 ;
N005 G03 X80.0 Y50.0 R30.0 ,R8.0 ;
N006 G01 X50.0 ,R8.0 ;
N007 Y70.0 ,C5.0 ;
N008 X10.0 ,C5.0 ;
N009 Y10.0 ;
N010 G00 X0 Y0 ;
N011 M0 ;
13. FUNCTIONS TO SIMPLIFY PROGRAMMING

Restrictions

- **Plane selection**
  Chamfering and corner rounding can be performed only in the plane specified by plane selection (G17, G18, or G19). These functions cannot be performed for parallel axes.

- **Next block**
  A block specifying chamfering or corner rounding must be followed by a block that specifies a move command using linear interpolation (G01) or circular interpolation (G02 or G03). If the next block does not contain these specifications, P/S alarm No. 052 is issued.

- **Plane switching**
  A chamfering or corner rounding block can be inserted only for move commands which are performed in the same plane. In a block that comes immediately after plane switching (G17, G18, or G19 is specified), neither chamfering nor corner rounding can be specified.

- **Exceeding the move range**
  If the inserted chamfering or corner rounding block causes the tool to go beyond the original interpolation move range, P/S alarm No.055 is issued.

- **Coordinate system**
  In a block that comes immediately after the coordinate system is changed (G92, or G52 to G59) or a return to the reference position (G28 to G30) is specified, neither chamfering nor corner rounding can be specified.

- **Travel distance 0**
  When two linear interpolation operations are performed, the chamfering or corner rounding block is regarded as having a travel distance of zero if the angle between the two straight lines is within ±1°. When linear interpolation and circular interpolation operations are performed, the corner rounding block is regarded as having a travel distance of zero if the angle between the straight line and the tangent to the arc at the intersection is within ±1°. When two circular interpolation operations are performed, the corner rounding block is regarded as having a travel distance of zero if the angle between the tangents to the arcs at the intersection is within ±1°.

- **Unavailable G codes**
  The following G codes cannot be used in a block that specifies chamfering or corner rounding. They also cannot be used between chamfering and corner rounding blocks that define a continuous figure.
  - G codes of group 00 (except G04)
  - G68 of group 16

- **Threading**
  Corner rounding cannot be specified in a threading block.

- **DNC operation**
  Arbitrary angle chamfering and corner rounding cannot be enabled for DNC operation.

---

Programmable G codes

- G91 G01 X30.0 ;
- G03 X7.5 Y16.0 R37.0 ,C28.0 ;
- G03 X67.0 Y–27.0 R55.0 ;

The tool path without chamfering is indicated with a solid line.

Chamfering block to be inserted
13.8 EXTERNAL MOTION FUNCTION (G81)

Upon completion of positioning in each block in the program, an external operation function signal can be output to allow the machine to perform specific operation. Concerning this operation, refer to the manual supplied by the machine tool builder.

Format

\[ \text{G81 IP_ ; (IP_ Axis move command )} \]

Explanations

Every time positioning for the IP_ move command is completed, the CNC sends a external operation function signal to the machine. An external operation signal is output for each positioning operation until canceled by G80 or a group 01 G code.

Restrictions

- **A block without X or Y axis**
  - No external operation signals are output during execution of a block that contains neither X nor Y.

- **Relationship with canned cycle G81**
  - G81 can also be used for a drilling canned cycle (II–13.1.4). Whether G81 is to be used for an external motion function or for a drilling canned cycle is specified with EXC, bit 1 of parameter No.5101.
13.9 FIGURE COPY (G72.1, G72.2)

Format

- Rotational copy

Machining can be repeated after moving or rotating the figure using a subprogram.

| Xp–Yp plane (specified by G17) | G72.1 P L Xp Yp R |
| Zp–Xp plane (specified by G18) | G72.1 P L Zp Xp R |
| Yp–Zp plane (specified by G19) | G72.1 P L Yp Zp R |

- Linear copy

Specify a plane selection command (G17, G18, or G19) to select the plane on which the rotational copy is made.

| Xp–Yp plane (specified by G17) | G72.2 P L I J |
| Zp–Xp plane (specified by G18) | G72.2 P L I K |
| Yp–Zp plane (specified by G19) | G72.2 P L J K |

Explanations

- First block of the subprogram

Always specify a move command in the first block of a subprogram that performs a rotational or linear copy. If the first block contains only the program number such as O1234; and does not have a move command, movement may stop at the start point of the figure made by the n–th (n = 1, 2, 3, ...) copying.

Specify the first move command in the absolute mode.

(Example of an incorrect program)

```
O1234 ;
G00 G90 X100.0 Y200.0 ;
.... ;
.... ;
M99 ;
```
(Example of a correct program)
O1000 G00 G90 X100.0 Y200.0 ;
· · · ;
· · · ;
M99 ;

- **Combination of rotational and linear copying**
  The linear copy command can be specified in a subprogram for a rotational copy. Also, the rotational copy command can be specified in a subprogram for a linear copy.

- **Subprogram calling**
  In a subprogram for rotational or linear copying, M98 for calling another subprogram or G65 for calling a macro can be specified.

- **Specifying the center of rotation**
  The center of rotation specified with G72.1 is processed as an absolute position even in the incremental mode.

- **Specifying address**
  In a block with G72.1, addresses other than P, L, Xp, Yp, Zp, or R are ignored. The subprogram number (P), coordinates of the center of rotation (Xp, Yp, Zp), and angular displacement (R) must be specified. In a block with G72.2, addresses other than P, L, I, J, or K are ignored. The subprogram number (P) and shift (I, J, K) must be specified.

- **Address P**
  If the subprogram number specified with P is not found, P/S alarm No. 078 occurs. If P is not specified, P/S alarm No. 076 occurs.

- **Address L**
  If L is omitted, the repetition count is assumed to be 1 and the subprogram is called only once.

- **Increment in angular displacement or shift**
  In a block with G72.1, an increment in angular displacement is specified with address R. The angular displacement of the figure made by the n-th rotation is calculated as follows: R x (n – 1).
  In a block with G72.2, an increment in shift is specified with addresses I, J, and K. The shift of the figure made by the n-th movement is calculated as follows: (Programmed shift) x (n – 1).

- **Nesting level of a subprogram**
  If a subprogram is called by G72.1 or G72.2, the nesting level is increased by one in the same manner as when M98 is specified.

- **Block end position**
  The coordinates of a figure moved rotationally or linearly (block end position) can be read from #5001 and subsequent system variables of the custom macro of rotational or linear copy.

- **Disagreement between end point and start point**
  If the end point of the figure made by the n-th copy does not agree with the start point of the figure to be made by the next (n + 1) copy, the figure is moved from the end point to the start point, then copying is started. (Generally, this disagreement occurs if an incorrect angular displacement or shift is specified.)
13. FUNCTIONS TO SIMPLIFY PROGRAMMING

Main program

```
O1000 ;
N10 G92 X–20.0 Y0 ;
N20 G00 G90 X0 Y0 ;
N30 G01 G17 G41 X20. Y0 D01 F10 ; (P0)
N40 Y20. ; (P1)
N50 X30. ; (P2)
N60 G72.2 P2000 L3 I90.0 J0 ;
```

Although a shift of 70 mm was required, I90.0 was specified instead of I70.0. Since an incorrect shift was specified, the end point of the figure made by the n-th copy disagrees with the start point of the figure to be made by the next (n + 1) copy.

Subprogram

```
O2000 G90 G01 X40. ; (P3)
N100 Y40. ; (P4)
N200 G01 X80. ; (P5)
N300 G01 Y20. ; (P6)
N400 X100. ; (P7)
N500 M99;
```

Limitations

- **Specifying two or more commands to copy a figure**

  G72.1 cannot be specified more than once in a subprogram for making a rotational copy (If this is attempted, P/S alarm No.160 will occur). G72.2 cannot be specified more than once in a subprogram for making a linear copy (If this is attempted, P/S alarm No. 161 will occur).

- **Commands that must not be specified**

  Within a program that performs a rotational or linear copy, the following must not be specified:
  - Command for changing the selected plane (G17 to G19)
  - Command for specifying polar coordinates
  - Reference position return command
  - Coordinate system rotation, scaling, programmable mirror image
  The command for rotational or linear copying can be specified after a command for coordinate system rotation, scaling, or programmable mirror image is executed.
• Modes that must not be selected
The figure cannot be copied during chamfering, corner rounding, or tool offset.

• Unit system
The two axes of the plane for copying a figure must have an identical unit system.

• Single block
Single–block stops are not performed in a block with G72.1 or G72.2.

• Specifying cutter compensation and the workpiece coordinate system
In a subprogram for copying a figure, the G code for cutter compensation B or C or compensation amount (H or D code) cannot be changed. G92 and G54 to G59 cannot be changed either. Those codes must be specified before figure copying is started.

Examples

• Rotational copy

![Diagram of rotational copy]

Main program
O1000 ;
N10 G92 X40.0 Y50.0 ;
N20 G00 G90 X_ Y_ ; (P0)
N30 G01 G17 G41 X_ Y_ D01 F10 ; (P1)
N40 G72.1 P2000 L3 X0 Y0 R120.0 ;
N50 G40 G01 X_ Y_ I_ J_ ; (P0)
N60 G00 X40.0 Y50.0 ;
N70 M30 ;

Sub program
O2000 G03 X_ Y_ R30.0 ; (P2)
N100 G01 X_ Y_ ; (P3)
N200 G03 X_ Y_ R10.0 ; (P4)
N300 G01 X_ Y_ ; (P5)
N400 G03 X_ Y_ R30.0 ; (P6)
N500 M99;
- Rotational copy (spot boring)

Main program
O3000 ;
N10 G92 G17 X80.0 Y50.0 ; (P0)
N20 G72.1 P4000 L6 X0 Y0 R60.0 ; (P0)
N30 G80 G00 X80.0 Y50.0 ; (P0)
N40 M30 ;

Subprogram
O4000 N100 G90 G81 X_ Y_ R_ Z_ F_ ; (P1)
N200 M99 ;


**Linear copy**

<table>
<thead>
<tr>
<th>P0</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
<th>P5</th>
<th>P6</th>
<th>P7</th>
<th>P8</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>Y</td>
<td>X</td>
<td>Y</td>
<td>X</td>
<td>Y</td>
<td>X</td>
<td>Y</td>
<td>X</td>
</tr>
</tbody>
</table>

Main program

O1000;
N10 G92 X–20.0 Y0;
N20 G00 G90 X0 Y0;
N30 G01 G17 G41 X_ Y_ D01 F10; (P0)
N40 Y_ ; (P1)
N50 X_ ; (P2)
N60 G72.2 P2000 L3 I70.0 J0 ;
N70 X_ Y_ ; (P8)
N80 X0 ;
N90 G00 G40 X–20.0 Y0 ;
N100 M30 ;

Subprogram

O2000 G90 G01 X_ ; (P3)
N100 Y_ ; (P4)
N200 G02 X_ I_ ; (P5)
N300 G01 Y_ ; (P6)
N400 X_ ; (P7)
N500 M99 ;
Combination of rotational copying and linear copying (bolt hole circle)

Main program
O1000 ;
N10 G92 G17 X100.0 Y80.0 ; (P0)
N20 G72.1 P2000 X0 Y0 L8 R45.0 ;
N30 G80 G00 X100.0 Y80.0 ; (P0)
N40 M30 ;

Subprogram (rotational copy)
O2000 N100 G72.2 P3000 10 J_ L3 ;
N200 M99 ;

Subprogram (linear copy)
O3000 N110 G90 G81 X_ Y_ R_ Z_ F_ ; (P1)
N210 M99 ;
13.10 THREE-DIMENSIONAL COORDINATE CONVERSION (G68, G69)

Coordinate conversion about an axis can be carried out if the center of rotation, direction of the axis of rotation, and angular displacement are specified. This function is very useful in three-dimensional machining by a die-sinking machine or similar machine. For example, if a program specifying machining on the XY plane is converted by the three-dimensional coordinate conversion function, the identical machining can be executed on a desired plane in three-dimensional space.

Format

```
G68 Xp x1 Yp y1 Zp z1 I11 J11 K11 R α1;
```

Starting three-dimensional coordinate conversion

```
```

```
```

```
```

```
G69;
```

Canceling three-dimensional coordinate conversion

N1 G68 Xp x1 Yp y1 Zp z1 I11 J11 K11 R α1;
N2 G68 Xp x2 Yp y2 Zp z2 I12 J12 K12 R β2;
```

Three-dimensional coordinate conversion can be executed twice.

In the N1 block, specify the center, direction of the axis of rotation, and angular displacement of the first rotation. When this block is executed, the center of the original coordinate system is shifted to (x1, y1, z1), then rotated around the vector (i1, j1, k1) by angular displacement α1. The new coordinate system is called X’Y’Z’. In the N2 block, specify the center, direction of the axis of rotation, and angular displacement of the second rotation. In the N2 block, specify coordinates and the angle with the coordinate system formed after the N1 block in Xp, Yp, Zp, I, J, K, and R. When the N2 block is executed, the X’Y’Z’ coordinate system is shifted to (x2, y2, z2), then rotated around the vector (i2, j2, k2) by angular displacement β2. The newest coordinate system is called X”Y”Z”. In the
subsequent N3 block, coordinates in the X"Y"Z" coordinate system are specified with Xp, Yp, and Zp. The X"Y"Z" coordinate system is called the program coordinate system.

If (Xp, Yp, Zp) is not specified in the N2 block, (Xp, Yp, Zp) in the N1 block is assumed to be the center of the second rotation (the N1 and N2 blocks have a common center of rotation). If the coordinate system is to be rotated only once, the N2 block need not be specified.

Example) G68 Xx0 Yy0 Zz0 I0 J0 K1 Rα;  
       G68  I1 J0 K0 Rβ;

\[ \text{X, Y, Z: Workpiece coordinate system} \]
\[ \text{X', Y', Z': Coordinate system formed after the first conversion} \]
\[ \text{X", Y", Z": Coordinate system formed after the second conversion} \]
\[ \alpha: \text{Angular displacement of the first rotation} \]
\[ \beta: \text{Angular displacement of the second rotation} \]
\[ \text{O (x0, y0, z0): Center of rotation} \]
\[ \text{P (x, y, z): Coordinates in the X"Y"Z" coordinate system (program coordinate system)} \]

- **Format error**

If one of the following format errors is detected, P/S alarm No. 5044 occurs:

1. When I, J, or K is not specified in a block with G68  
   (a parameter of coordinate system rotation is not specified)
2. When I, J, and K are all set to 0 in a block with G68
3. When R is not specified in a block with G68

- **Center of rotation**

Specify absolute coordinates with Xp, Yp, and Zp in the G68 block.
The following equation shows the general relationship between \((x, y, z)\) in the program coordinate system and \((X, Y, Z)\) in the original coordinate system (workpiece coordinate system).

\[
\begin{pmatrix}
X \\
Y \\
Z
\end{pmatrix} = \begin{pmatrix} M_1 \end{pmatrix} \begin{pmatrix} x \\
y \\
z \end{pmatrix} + \begin{pmatrix} x_1 \\
y_1 \\
z_1 \end{pmatrix}
\]

When conversion is carried out twice, the relationship is expressed as follows:

\[
\begin{pmatrix}
X \\
Y \\
Z
\end{pmatrix} = \begin{pmatrix} M_1 \end{pmatrix} \begin{pmatrix} M_2 \end{pmatrix} \begin{pmatrix} x \\
y \\
z \end{pmatrix} + \begin{pmatrix} M_1 \end{pmatrix} \begin{pmatrix} x_2 \\
y_2 \\
z_2 \end{pmatrix} + \begin{pmatrix} x_1 \\
y_1 \\
z_1 \end{pmatrix}
\]

\(X, Y, Z\) : Coordinates in the original coordinate system (workpiece coordinate system)
\(x, y, z\) : Programmed value (coordinates in the program coordinate system)
\(x_1, y_1, z_1\) : Center of rotation of the first conversion (coordinates in the coordinate system formed after the first conversion)
\(x_2, y_2, z_2\) : Center of rotation of the second conversion (coordinates in the coordinate system formed after the first conversion)

\(M_1\) : First conversion matrix
\(M_2\) : Second conversion matrix

\(n_1^2+(1-n_2^2)\cos \theta - n_1n_2 (1-\cos \theta)-n_3\sin \theta \quad n_1n_3 (1-\cos \theta)+n_2\sin \theta \)
\(n_1 n_2 (1-\cos \theta)+n_3 \sin \theta \quad n_2^2+(1-n_2^2)\cos \theta \quad n_2 n_3 (1-\cos \theta)-n_1 \sin \theta \)
\(n_1 n_3 (1-\cos \theta)-n_2\sin \theta \quad n_2 n_3 (1-\cos \theta)+n_1 \sin \theta \quad n_3^2+(1-n_3^2)\cos \theta \)

\(n_1\) : Cosine of the angle made by the rotation axis and \(X\)-axis \(\frac{i}{p}\)
\(n_2\) : Cosine of the angle made by the rotation axis and \(Y\)-axis \(\frac{j}{p}\)
\(n_3\) : Cosine of the angle made by the rotation axis and \(Z\)-axis \(\frac{k}{p}\)

\(\theta\) : Angular displacement

Value \(p\) is obtained by the following:

\[p = \sqrt{i^2+j^2+k^2}\]

Conversion matrices for rotation on two-dimensional planes are shown below:

(1) Coordinate conversion on the XY plane

\[
M = \begin{pmatrix} \cos \theta & -\sin \theta & 0 \\ \sin \theta & \cos \theta & 0 \\ 0 & 0 & 1 \end{pmatrix}
\]

(2) Coordinate conversion on the YZ plane

\[
M = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos \theta & -\sin \theta \\ 0 & \sin \theta & \cos \theta \end{pmatrix}
\]

(3) Coordinate conversion on the ZX plane

\[
M = \begin{pmatrix} \cos \theta & 0 & \sin \theta \\ 0 & 1 & 0 \\ -\sin \theta & 0 & \cos \theta \end{pmatrix}
\]
• Three basic axes and their parallel axes

Three-dimensional coordinate conversion can be applied to a desired combination of three axes selected out of the basic three axes (X, Y, Z) and their parallel axes. The three-dimensional coordinate system subjected to three-dimensional coordinate conversion is determined by axis addresses specified in the G68 block. If Xp, Yp, or Zp is not specified, X, Y, or Z of the basic three axes is assumed. However, if the basic three axes are not specified in parameter 1022, P/S alarm No. 048 occurs.

In a single G68 block, both a basic axis and a parallel axis cannot be specified. If this is attempted, P/S alarm No.047 occurs.

(Example)

When U–axis, V–axis, and W–axis are parallel to the X–axis, Y–axis, and Z–axis respectively

G68 X I J K R ; XYZ coordinate system
G68 U V Z I J K R ; UVZ coordinate system
G68 W I J K R ; XYW coordinate system

• Specifying the second conversion

Three-dimensional coordinate conversion can be executed twice. The center of rotation of the second conversion must be specified with the axis addresses specified for the first conversion. If the axis addresses of the second conversion are different from the axis addresses of the first conversion, the different axis addresses are ignored. An attempt to execute three-dimensional coordinate conversion three or more times causes P/S alarm No.5043.

• Angular displacement R

A positive angular displacement R indicates a clockwise rotation along the axis of rotation. Specify angular displacement R in 0.001 degrees within the range of −360000 to 360000.

• G codes that can be specified

The following G codes can be specified in the three-dimensional coordinate conversion mode:

G00 Positioning
G01 Linear interpolation
G02 Circular interpolation (clockwise)
G03 Circular interpolation (counterclockwise)
G04 Dwell
G10 Data setting
G17 Plane selection (XY)
G18 Plane selection (ZX)
G19 Plane selection (YZ)
G28 Reference position return
G29 Return from the reference position
G30 Return to the second, third, or fourth reference position
G40 Canceling cutter compensation
G41 Cutter compensation to the left
G42 Cutter compensation to the right
G43 Increasing tool length compensation
G44 Decreasing tool length compensation
G45 Increasing the tool offset
G46 Decreasing the tool offset
G47 Doubling the tool offset
G48 Halving the tool offset
G49 Canceling tool length compensation
G50.1 Canceling programmable mirror image
G51.1 Programmable mirror image
G53  Selecting the machine coordinate system
G65  Custom macro calling
G66  Continuous–state custom macro calling
G67  Canceling continuous–state custom macro calling
G73  Canned cycle (peck drilling cycle)
G74  Canned cycle (reverse tapping cycle)
G76  Canned cycle (fine boring cycle)
G80  Canceling a canned cycle
G81 to G89  Canned cycle
G90  Absolute mode
G91  Incremental mode
G94  Feed per minute
G95  Feed per rotation
G98  Canned cycle (return to the initial level)
G99  Canned cycle (return to the level of point R)

- **Rapid traverse rate in drilling of a canned cycle**
  In the three–dimensional coordinate conversion mode, the rapid traverse rate in drilling of a canned cycle equals the maximum cutting feedrate.

- **Compensation functions**
  If tool length compensation, cutter compensation, or tool offset is specified with three–dimensional coordinate conversion, compensation is performed first, followed by three–dimensional coordinate conversion.

- **Relationship between three–dimensional and two–dimensional coordinate conversion (G68, G69)**
  Three–dimensional and two–dimensional coordinate conversion use identical G codes (G68 and G69). A G code specified with I, J, and K is processed as the command for three–dimensional coordinate conversion. A G code not specified with I, J, and K is processed as the command for two–dimensional coordinate conversion.

- **Custom macro system variables**
  Coordinates on the workpiece coordinate system are assigned to system variables #5041 to #5048 (current position on each axis).

- **Reset**
  If a reset occurs during three–dimensional coordinate conversion mode, the mode is canceled and the continuous–state G code is changed to G69.

- **Absolute position display**
  The absolute coordinates based on the program or workpiece coordinate system can be displayed in the three–dimensional coordinate conversion mode. Specify a desired coordinate system in the DAK bit (bit 6 of parameter 3106).

- **Three–dimensional rigid tapping**
  By specifying the rigid tapping command in three–dimensional coordinate conversion mode, tapping can be executed in the direction of the angle programmed by the three–dimensional coordinate conversion command.
  In three–dimensional coordinate conversion mode, "Position Error Z", displayed on the spindle adjustment screen, is taken from the longitudinal tapping axis after three–dimensional conversion.
  Positioning in three–dimensional coordinate conversion mode must be linear interpolation positioning (the LRP bit (bit 1 of parameter 1401) is set to 1).
  Three–dimensional rigid tapping cannot be executed for an axis under simple synchronous control.
Three-dimensional coordinate conversion does not affect the degree of manual intervention or manual handle interrupt.

Three-dimensional coordinate conversion does not affect positioning in the machine coordinate system (e.g. specified with G28, G30, or G53).

Specify linear rapid traverse when three-dimensional coordinate conversion is executed. (Set the LRP bit, bit 1 of parameter No.1401, to 1.)

In a block with G68 or G69, other G codes must not be specified. G68 must be specified with I, J, and K.

Programmable mirror image can be specified, but external mirror image (mirror image by the mirror image signal or setting) cannot be specified. Three-dimensional coordinate conversion is carried out after the programmable mirror image function is executed.

To display the absolute position when three-dimensional coordinate conversion is executed, set bits 4 to 7 of parameter DRL, DRC, DAL, and DAC No.3104 to 0.

Canned cycles G41, G42, or G51.1 must be nested between G68 and G69.

(Example)

```
G68 X100. Y100. Z100. I0. J0. K1. R45. ;
G41 D01 ;
G40 ;
G69 ;
```
Examples

N1 G90 X0 Y0 Z0 ; Carries out positioning to zero point H.
N2 G68 X10. Y0 Z0 I0 J1 K0 R30. ; Forms new coordinate system X"Y"Z".
N3 G68 X0 Y–10. Z0 I0 J0 K1 R–90. ; Forms other coordinate system X"Y"Z". The origin agrees with (0, –10, 0) in coordinate system X"Y"Z".
N4 G90 X0 Y0 Z0 ; Carries out positioning to zero point H" on coordinate system X"Y"Z".
N5 X10. Y10. Z0 ; Carries out positioning to (10, 10, 0) on coordinate system X"Y"Z".
13.11 INDEX TABLE INDEXING FUNCTION

By specifying indexing positions (angles) for the indexing axis (one rotation axis, A, B, or C), the index table of the machining center can be indexed. Before and after indexing, the index table is automatically unclamped or clamped.

Explanations

- **Indexing position**

Specify an indexing position with address A, B, or C (set to bit 0 of parameter \( \text{ROT}_x \) No.1006).

The indexing position is specified by either of the following (depending on bit 4 of parameter G90 No.5500):

1. Absolute value only
2. Absolute or incremental value depending on the specified G code: G90 or G91

A positive value indicates an indexing position in the counterclockwise direction. A negative value indicates an indexing position in the clockwise direction.

The minimum indexing angle of the index table is the value set to parameter 5512. Only multiples of the least input increment can be specified as the indexing angle. If any value that is not a multiple is specified, an P/S alarm (No. 135) occurs. Decimal fractions can also be entered. When a decimal fraction is entered, the 1's digit corresponds to degree units.

![Diagram showing indexing position from A to B](image)

- **Direction and value of rotation**

The direction of rotation and angular displacement are determined by either of the following two methods. Refer to the manual written by the machine tool builder to find out which method is applied.

1. Using the miscellaneous function specified in parameter No. 5511 (Address) (Indexing position) (Miscellaneous function); Rotation in the negative direction (Address) (Indexing position); Rotation in the positive direction (No miscellaneous functions are specified.)

An angular displacement greater than 360° is rounded down to the corresponding angular displacement within 360° when bit 2 of parameter ABS No. 5500 specifies this option.

For example, when G90 B400.0 (miscellaneous function); is specified at a position of 0°, the table is rotated by 40° in the negative direction.
2. Using no miscellaneous functions
   By setting to bits 2, 3, and 4 of parameter ABS, INC, G90 No.5500, operation can be selected from the following two options.
   Select the operation by referring to the manual written by the machine tool builder.

   (1) Rotating in the direction in which an angular displacement becomes shortest
       This is valid only in absolute mode. A specified angular displacement greater than 360° is rounded down to the corresponding angular displacement within 360° when bit 2 of parameter ABS No.5500 specifies this option.
       For example, when G90 B400.0; is specified at a position of 0, the table is rotated by 40° in the positive direction.

   (2) Rotating in the specified direction
       In the absolute mode, the value set in bit 2 of parameter ABS No.5500 determines whether an angular displacement greater than 360° is rounded down to the corresponding angular displacement within 360°.
       In the incremental mode, the angular displacement is not rounded down.
       For example, when G90 B720.0; is specified at a position of 0, the table is rotated twice in the positive direction, when the angular displacement is not rounded down.

- **Feedrate**

   The table is always rotated around the indexing axis in the rapid traverse mode.
   Dry runs cannot be executed for the indexing axis.

---

**WARNING**

If a reset is made during indexing of the index table, a reference position return must be made before each time the index table is indexed subsequently.

---

**NOTE**

1. Specify the indexing command in a single block. If the command is specified in a block in which another controlled axis is specified, P/S alarm (No.136) occurs.
2. The waiting state which waits for completion of clamping or unclamping of the index table is indicated on diagnostic screen 12.
3. The miscellaneous function specifying a negative direction is processed in the CNC.
   The relevant M code signal and completion signal are sent between the CNC and the machine.
4. If a reset is made while waiting for completion of clamping or unclamping, the clamp or unclamp signal is cleared and the CNC exits the completion wait state.
### 13. FUNCTIONS TO SIMPLIFY

#### PROGRAMMING

- **Indexing function and other functions**

**Table 13.11 (a) Index indexing function and other functions**

<table>
<thead>
<tr>
<th>Item</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative position display</td>
<td>This value is rounded down when bit 1 of parameter REL No. 5500 specifies this option.</td>
</tr>
<tr>
<td>Absolute position display</td>
<td>This value is rounded down when bit 2 of parameter ABS No. 5500 specifies this option.</td>
</tr>
<tr>
<td>Automatic return from the reference position (G29)</td>
<td>Impossible to return</td>
</tr>
<tr>
<td>2nd reference position return (G30)</td>
<td>Impossible to return</td>
</tr>
<tr>
<td>Movement in the machine coordinate system</td>
<td>Impossible to move</td>
</tr>
<tr>
<td>Single direction positioning</td>
<td>Impossible to specify</td>
</tr>
<tr>
<td>2nd auxiliary function (B code)</td>
<td>Possible with any address other than B that of the indexing axis.</td>
</tr>
<tr>
<td>Operations while moving the indexing axis</td>
<td>Unless otherwise processed by the machine, feed hold, interlock and emergency stop can be executed. Machine lock can be</td>
</tr>
<tr>
<td></td>
<td>executed after indexing is completed.</td>
</tr>
<tr>
<td>SERVO OFF signal</td>
<td>Disabled</td>
</tr>
<tr>
<td></td>
<td>The indexing axis is usually in the servo–off state.</td>
</tr>
<tr>
<td>Incremental commands for indexing the index table</td>
<td>The workpiece coordinate system and machine coordinate system must always agree with each other on the indexing axis (the workpiece</td>
</tr>
<tr>
<td></td>
<td>zero point offset value is zero.).</td>
</tr>
<tr>
<td>Operations for indexing the index table</td>
<td>Manual operation is disabled in the JOG, INC, or HANDLE mode. A manual reference position return can be made. If the axis selection</td>
</tr>
<tr>
<td></td>
<td>signal is set to zero during manual reference position return, movement is stopped and the clamp command is not executed.</td>
</tr>
</tbody>
</table>
This chapter describes the following compensation functions:

14.1 TOOL LENGTH OFFSET (G43, G44, G49)
14.2 AUTOMATIC TOOL LENGTH MEASUREMENT (G37)
14.3 TOOL OFFSET (G45–G48)
14.4 CUTTER COMPENSATION B (G39–G42)
14.5 CUTTER COMPENSATION C (G40–G42)
14.6 DETAILS OF CUTTER COMPENSATION C
14.7 THREE-DIMENSIONAL TOOL COMPENSATION (G40, G41)
14.8 TOOL COMPENSATION VALUES, NUMBER OF COMPENSATION VALUES, AND ENTERING VALUES FROM THE PROGRAM (G10)
14.9 SCALING (G50, G51)
14.10 COORDINATE SYSTEM ROTATION (G68, G69)
14.11 NORMAL DIRECTION CONTROL (G40.1, G41.1, G42.1 OR G150, G151, G152)
14.12 PROGRAMMABLE MIRROR IMAGE (G50.1, G51.1)
14.13 GRINDING WHEEL WEAR COMPENSATION
14.14 ROTARY TABLE DYNAMIC FIXTURE OFFSET
This function can be used by setting the difference between the tool length assumed during programming and the actual tool length of the tool used into the offset memory. It is possible to compensate the difference without changing the program.

Specify the direction of offset with G43 or G44. Select a tool length offset value from the offset memory by entering the corresponding address and number (H code).

The following three methods of tool length offset can be used, depending on the axis along which tool length offset can be made.

- **Tool length offset A**
  - Compensates for the difference in tool length along the Z-axis.

- **Tool length offset B**
  - Compensates for the difference in tool length along the X-, Y-, or Z-axis.

- **Tool length offset C**
  - Compensates for the difference in tool length along a specified axis.

### Format

| Tool length offset A | G43 Z_ H_;  
| G44 Z_ H_;  
| Explanation of each address  
| G43 : Positive offset  
| G44 : Negative offset  
| G17 : XY plane selection  
| G18 : ZX plane selection  
| G19 : YZ plane selection  
| α : Address of a specified axis  
| H : Address for specifying the tool length offset value  |
| Tool length offset B | G17 G43 Z_ H_;  
| G17 G44 Z_ H_;  
| G18 G43 Y_ H_;  
| G18 G44 Y_ H_;  
| G19 G43 X_ H_;  
| G19 G44 X_ H_;  |
| Tool length offset C | G43 α_ H_;  
| G44 α_ H_;  |
| Tool length offset cancel | G49 ; or H0 ; |
Select tool length offset A, B, or C, by setting bits 0 and 1 of parameter TLC,TLB No. 5001.

When G43 is specified, the tool length offset value (stored in offset memory) specified with the H code is added to the coordinates of the end position specified by a command in the program. When G44 is specified, the same value is subtracted from the coordinates of the end position. The resulting coordinates indicate the end position after compensation, regardless of whether the absolute or incremental mode is selected.

If movement along an axis is not specified, the system assumes that a move command that causes no movement is specified. When a positive value is specified for tool length offset with G43, the tool is moved accordingly in the positive direction. When a positive value is specified with G44, the tool is moved accordingly in the negative direction. When a negative value is specified, the tool is moved in the opposite direction. G43 and G44 are modal G codes. They are valid until another G code belonging to the same group is used.

The tool length offset value assigned to the number (offset number) specified in the H code is selected from offset memory and added to or subtracted from the moving command in the program.

(1) Tool length offset A/B
When the offset numbers for tool length offset A/B are specified or modified, the offset number validation order varies, depending on the condition, as described below.

<table>
<thead>
<tr>
<th>Offset Number Validation Order</th>
</tr>
</thead>
<tbody>
<tr>
<td>H01 - Valid</td>
</tr>
<tr>
<td>G43Z_ - (1)</td>
</tr>
<tr>
<td>G44Z_H02 - (2)</td>
</tr>
<tr>
<td>H03 - (3)</td>
</tr>
</tbody>
</table>

(1) Offset number H01 is valid.
(2) Offset number H02 is valid.
(3) Offset number H03 is valid.

When OFH (bit 2 of parameter No. 5001) = 0

<table>
<thead>
<tr>
<th>Offset Number Validation Order</th>
</tr>
</thead>
<tbody>
<tr>
<td>H01 - Valid</td>
</tr>
<tr>
<td>G43Z_ - (1)</td>
</tr>
<tr>
<td>G44Z_H02 - (2)</td>
</tr>
<tr>
<td>H03 - (3)</td>
</tr>
</tbody>
</table>

(1) Offset number H01 is valid.
(2) Offset number H02 is valid.
(3) Offset number H03 is valid.

When OFH (bit 2 of parameter No. 5001) = 1
(2) Cutter compensation \( C \)

When the offset numbers for cutter compensation \( C \) are specified or modified, the offset number validation order varies, depending on the condition, as described below.

- **When OFH (bit 2 of parameter No. 5001) = 0**

```
Oxxxx;  
H01 ;  
G43P_ ;  (1)  
G44P_H02 ;  (2)  
H03 ;  (3)  
```

- **When OFH (bit 2 of parameter No. 5001) = 1**

```
Oxxxx;  
H01 ;  
G43P_ ;  (1)  
G44P_H02 ;  (2)  
H03 ;  (3)  
```

The tool length offset value may be set in the offset memory through the CRT/MDI panel.

The range of values that can be set as the tool length offset value is as follows.

<table>
<thead>
<tr>
<th>Tool length offset value</th>
<th>Metric input</th>
<th>Inch input</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to ±999.999mm</td>
<td>0 to ±99.9999inch</td>
<td></td>
</tr>
</tbody>
</table>

**WARNING**

When the tool length offset value is changed due to a change of the offset number, the offset value changes to the new tool length offset value, the new tool length offset value is not added to the old tool length offset value.

- \( H1 \) : tool length offset value 20.0
- \( H2 \) : tool length offset value 30.0

```
G90 G43 Z100.0 H1 ;  Z will move to 120.0  
G90 G43 Z100.0 H2 ;  Z will move to 130.0
```

**CAUTION**

When the tool length offset is used and set a parameter OFH (No. 5001#2) to 0, specify the tool length offset with \( H \) code and the cutter compensation with \( D \) code.
NOTE
The tool length offset value corresponding to offset No. 0, that is, H0 always means 0. It is impossible to set any other tool length offset value to H0.

• Performing tool length offset along two or more axes

Tool length offset B can be executed along two or more axes when the axes are specified in two or more blocks.

Offset in X and Y axes.
  G19 G43 H_ ; Offset in X axis
  G18 G43 H_ ; Offset in Y axis
  (Offsets in X and Y axes are performed)

If the TAL bit (bit 3 of parameter No. 5001) is set to 1, an alarm will not occur even when tool length offset C is executed along two or more axes at the same time.

• Tool length offset cancel

To cancel tool length offset, specify G49 or H0. After G49 or H0 is specified, the system immediately cancels the offset mode.

NOTE
• After tool length offset B is executed along two or more axes, offset along all the axes is canceled by specifying G49. If H0 is specified, only offset along an axis perpendicular to the specified plane is canceled.
• In the case of the offset in three axes or more, if the offset is canceled by G49 code, the P/S alarm 015 is generated. Cancel the offset by using G49 and H0.
### Examples

#### Tool length offset (in boring holes No.1, 2, and 3)

- **Program**
  
  H1 = -4.0 (Tool length offset value)

  N1 G91 G00 X120.0 Y80.0 ; (1)
  N2 G43 Z–32.0 H1 ; (2)
  N3 G01 Z–21.0 F1000 ; (3)
  N4 G04 P2000 ; (4)
  N5 G00 Z21.0 ; (5)
  N6 X30.0 Y–50.0 ; (6)
  N7 G01 Z–41.0 ; (7)
  N8 G00 Z41.0 ; (8)
  N9 X50.0 Y30.0 ; (9)
  N10 G01 Z–25.0 ; (10)
  N11 G04 P2000 ; (11)
  N12 G00 Z57.0 H0 ; (12)
  N13 X–200.0 Y–60.0 ; (13)
  N14 M2 ;
14.1.2 G53, G28, G30, and G30.1 Commands in Tool Length Offset Mode

This section describes the tool length offset cancellation and restoration performed when G53, G28, G30, or G30.1 is specified in tool length offset mode. Also described is the timing of tool length offset.

(1) Tool length offset vector cancellation and restoration, performed when G53, G28, G30, or G30.1 is specified in tool length offset mode

(2) Specification of the G43/G44 command for tool length offset A/B/C, and independent specification of the H command

Explanations

- Tool length offset vector cancellation

When G53, G28, G30, or G30.1 is specified in tool length offset mode, tool length offset vectors are canceled as described below. However, the previously specified modal G code remains displayed; modal code display is not switched to G49.

(1) When G53 is specified

<table>
<thead>
<tr>
<th>Command</th>
<th>Specified axis</th>
<th>Common to type A/B/C</th>
</tr>
</thead>
<tbody>
<tr>
<td>G53P_;</td>
<td>Tool length offset axis</td>
<td>Canceled upon movement being performed according to a specified value</td>
</tr>
<tr>
<td></td>
<td>Other than tool length offset axis</td>
<td>Not canceled</td>
</tr>
</tbody>
</table>

NOTE

When tool length offset is applied to multiple axes, all specified axes are subject to cancellation.

When tool length offset cancellation is specified at the same time, tool length offset vector cancellation is performed as indicated below.

<table>
<thead>
<tr>
<th>Command</th>
<th>Specified axis</th>
<th>Common to type A/B/C</th>
</tr>
</thead>
<tbody>
<tr>
<td>G49G53P_;</td>
<td>Tool length offset axis</td>
<td>Canceled upon movement being performed according to a specified value</td>
</tr>
<tr>
<td></td>
<td>Other than tool length offset axis</td>
<td>Canceled upon movement being performed according to a specified value</td>
</tr>
</tbody>
</table>

(2) When G28, G30, or G30.1 is specified

<table>
<thead>
<tr>
<th>Command</th>
<th>Specified axis</th>
<th>Common to type A/B/C</th>
</tr>
</thead>
<tbody>
<tr>
<td>G28P_;</td>
<td>Tool length offset axis</td>
<td>Canceled upon movement to a reference position being performed</td>
</tr>
<tr>
<td></td>
<td>Other than tool length offset axis</td>
<td>Not canceled</td>
</tr>
</tbody>
</table>
NOTE
When tool length offset is applied to multiple axes, all specified axes involved in reference position return are subject to cancellation.

When tool length offset cancellation is specified at the same time, tool length offset vector cancellation is performed as indicated below.

<table>
<thead>
<tr>
<th>Command</th>
<th>Specified axis</th>
<th>Common to type A/B/C</th>
</tr>
</thead>
<tbody>
<tr>
<td>G49G28P_;</td>
<td>Tool length offset axis</td>
<td>Canceled upon movement to an intermediate position being performed</td>
</tr>
<tr>
<td></td>
<td>Other than tool length offset axis</td>
<td>Canceled upon movement to an intermediate position being performed</td>
</tr>
</tbody>
</table>

● Tool length offset vector restoration

Tool length offset vectors, canceled by specifying G53, G28, G30, or G30.1 in tool length offset mode, are restored as described below.

(1) When OFH (bit 2 of parameter No. 5001) = 0

<table>
<thead>
<tr>
<th>Type</th>
<th>EVO (bit 6 of parameter No. 5001)</th>
<th>Restoration block</th>
</tr>
</thead>
<tbody>
<tr>
<td>A/B</td>
<td>1</td>
<td>Block to be buffered next</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>Block containing an H command or G43/44 command</td>
</tr>
<tr>
<td>C</td>
<td>Ignored</td>
<td>Block containing an H command Block containing a G43P_/G44P_ command</td>
</tr>
</tbody>
</table>

(2) When OFH (bit 2 of parameter No. 5001) = 1

In a mode other than tool length offset mode

<table>
<thead>
<tr>
<th>Type</th>
<th>EVO (bit 6 of parameter No. 5001)</th>
<th>Restoration block</th>
</tr>
</thead>
<tbody>
<tr>
<td>A/B</td>
<td>1</td>
<td>Block to be buffered next</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>Block containing an H command or G43/44 command</td>
</tr>
<tr>
<td>C</td>
<td>Ignored</td>
<td>Block containing an H command Block containing a G43P_/G44P_ command</td>
</tr>
</tbody>
</table>
In tool length offset mode

<table>
<thead>
<tr>
<th>Type</th>
<th>EVO (bit 6 of parameter No. 5001)</th>
<th>Restoration block</th>
</tr>
</thead>
<tbody>
<tr>
<td>A/B</td>
<td>1</td>
<td>Block containing a G43/G44 block</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>Block containing an H command and G43/44 command</td>
</tr>
<tr>
<td>C</td>
<td>Ignored</td>
<td>Block containing a G43P_H_/G44P_H_ command</td>
</tr>
</tbody>
</table>

**WARNING**

When tool length offset is applied to multiple axes, all axes for which G53, G28, G30, and G30.1 are specified are subject to cancellation. However, restoration is performed only for that axis to which tool length offset was applied last; restoration is not performed for any other axes.

**NOTE**

In a block containing G40, G41, or G42, the tool length offset vector is not restored.
14.2 AUTOMATIC TOOL LENGTH MEASUREMENT (G37)

By issuing G37 the tool starts moving to the measurement position and keeps on moving till the approach end signal from the measurement device is output. Movement of the tool is stopped when the tool tip reaches the measurement position. Difference between coordinate value when tool reaches the measurement position and coordinate value commanded by G37 is added to the tool length offset amount currently used.

Fig. 14.2 (a) Automatic tool length measurement

Format

- **G92 ip_;** Sets the workpiece coordinate system. (It can be set with G54 to G59. See Chapter 7, “Coordinate System.”)
- **H00;** Specifies an offset number for tool length offset.
- **G90 G37 ip_;** Absolute command
  - G37 is valid only in the block in which it is specified.
  - ip_ indicates the X-, Y-, Z-, or fourth axis.

Explanations

- **Setting the workpiece coordinate system**
  - Set the workpiece coordinate system so that a measurement can be made after moving the tool to the measurement position. The coordinate system must be the same as the workpiece coordinate system for programming.

- **Specifying G37**
  - Specify the absolute coordinates of the correct measurement position. Execution of this command moves the tool at the rapid traverse rate toward the measurement position, reduces the federate halfway, then continuous to move it until the approach end signal from the measuring instrument is issued. When the tool tip reaches the measurement position, the measuring instrument sends an approach end signal to the CNC which stops the tool.
• Changing the offset value

The difference between the coordinates of the position at which the tool reaches for measurement and the coordinates specified by G37 is added to the current tool length offset value.

\[
\text{Offset value} = (\text{Current compensation value}) + [(\text{Coordinates of the position at which the tool reaches for measurement}) \ - \ (\text{Coordinates specified by G37})]
\]

These offset values can be manually changed from MDI.

• Alarm

When automatic tool length measurement is executed, the tool moves as shown in Fig. 14.2 (b). If the approach end signal goes on while the tool is traveling from point B to point C, an alarm occurs. Unless the approach end signal goes on before the tool reaches point F, the same alarm occurs. The P/S alarm number is 080.

![Fig. 14.2 (b) Tool movement to the measurement position](image-url)
WARNING

When a manual movement is inserted into a movement at a measurement federate, return the tool to the position before the inserted manual movement for restart.

NOTE

1 When an H code is specified in the same block as G37, an alarm is generated. Specify H code before the block of G37.

2 The measurement speed (parameter No. 6241), deceleration position (parameter No. 6251), and permitted range of the approach end signal (parameter No. 6254) are specified by the machine tool builder.

3 When offset memory A is used, the offset value is changed. When offset memory B is used, the tool wear compensation value is changed. When offset memory C is used, the tool wear compensation value for the H code is changed.

4 The approach end signal is monitored usually every 2 ms. The following measuring error is generated:

\[ \text{ERR}_{\text{max.}} = F_m \times \frac{1}{60} \times \frac{T_S}{1000} \]

where

- \( T_S \): Sampling period, for usual 2 (ms)
- \( F_m \): measurement federate (mm/min.)

For example, when \( F_m = 1000 \text{ mm/min.} \), \( \text{ERR}_{\text{max.}} = 0.003 \text{ mm} \)

5 The tool stops a maximum of 16 ms after the approach end signal is detected. But the value of the position at which the approach end signal was detected (note the value when the tool stopped) is used to determine the offset amount. The overrun for 16 ms is:

\[ Q_{\text{max.}} = F_m \times \frac{1}{60} \times \frac{16}{1000} \]

- \( Q_{\text{max.}} \): maximum overrun (mm)
- \( F_m \): measurement federate (mm/min.)
Examples

G92 Z760.0 X1100.0 ; Sets a workpiece coordinate system with respect to the programmed absolute zero point.

G00 G90 X850.0 ; Moves the tool to X850.0. That is the tool is moved to a position that is a specified distance from the measurement position along the Z-axis.

H01 ; Specifies offset number 1.

G37 Z200.0 ; Moves the tool to the measurement position.

G00 Z204.0 ; Retracts the tool a small distance along the Z-axis.

For example, if the tool reaches the measurement position with Z198.0;., the compensation value must be corrected. Because the correct measurement position is at a distance of 200 mm, the compensation value is lessened by 2.0 mm (198.0 – 200.0 = –2.0).
14.3 TOOL OFFSET (G45–G48)

The programmed travel distance of the tool can be increased or decreased by a specified tool offset value or by twice the offset value. The tool offset function can also be applied to an additional axis.

Format

- **G45 P_D_;** Increase the travel distance by the tool offset value
- **G46 P_D_;** Decrease the travel distance by the tool offset value
- **G47 P_D_;** Increase the travel distance by twice the tool offset value
- **G48 P_D_;** Decrease the travel distance by twice the tool offset value

G45 to G48: One-shot G code for increasing or decreasing the travel distance

P: Command for moving the tool
D: Code for specifying the tool offset value
Explanations

- **Increase and decrease**

As shown in Table 14.3(a), the travel distance of the tool is increased or decreased by the specified tool offset value.

In the absolute mode, the travel distance is increased or decreased as the tool is moved from the end position of the previous block to the position specified by the block containing G45 to G48.

<table>
<thead>
<tr>
<th>G code</th>
<th>When a positive tool offset value is specified</th>
<th>When a negative tool offset value is specified</th>
</tr>
</thead>
<tbody>
<tr>
<td>G45</td>
<td><img src="image" alt="Start position" /> <img src="image" alt="End position" /></td>
<td><img src="image" alt="Start position" /> <img src="image" alt="End position" /></td>
</tr>
<tr>
<td>G46</td>
<td><img src="image" alt="Start position" /> <img src="image" alt="End position" /></td>
<td><img src="image" alt="Start position" /> <img src="image" alt="End position" /></td>
</tr>
<tr>
<td>G47</td>
<td><img src="image" alt="Start position" /> <img src="image" alt="End position" /></td>
<td><img src="image" alt="Start position" /> <img src="image" alt="End position" /></td>
</tr>
<tr>
<td>G48</td>
<td><img src="image" alt="Start position" /> <img src="image" alt="End position" /></td>
<td><img src="image" alt="Start position" /> <img src="image" alt="End position" /></td>
</tr>
</tbody>
</table>

Programmed movement distance

Tool offset value

Actual movement position

Table 14.3 (a)  Increase and decrease of the tool travel distance

If a move command with a travel distance of zero is specified in the incremental command (G91) mode, the tool is moved by the distance corresponding to the specified tool offset value.

If a move command with a travel distance of zero is specified in the absolute command (G90) mode, the tool is not moved.

- **Tool offset value**

Once selected by D code, the tool offset value remains unchanged until another tool offset value is selected.

Tool offset values can be set within the following range:

<table>
<thead>
<tr>
<th>Tool offset value</th>
<th>Metric input</th>
<th>Inch input</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to ±999.999mm</td>
<td>0 to ±999.999inch</td>
<td></td>
</tr>
<tr>
<td>0 to ±999.999deg</td>
<td>0 to ±999.999deg</td>
<td></td>
</tr>
</tbody>
</table>

D0 always indicates a tool offset value of zero.
**WARNING**

1. When G45 to G48 is specified to n axes (n=1–6) simultaneously in a motion block, offset is applied to all n axes. When the cutter is offset only for cutter radius or diameter in taper cutting, overcutting or undercutting occurs. Therefore, use cutter compensation (G40 or G42) shown in II–14.4 or 14.5.

![Diagram](image)

2. G45 to G48 (tool offset) must not be used in the G41 or G42 (cutter compensation) mode.
NOTE

1 When the specified direction is reversed by decrease as shown in the figure below, the tool moves in the opposite direction.

2 Tool offset can be applied to circular interpolation (G02, G03) with the G45 to G48 commands only for 1/4 and 3/4 circles using addresses I, J and K by the parameter setting, providing that the coordinate rotation be not specified at the same time. This function is provided for compatibility with the conventional CNC tape without any cutter compensation. The function should not be used when a new CNC program is prepared.

3 D code should be used in tool offset mode (G45 to G48). However, H code can be used by setting the parameter TPH (No. 5001#5) because of compatibility with conventional CNC tape format. The H code must be used under tool length offset cancel (G49).

4 G45 to G48 are ignored in canned cycle mode. Perform tool offset by specifying G45 to G48 before entering canned cycle mode and cancel the offset after releasing the canned cycle mode.
Examples

Program using tool offset

---

Program

N1 G91 G46 G00 X80.0 Y50.0 D01 ;
N2 G47 G01 X50.0 F120.0 ;
N3 Y40.0 ;
N4 G48 X40.0 ;
N5 Y–40.0 ;
N6 G45 X30.0 ;
N7 G45 G03 X30.0 Y30.0 J30.0 ;
N8 G45 G01 Y20.0 ;
N9 G46 X0 ;  Decreases toward the positive direction for movement amount “0”. The tool moves in the –X direction by the offset value.
N10 G46 G02 X–30.0 Y30.0 J30.0 ;
N11 G45 G01 Y0 ;  Increase toward the positive direction for movement amount “0”. The tool moves in the +Y direction by the offset value.
N12 G47 X–120.0 ;
N13 G47 Y–80.0 ;
N14 G46 G00 X80.0 Y–50.0 ;
When the tool is moved, the tool path can be shifted by the radius of the tool (Fig. 14.4).
To make an offset as large as the radius of the tool, first create an offset vector with a length equal to the radius of the tool (start–up). The offset vector is perpendicular to the tool path. The tail of the vector is on the workpiece side and the head points to the center of the tool.
If a linear interpolation, corner offset, or circular interpolation command is specified after start–up, the tool path can be shifted by the length of the offset vector during machining.
To return the tool to the start point at the end of machining, cancel the cutter compensation mode.

![Fig. 14.4 Outline of Cutter Compensation B](image-url)
### Format

- **Start up (Cutter compensation start)**

  
  \[
  \text{G00 (or G01) G41 (or G42) IP}_- IR_- H_- ;
  \]

  \[
  \text{G41 : Cutter compensation left (Group 07)}
  \]

  \[
  \text{G42 : Cutter compensation right (Group 07)}
  \]

  \[
  \text{IP}_- : \text{Command for axis movement}
  \]

  \[
  \text{IR}_- : \text{Incremental value from the end position. Perpendicular to the offset vector at the end position.}
  \]

  \[
  \text{H_- : Code for specifying the cutter compensation value (1 to 3 digits)}
  \]

- **Corner offset circular interpolation**

  \[
  \text{G39 IP}_- (or IR_-) ;
  \]

  \[
  \text{G39 : Corner offset circular interposition (Group 00)}
  \]

  \[
  \text{IP}_- (or) IR_- : \text{Incremental value from the end position. Perpendicular to the offset vector at the end position.}
  \]

- **Cutter compensation cancel**

  \[
  \text{G40 IP}_- ;
  \]

  \[
  \text{G40 : Cutter compensation cancel (Group 07)}
  \]

  \[
  \text{IP}_- : \text{Command for axis movement}
  \]

- **Selection of the offset plane**

  \[
  \begin{array}{|c|c|c|}
  \hline
  \text{Offset plane} & \text{Command of the plane selection} & \text{IP}_- & \text{IR}_- \\
  \hline
  \text{XpYp} & \text{G17 ;} & \text{Xp}_- \text{Yp}_- & \text{I}_- \text{J}_- \\
  \hline
  \text{ZpXp} & \text{G18 ;} & \text{Xp}_- \text{Zp}_- & \text{I}_- \text{K}_- \\
  \hline
  \text{YpZp} & \text{G19 ;} & \text{Yp}_- \text{Zp}_- & \text{J}_- \text{K}_- \\
  \hline
  \end{array}
  \]

### Explanations

- **H code**

  Specify the number assigned to a cutter compensation value with a 1– to 3–digit number after address H (H code) in the program. The H code can be specified in any position before the offset cancel mode is first switched to the cutter compensation mode. The H code need not be specified again unless the cutter compensation value needs to be changed.

  Assign cutter compensation values to the H codes on the MDI panel. For the specification of the cutter compensation value, see III–11.4.1 in the section on operation.

  The table below shows the range in which the cutter compensation values can be specified.

  \[
  \text{Table 14.4 Valid range of cutter compensation values}
  \]

  \[
  \begin{array}{|c|c|c|}
  \hline
  \text{Cutter compensation value} & \text{Metric input} & \text{Inch input} \\
  \hline
  0 \text{ to } \pm 999.999 \text{mm} & 0 \text{ to } \pm 99.9999 \text{inch} \\
  \hline
  \end{array}
  \]

  **NOTE**

  The cutter compensation value corresponding to offset No.0, that is, H0 always gets 0. It is impossible to set H0 to any other cutter compensation value.
Cutter compensation is carried out in the plane determined by G17, G18 and G19 (G codes for plane selection.). This plane is called the offset plane. If the offset plane is not specified, G17 is assumed to be programmed.

Compensation is not executed for the coordinates of a position which is not in the specified plane. The programmed values are used as they are. In the sequel, what vector is created, what offset calculation is made, by an offset command, will be discussed on assumption that an XY plane is selected. This discussion applies also when another plane is selected.

The offset vector is cleared by reset.

After the power is turned on, the length of the offset vector is set to zero and the cutter compensation cancel mode is selected.

**Notes**

**Transition from the offset cancel mode to the cutter compensation mode (Start up)**

**NOTE**

A move command mode at the time of change from the offset cancel mode to the cutter compensation mode, is positioning (G00) or linear interpolation (G01). The circular interpolation (G02, G03) cannot be used.
14.4.1  
Cutter Compensation  
Left (G41) 

Explanations 

- **G00 (positioning) or G01 (linear interpolation)**

G41 offsets the tool towards the left of the workpiece as you see when you face in the same direction as the movement of the cutting tool.

G41 X_ Y_ I_ J_ H_; 

specifies a new vector to be created at right angles with the direction of (I, J) on the end point, and the tool center moves toward the point of the new vector from that of the old vector on the start point. (I, J) is expressed in an incremental value from the end point, and is significant only as a direction, and its amount is arbitrary.

```
Tool center path

Old vector

New vector

Start position

(X, Y)

(I, J)

Programmed path
```

In case the old vector is 0, this command specifies the equipment to enter from the cancel mode into the cutter compensation mode. At this time, the offset number is specified by the H code.

```
Start position

Tool center path

Old vector=0

Programmed path

(X, Y)

(I, J)
```

Unless otherwise specified, (I, J) are assumed to be equal to (X, Y). When the following command is specified, a vector perpendicular to a line connecting the start position and position (X, Y) is created.

**G41 X_ Y_;**

If, however, G00 is specified, each axis moves independently at the rapid traverse rate.

```
Tool center path

Old vector

New vector

Start position

(X, Y)

Programmed path
```
G02, G03
(Circular interpolation)

G41...;

G02 (or G03) X_ Y_ R_;  

Above command specifies a new vector to be created to the left looking toward the direction in which an arc advances on a line connecting the arc center and the arc end point, and the tool center to move along the arc advancing from the point of the old vector on the arc start point toward that of the new vector. This is, however, established on assumption the old vector is created correctly.

The offset vector is created toward the arc center or opposite direction against the arc center.
14.4.2 Cutter Compensation Right (G42)

G42, contrary to G41, specifies a tool to be offset to the right of work piece looking toward the direction in which the tool advances. G42 has the same function as G41, except that the directions of the vectors created by the commands are the opposite.

Explanations

- G00 (positioning) or G01 (linear interpolation)

G42, contrary to G41, specifies a tool to be offset to the right of work piece looking toward the direction in which the tool advances. G42 has the same function as G41, except that the directions of the vectors created by the commands are the opposite.

In the case of G00, however, each axis moves independently at the rapid traverse rate.
- **G02 or G03** (Circular interpolation)

  G42… ;
  
  :  
  G02 (or G03) X_ Y_ R_;
14.4.3 Corner Offset Circular Interpolation (G39)

When the following command is specified in the G01, G02, or G03 mode, corner offset circular interpolation can be executed with respect to the radius of the tool.

Format

In offset mode

\[
\text{G39} \begin{cases} 
X & Y \\
X & Z \\
Y & Z 
\end{cases} ; \\
or \\
\text{G39} \begin{cases} 
I & J \\
I & K \\
J & K 
\end{cases} ; 
\]

A new vector is created to the left (G41) or to the right (G42) looking toward (X, Y) from the end point at right angles therewith, and the tool moves along the arc from the point of the old vector toward that of the new vector. (X, Y, Z) is expressed in a value according to the G90/G91 respectively. (I, J, K) is expressed in an incremental value from the end point.

This command can be given in offset mode, that is, only when G41 or G42 has already been specified. Whether the arc is to turn clockwise or counterclockwise, is defined by G41 or G42, respectively. This command is not modal, and executes circular interpolation, whatever the G function of group 01 may be. The G function of group 01 remains even though this command is specified.
14.4.4 Cutter Compensation Cancel (G40)

When the following command is specified in the G00 or G01 mode, the tool moves from the head of the old vector at the start position to the end position (X, Y). In the G01 mode, the tool moves linearly. In the G00 mode, rapid traverse is carried out along each axis.

\[ \text{G40 X}_-\text{Y}_-; \]

This command changes the mode of the equipment from the cutter compensation mode to the cancel mode.

When only G40; is specified, and X Y is not specified, the tool moves by the old vector amount in the opposite direction.

**NOTE**

Cutter compensation cannot be canceled in the circular interpolation (G02, G03) mode.
14.4.5
Switch between Cutter Compensation Left and Cutter Compensation Right

The offset direction is switched from left to right, or from right to left generally through the offset cancel mode, but can be switched not through it only in positioning (G00) or linear interpolation (G01). In this case, the tool path is as shown in Fig 14.4.5.

![Diagram of tool path and vector directions](image-url)

Fig. 14.4.5 Switching the Direction of Cutter Compensation
14.4.6 Change of the Cutter Compensation Value

The offset amount is changed generally when the tool is changed in the offset cancel mode, but can be changed in the offset mode only in positioning (G00) or linear interpolation (G01).

Program as described below:

**G00 (or G01) X_ Y_ H_ ;** (H_ indicates the number of a new cutter compensation value.)

Fig. 14.4.6 shows how the tool is moved when the change in compensation is specified.

![Fig 14.4.6 Change of the cutter compensation value in offset mode](image-url)
14.4.7 Positive/Negative Cutter Compensation Value and Tool Center Path

If the tool compensation value is made negative (−), it is equal that G41 and G42 are replaced with each other in the process sheet. Consequently, if the tool center is passing around the outside of the workbench it will pass around the inside thereof, and vice versa.

Fig. 14.4.7 shows one example. Generally speaking, the cutter compensation value shall be programmed to be positive (+). When a tool path is programmed as shown in (1), if the cutter compensation value is made negative (−), the tool center moves as shown in (2).

If the cutter compensation value is changed to a negative value when tool path (2) shown in Fig. 14.4.7 is programmed, the tool follows tool path (1) shown in the same figure.

---

**Fig. 14.4.7 Tool Center Paths when Positive and Negative Cutter Compensation Values are Specified**

For a cornered figure (involved in corner circular interpolation) in general, the cutter compensation value naturally cannot be made negative (−) to cut the inside. In order to cut the inside corner of a cornered figure, an arc with an appropriate radius must be inserted there to provide smooth cutting.

---

**WARNING**

If the tool length offset is commanded during cutter compensation, the offset amount of cutter compensation is also regarded to have been changed.
Examples

N1 G91 G17 G00 G41 J1 X20.0 Y20.0 H08 ;
N2 G01 Z–25.0 F100 ;
N3 Y40.0 F250 ;
N4 G39 I40.0 J20.0 ;
N5 X40.0 Y20.0 ;
N6 G39 I40.0 ;
N7 G02 X40.0 Y–40.0 R40.0 ;
N8 X–20.0 Y–20.0 R20.0 ;
N9 G01 X–60.0 ;
N10 G00 Z25.0 ;
N11 G40 X–20.0 Y–20.0 M02 ;

(H08 is a tool offset number, and the cutter radius value should be stored in the memory corresponding to this number).
14.5
OVERVIEW OF CUTTER COMPENSATION C (G40–G42)

When the tool is moved, the tool path can be shifted by the radius of the tool (Fig. 14.5 (a)). To make an offset as large as the radius of the tool, CNC first creates an offset vector with a length equal to the radius of the tool (start–up). The offset vector is perpendicular to the tool path. The tail of the vector is on the workpiece side and the head positions to the center of the tool. If a linear interpolation or circular interpolation command is specified after start–up, the tool path can be shifted by the length of the offset vector during machining.

To return the tool to the start position at the end of machining, cancel the cutter compensation mode.

![Fig. 14.5 (a) Outline of Cutter Compensation C](image-url)
Format

- **Start up**
  (Tool compensation start)

  \[
  \text{G00 (or G01, G41 or G42)} \quad \text{IP}_- \text{ D}_- ; \\
  \text{G41} : \text{Cutter compensation left (Group07)} \\
  \text{G42} : \text{Cutter compensation right (Group07)} \\
  \text{IP}_- : \text{Command for axis movement} \\
  \text{D}_- : \text{Code for specifying as the cutter compensation value (1–3 digits) (D code)}
  \]

- **Cutter compensation cancel**
  (offset mode cancel)

  \[
  \text{G40} ; \\
  \text{G40} : \text{Cutter compensation cancel (Group 07)} \\
  \text{IP}_- : \text{Command for axis movement}
  \]

- **Selection of the offset plane**

<table>
<thead>
<tr>
<th>Offset plane</th>
<th>Command for plane selection</th>
<th>IP_-</th>
</tr>
</thead>
<tbody>
<tr>
<td>XpYp</td>
<td>G17 ;</td>
<td>Xp_Yp_-</td>
</tr>
<tr>
<td>ZpXp</td>
<td>G18 ;</td>
<td>Xp_Zp_-</td>
</tr>
<tr>
<td>YpZp</td>
<td>G19 ;</td>
<td>Yp_Zp_-</td>
</tr>
</tbody>
</table>

Explanations

- **Offset cancel mode**

  At the beginning when power is applied the control is in the cancel mode. In the cancel mode, the vector is always 0, and the tool center path coincides with the programmed path.

- **Start Up**

  When a cutter compensation command (G41 or G42, nonzero dimension words in the offset plane, and D code other than D0) is specified in the offset cancel mode, the CNC enters the offset mode. Moving the tool with this command is called start–up. Specify positioning (G00) or linear interpolation (G01) for start–up. If circular interpolation (G02, G03) is specified, P/S alarm 34 occurs. When processing the start–up block and subsequent blocks, the CNC prereads two blocks.

- **Offset mode**

  In the offset mode, compensation is accomplished by positioning (G00), linear interpolation (G01), or circular interpolation (G02, G03). If two or more blocks that do not move the tool (miscellaneous function, dwell, etc.) are processed in the offset mode, the tool will make either an excessive or insufficient cut. If the offset plane is switched in the offset mode, P/S alarm 37 occurs and the tool is stopped.
• Offset mode cancel

In the offset mode, when a block which satisfies any one of the following conditions is executed, the CNC enters the offset cancel mode, and the action of this block is called the offset cancel.

1. **G40 has been commanded.**
2. **0 has been commanded as the offset number for cutter compensation.**

When performing offset cancel, circular arc commands (G02 and G03) are not available. If a circular arc is commanded, an P/S alarm (No. 034) is generated and the tool stops.

In the offset cancel, the control executes the instructions in that block and the block in the cutter compensation buffer. In the meantime, in the case of a single block mode, after reading one block, the control executes it and stops. By pushing the cycle start button once more, one block is executed without reading the next block.

Then the control is in the cancel mode, and normally, the block to be executed next will be stored in the buffer register and the next block is not read into the buffer for cutter compensation.

![Fig. 14.5 (b) Changing the offset mode](image)

• Change of the Cutter compensation value

In general, the cutter compensation value shall be changed in the cancel mode, when changing tools. If the cutter compensation value is changed in offset mode, the vector at the end point of the block is calculated for the new cutter compensation value.

![Fig. 14.5 (c) Changing the Cutter Compensation Value](image)
• Positive/negative cutter compensation value and tool center path

If the offset amount is negative (−), distribution is made for a figure in which G41’s and G42’s are all replaced with each other on the program. Consequently, if the tool center is passing around the outside of the workpiece, it will pass around the inside, and vice versa. The figure below shows one example. Generally, the offset amount is programmed to be positive (+). When a tool path is programmed as in ((1)), if the offset amount is made negative (−), the tool center moves as in ((2)), and vice versa. Consequently, the same tape permits cutting both male and female shapes, and any gap between them can be adjusted by the selection of the offset amount. Applicable if start-up and cancel is A type. (See II–14.6.2 and 14.6.4)

![Tool Center Paths when Positive and Negative Cutter Compensation Values are Specified](image)

• Cutter compensation value setting

Assign a cutter compensation values to the D codes on the MDI panel. The table below shows the range in which cutter compensation values can be specified.

<table>
<thead>
<tr>
<th>Cutter compensation value</th>
<th>mm input</th>
<th>inch input</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to ±999.999mm</td>
<td>0 to ±99.9999inch</td>
<td></td>
</tr>
</tbody>
</table>

**NOTE**
1. The cutter compensation value corresponding to offset No. 0, that is, D0 always means 0. It is impossible to set D0 to any other offset amount.
2. Cutter compensation C can be specified by H code with parameter OFH (No. 5001 #2) set to 1.

• Offset vector

The offset vector is the two dimensional vector that is equal to the cutter compensation value assigned by D code. It is calculated inside the control unit, and its direction is up–dated in accordance with the progress of the tool in each block. The offset vector is deleted by reset.

• Specifying a cutter compensation value

Specify a cutter compensation value with a number assigned to it. The number consists of 1 to 3 digits after address D (D code). The D code is valid until another D code is specified. The D code is used to specify the tool offset value as well as the cutter compensation value.
Offset calculation is carried out in the plane determined by G17, G18 and G19, (G codes for plane selection). This plane is called the offset plane. Compensation is not executed for the coordinate of a position which is not in the specified plane. The programmed values are used as they are. In simultaneous 3 axes control, the tool path projected on the offset plane is compensated. The offset plane is changed during the offset cancel mode. If it is performed during the offset mode, a P/S alarm (No. 37) is displayed and the machine is stopped.
Examples

G92 X0 Y0 Z0 ; Specifies absolute coordinates. The tool is positioned at the start position (X0, Y0, Z0).
N1 G90 G17 G00 G41 D07 X250.0 Y550.0 ; Starts cutter compensation (start–up). The tool is shifted to the left of the programmed path by the distance specified in D07. In other words the tool path is shifted by the radius of the tool (offset mode) because D07 is set to 15 beforehand (the radius of the tool is 15 mm).

N2 G01 Y900.0 F150 ; Specifies machining from P1 to P2.
N3 X450.0 ; Specifies machining from P2 to P3.
N4 G03 X500.0 Y1150.0 R650.0 ; Specifies machining from P3 to P4.
N5 G02 X900.0 R–250.0 ; Specifies machining from P4 to P5.
N6 G03 X950.0 Y900.0 R650.0 ; Specifies machining from P5 to P6.
N7 G01 X1150.0 ; Specifies machining from P6 to P7.
N8 Y550.0 ; Specifies machining from P7 to P8.
N9 X700.0 Y650.0 ; Specifies machining from P8 to P9.
N10 X250.0 Y550.0 ; Specifies machining from P9 to P1.
N11 G00 G40 X0 Y0 ; Cancels the offset mode. The tool is returned to the start position (X0, Y0, Z0).
This section provides a detailed explanation of the movement of the tool for cutter compensation C outlined in Section 14.5. This section consists of the following subsections:

14.6.1 General
14.6.2 Tool Movement in Start-up
14.6.3 Tool Movement in Offset Mode
14.6.4 Tool Movement in Offset Mode Cancel
14.6.5 Interference Check
14.6.6 Over cutting by Cutter Compensation
14.6.7 Input command from MDI
14.6.8 G53,G28,G30 and G29 commands in cutter compensation C mode
14.6.9 Corner Circular Interpolation (G39)

14.6.1 General

• Inner side and outer side

When an angle of intersection created by tool paths specified with move commands for two blocks is over 180°, it is referred to as “inner side.” When the angle is between 0° and 180°, it is referred to as “outer side.”

• Meaning of symbols

The following symbols are used in subsequent figures:

– \( S \) indicates a position at which a single block is executed once.
– \( SS \) indicates a position at which a single block is executed twice.
– \( SSS \) indicates a position at which a single block is executed three times.
– \( L \) indicates that the tool moves along a straight line.
– \( C \) indicates that the tool moves along an arc.
– \( r \) indicates the cutter compensation value.
– An intersection is a position at which the programmed paths of two blocks intersect with each other after they are shifted by \( r \).
– \( \odot \) indicates the center of the tool.
14.6.2 Tool Movement in Start–up

Explanations

- Tool movement around an inner side of a corner \((180^\circ \leq \alpha)\)

When the offset cancel mode is changed to offset mode, the tool moves as illustrated below (start–up):
Tool path in start-up has two types A and B, and they are selected by parameter SUP (No. 5003#0).

- **Tool movement around the outside of a corner at an obtuse angle**
  \(90^\circ \leq \alpha < 180^\circ\)
Tool path in start-up has two types A and B, and they are selected by parameter SUP (No.5003#0).

- **Tool movement around the outside of an acute angle** ($\alpha<90^\circ$)

- **Tool movement around the outside linear→linear at an acute angle less than 1 degree** ($\alpha<1^\circ$)
A block without tool movement specified at start-up

If the command is specified at start-up, the offset vector is not created.

```
G91 G40 ... ;
N6 X100.0 Y100.0 ;
N7 G41 X0 ;
N8 Y-100.0 ;
N9 Y-100.0 X100.0 ;
```

**NOTE**
For the definition of blocks that do not move the tool, see II–14.6.3.
14.6.3 Tool Movement in Offset Mode

Explanations

- Tool movement around the inside of a corner ($180^\circ \leq \alpha$)

In the offset mode, the tool moves as illustrated below:
• Tool movement around the inside ($\alpha < 1^\circ$) with an abnormally long vector, linear $\rightarrow$ linear

Also in case of arc to straight line, straight line to arc and arc to arc, the reader should infer in the same procedure.
• Tool movement around the outside corner at an obtuse angle \((90^\circ \leq \alpha < 180^\circ)\)
• Tool movement around the outside corner at an acute angle ($\alpha<90^\circ$)
When it is exceptional

End position for the arc is not on the arc

If the end of a line leading to an arc is programmed as the end of the arc by mistake as illustrated below, the system assumes that cutter compensation has been executed with respect to an imaginary circle that has the same center as the arc and passes the specified end position. Based on this assumption, the system creates a vector and carries out compensation. The resulting tool center path is different from that created by applying cutter compensation to the programmed path in which the line leading to the arc is considered straight.

The same description applies to tool movement between two circular paths.

There is no inner intersection

If the cutter compensation value is sufficiently small, the two circular tool center paths made after compensation intersect at a position (P). Intersection P may not occur if an excessively large value is specified for cutter compensation. When this is predicted, P/S alarm No.033 occurs at the end of the previous block and the tool is stopped. In the example shown below, tool center paths along arcs A and B intersect at P when a sufficiently small value is specified for cutter compensation. If an excessively large value is specified, this intersection does not occur.
If the center of the arc is identical with the start position or end point, P/S alarm (No. 038) is displayed, and the tool will stop at the end position of the preceding block.

```
N5 G01 X100.0 ;
N6 G02 X100.0 I0 J0 ;
N7 G03 Y-100.0 J-100.0 ;
```

The offset direction is decided by G codes (G41 and G42) for cutter radius and the sign of cutter compensation value as follows.

<table>
<thead>
<tr>
<th>Gcode</th>
<th>Sign of offset amount</th>
<th>+</th>
<th>-</th>
</tr>
</thead>
<tbody>
<tr>
<td>G41</td>
<td>Left side offset</td>
<td>Right side offset</td>
<td></td>
</tr>
<tr>
<td>G42</td>
<td>Right side offset</td>
<td>Left side offset</td>
<td></td>
</tr>
</tbody>
</table>

The offset direction can be changed in the offset mode. If the offset direction is changed in a block, a vector is generated at the intersection of the tool center path of that block and the tool center path of a preceding block. However, the change is not available in the start-up block and the block following it.
Tool center path with an intersection

Linear→Linear

Linear→Circular

Circular→Linear

Circular→Circular
When changing the offset direction in block A to block B using G41 and G42, if intersection with the offset path is not required, the vector normal to block B is created at the start point of block B.
Normally there is almost no possibility of generating this situation. However, when G41 and G42 are changed, or when a G40 was commanded with address I, J, and K this situation can occur. In this case of the figure, the cutter compensation is not performed with more than one circle circumference: an arc is formed from P1 to P2 as shown. Depending on the circumstances, an alarm may be displayed due to the "Interference Check" described later. To execute a circle with more than one circumference, the circle must be specified in segments.

```
N5 G01 G91 X500.0 Y=-700.0 ;
N6 G41 G02 J=-500.0 ;
N7 G42 G01 X500.0 Y700.0 ;
```
### Temporary cutter compensation cancel

If the following command is specified in the offset mode, the offset mode is temporarily canceled then automatically restored. The offset mode can be canceled and started as described in II–15.6.2 and 15.6.4.

### Specifying G28 (automatic return to the reference position) in the offset mode

If G28 is specified in the offset mode, the offset mode is canceled at an intermediate position. If the vector still remains after the tool is returned to the reference position, the components of the vector are reset to zero with respect to each axis along which reference position return has been made.

### Specifying G29 (automatic return from the reference position) in the offset mode

If G29 is commanded in the offset mode, the offset will be cancelled at the intermediate point, and the offset mode will be restored automatically from the subsequent block.
• **Cutter compensation G code in the offset mode**

The offset vector can be set to form a right angle to the moving direction in the previous block, irrespective of machining inner or outer side, by commanding the cutter compensation G code (G41, G42) in the offset mode, independently. If this code is specified in a circular command, correct circular motion will not be obtained.

When the direction of offset is expected to be changed by the command of cutter compensation G code (G41, G42), refer to Subsec.15.6.3.

![Linear→Linear](image1)

![Circular→Linear](image2)

• **Command cancelling the offset vector temporarily**

During offset mode, if G92 (absolute zero point programming) is commanded, the offset vector is temporarily cancelled and thereafter offset mode is automatically restored.

In this case, without movement of offset cancel, the tool moves directly from the intersecting point to the commanded point where offset vector is canceled. Also when restored to offset mode, the tool moves directly to the intersecting point.

```
G92 block(G41)
N5 G91 G01 X300.0 Y700.0 ;
N6 X–300.0 Y600.0 ;
N7 G92 X100.0 Y200.0 ;
N8 G90 G01 X400.0 Y800.0 ;
```
• A block without tool movement

The following blocks have no tool movement. In these blocks, the tool will not move even if cutter compensation is effected.

```
M05 ; M code output
S21 ; S code output
G04 X10.0 ; Dwell
G10 L11 P01 R10.0 ; Cutter compensation value setting
(G17) Z200.0 ; Move command not included in the offset plane.
G90 ; G code only
G91 X0 ; Move distance is zero.
```

Commands (1) to (6) are of no movement.

A block without tool movement specified in offset mode

When a single block without tool movement is commanded in the offset mode, the vector and tool center path are the same as those when the block is not commanded. This block is executed at the single block stop point.

```
N6 G91 X100.0 Y100.0 ;
N7 G04 X100.0 ;
N8 X100.0 ;
```

Programmed path

Tool center path

Block N7 is executed here.

However, when the move distance is zero, even if the block is commanded singly, tool motion becomes the same as that when more than one block of without tool movement are commanded, which will be described subsequently.

```
N6 G91 X100.0 Y100.0 ;
N7 X0 ;
N8 X100.0 ;
```

Programmed path

Tool center path

Two blocks without tool movement should not be commanded consecutively. If commanded, a vector whose length is equal to the offset value is produced in a normal direction to tool motion in earlier block, so overcutting may result.

```
N6 G91 X100.0 Y100.0 ;
N7 S21 ;
N8 G04 X10.0 ;
N9 X100.0 ;
```

Programmed path

Tool center path

Blocks N7 and N8 are executed here.
• **Corner movement**

When two or more vectors are produced at the end of a block, the tool moves linearly from one vector to another. This movement is called the corner movement.

If these vectors almost coincide with each other, the corner movement isn’t performed and the latter vector is ignored.

If \( \Delta V_x \leq \Delta V_{\text{Limit}} \) and \( \Delta V_y \leq \Delta V_{\text{Limit}} \), the latter vector is ignored. The \( \Delta V_{\text{Limit}} \) is set in advance by parameter (No. 5010).

If these vectors do not coincide, a move is generated to turn around the corner. This move belongs to the latter block.

However, if the path of the next block is semicircular or more, the above function is not performed.

The reason for this is as follows:
If the vector is not ignored, the tool path is as follows:
$P_1 \rightarrow P_2 \rightarrow P_3 \rightarrow \text{(Circle)} \rightarrow P_4 \rightarrow P_5 \rightarrow P_6$
But if the distance between $P_2$ and $P_3$ is negligible, the point $P_3$ is ignored. Therefore, the tool path is as follows:
$P_2 \rightarrow P_4$
Namely, circle cutting by the block N6 is ignored.

**Interruption of manual operation**

For manual operation during the cutter compensation, refer to Section III–3.5, "Manual Absolute ON and OFF.”
14.6.4
Tool Movement in Offset Mode Cancel

Explanations

- Tool movement around an inside corner ($180^\circ \leq \alpha$)
• Tool movement around an outside corner at an obtuse angle \( (90^\circ \leq \alpha < 180^\circ) \)

Tool path has two types, A and B; and they are selected by parameter SUP (No. 5003#0).

- **Type A**
  - Linear→Linear
    - Workpiece
    - Programmed path
    - Tool center path

- **Type B**
  - Circular→Linear
    - Workpiece
    - Programmed path
    - Tool center path

- **Type A**
  - Circular→Linear
    - Workpiece
    - Programmed path
    - Tool center path

- **Type B**
  - Linear→Linear
    - Workpiece
    - Programmed path
    - Tool center path
    - Intersection

- **Type B**
  - Circular→Linear
    - Workpiece
    - Programmed path
    - Tool center path
    - Intersection
Tool path has two types, A and B, and they are selected by parameter SUP (No. 5003#0).

- Tool movement around an outside corner at an acute angle ($\alpha < 90^\circ$)
• Tool movement around the outside linear→linear at an acute angle less than 1 degree ($\alpha < 1^\circ$)

![Diagram of tool movement]

• A block without tool movement specified together with offset cancel

When a block without tool movement is commanded together with an offset cancel, a vector whose length is equal to the offset value is produced in a normal direction to tool motion in the earlier block, the vector is cancelled in the next move command.

```
N6 G91 X100.0 Y100.0 ;
N7 G40 ;
N8 X100.0 Z0 ;
```

![Diagram of compensated movement]
If a G41 or G42 block precedes a block in which G40 and I, J, K are specified, the system assumes that the path is programmed as a path from the end position determined by the former block to a vector determined by (I, J), (I, K), or (J, K). The direction of compensation in the former block is inherited.

In this case, note that the CNC obtains an intersection of the tool path irrespective of whether inner or outer side machining is specified.

When an intersection is not obtainable, the tool comes to the normal position to the previous block at the end of the previous block.
In the example shown below, the tool does not trace the circle more than once. It moves along the arc from P1 to P2. The interference check function described in II–15.6.5 may raise an alarm.

To make the tool trace a circle more than once, program two or more arcs.
Tool overcutting is called interference. The interference check function checks for tool overcutting in advance. However, all interference cannot be checked by this function. The interference check is performed even if overcutting does not occur.

**14.6.5 Interference Check**

**Explanations**

- **Criteria for detecting interference**

  1. The direction of the tool path is different from that of the programmed path (from 90 degrees to 270 degrees between these paths).
(2) In addition to the condition (1), the angle between the start point and end point on the tool center path is quite different from that between the start point and end point on the programmed path in circular machining (more than 180 degrees).

```
(G41)
N5 G01 G91 X800.0 Y200.0 D1 ;
N6 G02 X320.0 Y-160.0 I-200.0 J-800.0 D2 ;
N7 G01 X200.0 Y-500.0 ;
```

(Tool compensation value corresponding to D1 : \( r_1 = 200.0 \))
(Tool compensation value corresponding to D2 : \( r_2 = 600.0 \))

In the above example, the arc in block N6 is placed in the one quadrant. But after cutter compensation, the arc is placed in the four quadrants.
(1) Removal of the vector causing the interference

When cutter compensation is performed for blocks A, B and C and vectors V1, V2, V3 and V4 between blocks A and B, and V5, V6, V7 and V8 between B and C are produced, the nearest vectors are checked first. If interference occurs, they are ignored. But if the vectors to be ignored due to interference are the last vectors at the corner, they cannot be ignored.

Check between vectors V4 and V5
   Interference —— V4 and V5 are ignored.

Check between V3 and V6
   Interference —— V3 and V6 are ignored

Check between V2 and V7
   Interference —— V2 and V7 are Ignored

Check between V1 and V8
   Interference —— V1 and V8 are cannot be ignored

If while checking, a vector without interference is detected, subsequent vectors are not checked. If block B is a circular movement, a linear movement is produced if the vectors are interfered.

(Example 1) The tool moves linearly from V1 to V8

V4, V5 : Interference
V3, V6 : Interference
V2, V7 : Interference
V1, V8 : No Interference
(Example 2) The tool moves linearly from V₁, V₂, V₇, to V₈

(2) If the interference occurs after correction (1), the tool is stopped with an alarm.
If the interference occurs after correction (1) or if there are only one pair of vectors from the beginning of checking and the vectors interfere, the P/S alarm (No.41) is displayed and the tool is stopped immediately after execution of the preceding block. If the block is executed by the single block operation, the tool is stopped at the end of the block.

After ignoring vectors V₂ and V₅ because of interference, interference also occurs between vectors V₁ and V₆. The alarm is displayed and the tool is stopped.
• When interference is assumed although actual interference does not occur

(1) Depression which is smaller than the cutter compensation value

There is no actual interference, but since the direction programmed in block B is opposite to that of the path after cutter compensation the tool stops and an alarm is displayed.

(2) Groove which is smaller than the cutter compensation value

Like (1), P/S alarm is displayed because of the interference as the direction is reverse in block B.
14.6.6 Overcutting by Cutter Compensation

Explanations

- **Machining an inside corner at a radius smaller than the cutter radius**

  When the radius of a corner is smaller than the cutter radius, because the inner offsetting of the cutter will result in overcuttings, an alarm is displayed and the CNC stops at the start of the block. In single block operation, the overcutting is generated because the tool is stopped after the block execution.

- **Machining a groove smaller than the tool radius**

  Since the cutter compensation forces the path of the center of the tool to move in the reverse of the programmed direction, overcutting will result. In this case an alarm is displayed and the CNC stops at the start of the block.
When machining of the step is commanded by circular machining in the case of a program containing a step smaller than the tool radius, the path of the center of tool with the ordinary offset becomes reverse to the programmed direction. In this case, the first vector is ignored, and the tool moves linearly to the second vector position. The single block operation is stopped at this point. If the machining is not in the single block mode, the cycle operation is continued. If the step is of linear, no alarm will be generated and cut correctly. However uncut part will remain.

It is usually used such a method that the tool is moved along the Z axis after the cutter compensation is effected at some distance from the workpiece at the start of the machining.

In the program example above, when executing block N1, blocks N3 and N6 are also entered into the buffer storage, and by the relationship among them the correct compensation is performed as in the figure above. Then, if the block N3 (move command in Z axis) is divided as follows: As there are two move command blocks not included in the selected plane and the block N6 cannot be entered into the buffer storage, the tool center path is calculated by the information of N1 in the figure above. That is, the offset vector is not calculated in start–up and the overcutting may result.
The above example should be modified as follows:

```
N1 G91 G00 G41 X500.0 Y500.0 D1 ;
N3 G01 Z–250.0 ;
N5 G01 Z–50.0 F100 ;
N6 Y1000.0 F200 ;
```

The move command in the same direction as that of the move command after the motion in Z axis should be programmed.

```
N1 G91 G00 G41 X500.0 Y400.0 D1 ;
N2 Y100.0 ;
N3 Z–250.0 ;
N5 G01 Z–50.0 F100 ;
N6 Y1000.0 F200 ;
```

As the block with sequence No. N2 has the move command in the same direction as that of the block with sequence No. N6, the correct compensation is performed.
Cutter compensation C is not performed for commands input from the MDI. However, when automatic operation using the absolute commands is temporarily stopped by the single block function, MDI operation is performed, then automatic operation starts again, the tool path is as follows:

In this case, the vectors at the start position of the next block are translated and the other vectors are produced by the next two blocks. Therefore, from next block but one, cutter compensation C is accurately performed.

When position $P_A$, $P_B$, and $P_C$ are programmed in an absolute command, tool is stopped by the single block function after executing the block from $P_A$ to $P_B$ and the tool is moved by MDI operation. Vectors $V_{B1}$ and $V_{B2}$ are translated to $V_{B1}'$ and $V_{B2}'$ and offset vectors are recalculated for the vectors $V_{C1}$ and $V_{C2}$ between block $P_B$–$P_C$ and $P_C$–$P_D$. However, since vector $V_{B2}$ is not calculated again, compensation is accurately performed from position $P_C$. 
A function has been added which performs positioning by automatically canceling a cutter compensation vector when G53 is specified in cutter compensation C mode, then automatically restoring that cutter compensation vector with the execution of the next move command. The cutter compensation vector restoration mode is of FS16 type when CCN (bit 2 of parameter No. 5003) is set to 0; it is of FS15 type when CCN is set to 1.

When G28, G30, or G30.1 is specified in cutter compensation C mode, automatic reference position return is performed by automatically canceling a cutter compensation vector, that cutter compensation vector automatically being restored with the execution of the next move command. In this case, the timing and format of cutter compensation vector cancellation/restoration, performed when CCN (bit 2 of parameter No. 5003) is set to 1, are changed to FS15 type.
When CCN (bit 2 of parameter No. 5003) is set to 0, the conventional specification remains applicable.

When G29 is specified in cutter compensation C mode, the cutter compensation vector is automatically canceled/restored. In this case, the timing and format of cutter compensation vector cancellation/restoration, performed when CCN (bit 2 of parameter No. 5003) is set to 1, are changed to FS15 type.
When CCN (bit 2 of parameter No. 5003) is set to 0, the conventional specification remains applicable.

Explanations

• **G53 command in cutter compensation C mode**

When G53 is specified in cutter compensation C mode, the previous block generates a vector that is perpendicular to the move direction and which has the same magnitude as the offset value. Then, the offset vector is canceled when movement to a specified position is performed in the machine coordinate system. In the next block, offset mode is automatically resumed.

Note that cutter compensation vector restoration is started when CCN (bit 2 of parameter No. 5003) is set to 0; when CCN is set to 1, an intersection vector is generated (FS15 type).
(1) G53 specified in offset mode
When CCN (bit 2 of parameter No.5003)=0

When CCN (bit 2 of parameter No.5003)=1

(2) Incremental G53 specified in offset mode
When CCN (bit 2 of parameter No.5003)=0
When CCN (bit2 of parameter No.5003)=1

(3) G53 specified in offset mode with no movement specified

When CCN (bit2 of parameter No.5003)=0

When CCN (bit2 of parameter No.5003)=1
WARNING

1 When cutter compensation C mode is set and all–axis machine lock is applied, the G53 command does not perform positioning along the axes to which machine lock is applied. The vector, however, is preserved. When CCN (bit 2 of parameter No. 5003) is set to 0, the vector is canceled. (Note that even if the FS15 type is used, the vector is canceled when each–axis machine lock is applied.)

Example 1: When CCN (bit 2 of parameter No. 5003) = 0, type A is used, and all–axis machine lock is applied

Example 2: When CCN (bit 2 of parameter No. 5003) = 1 and all–axis machine lock is applied [FS15 type]

Example 3: When CCN (bit 2 of parameter No. 5003) = 1 and specified–axis machine lock is applied [FS15 type]

2 When G53 is specified for a compensation axis in cutter compensation mode, the vectors along the other axes are also canceled. (This also applies when CCN (bit 2 of parameter No.5003) is set to 1. When the FS15 type is used, only the vector along a specified axis is canceled. Note that the FS15 type cancellation differs from the actual FS15 specification in this point.)

Example: When CCN (bit 2 of parameter No.5003)=1[FS 15 type]
NOTE
1 When a G53 command specifies an axis that is not in the cutter compensation C plane, a perpendicular vector is generated at the end point of the previous block, and the tool does not move. In the next block, offset mode is automatically resumed (in the same way as when two or more continuous blocks do not specify any move commands).

Example: When CCN (bit 2 of parameter No. 5003) = 0, and type A is used

2 When a G53 block is specified to become a start–up block, the next block actually becomes the start–up block. When CCN (bit 2 of parameter No. 5003) is set to 1, an intersection vector is generated.

Example: When CCN (bit 2 of parameter No. 5003) = 0 and type A is used
When G28, G30, or G30.1 is specified in cutter compensation C mode, an operation of FS15 type is performed if CCN (bit 2 of parameter No. 5003) is set to 1.

This means that an intersection vector is generated in the previous block, and a perpendicular vector is generated at an intermediate position. Offset vector cancellation is performed when movement is made from the intermediate position to the reference position. As part of restoration, an intersection vector is generated between a block and the next block.

(1) G28, G30, or G30.1, specified in offset mode (with movement to both an intermediate position and reference position performed)

(a) For return by G29

When CCN (bit 2 of parameter No. 5003) = 0

```
oxxxx;  
G91G41_ _ _;  
G28X40.Y0 ;  
G29X45.Y15. ;  
G29              
```

\[\text{[Type A]}\]

Intermediate position G28/30/30.1

Return position G01

G29

Reference position or floating reference position

\[\text{[Type B]}\]

Intermediate position G28/30/30.1

Return position G01

G29

Reference position or floating reference position

• G29 command in cutter compensation C mode

When CCN (bit 2 of parameter No. 5003) = 1

```
[FS15 Type]  
Intermediate position G28/30/30.1  
(G42G01)  
```

\[\text{Return position G01}\]

G29

Reference position or floating reference position
(b) For return by G00
When CCN (bit 2 of parameter No. 5003) = 0

When CCN (bit 2 of parameter No. 5003) = 1

(2) G28, G30, or G30.1, specified in offset mode (with movement to an intermediate position not performed)

(a) For return by G29
When CCN (bit 2 of parameter No. 5003) = 0
When CCN (bit 2 of parameter No. 5003) = 1

(b) For return by G00
When CCN (bit 2 of parameter No. 5003)=0

When CCN (bit 2 of parameter No. 5003)=1
(3) G28, G30, or G30.1, specified in offset mode
(with movement to a reference position not performed)
(a) For return by G29
When CCN (bit 2 of parameter No.5003)=0

When CCN (bit 2 of parameter No.5003)=1

(b) For return by G00
When CCN (bit 2 of parameter No.5003)=0

When CCN (bit 2 of parameter No.5003)=1
(4) G28, G30, or G30.1 specified in offset mode (with no movement performed)

(a) For return by G29
When CCN (bit 2 of parameter No.5003)=0

(b) For return by G00
When CCN (bit 2 of parameter No.5003)=0
When CCN (bit 2 of parameter No.5003) = 1

![Diagram showing G28/30/30.1 commands with FS15 Type]

**WARNING**

1. When a G28, G30, or G30.1 command is specified during all-axis machine lock, a perpendicular offset vector is applied at the intermediate position, and movement to the reference position is not performed; the vector is preserved. Note, however, that even if the FS15 type is used, the vector is canceled only when each-axis machine lock is applied. (The FS15 type preserves the vector even when each-axis machine lock is applied.)

   **Example 1:** When CCN (bit 2 of parameter No.5003) = 1 and all-axis machine lock is applied

![Diagram for Example 1]

   **Example 2:** When CCN (bit 2 of parameter No.5003) = 1 and each-axis machine lock is applied

![Diagram for Example 2]

2. When G28, G30, or G30.1 is specified for a compensation axis in cutter compensation mode, the vectors along the other axes are also canceled. (This also applies when CCN (bit 2 of parameter No. 5003) is set to 1. When the FS15 type is used, only the vector along a specified axis is canceled. Note that the FS15 type cancellation differs from the actual FS15 specification in this point.)

   **Example:** When CCN (bit 2 of parameter No.5003) = 1

![Diagram for Example with G28]
NOTE

1 When a G28, G30, or G30.1 command specifies an axis that is not in the cutter compensation C plane, a perpendicular vector is generated at the end point of the previous block, and the tool does not move. In the next block, offset mode is automatically resumed (in the same way as when two or more continuous blocks do not specify any move commands).

Example: When CCN (bit 2 of parameter No. 5003) = 1

![Diagram](image)

2 When a G28, G30, or G30.1 block is specified such that the block becomes a start-up block, a vector perpendicular to the move direction is generated at an intermediate position, then subsequently canceled at the reference position. In the next block, an intersection vector is generated.

Example: When CCN (bit 2 of parameter No.5003)=1

![Diagram](image)
When G29 is specified in cutter compensation C mode, an operation of FS15 type is performed if CCN (bit 2 of parameter No. 5003) is set to 1.

This means that an intersection vector is generated in the previous block, and vector cancellation is performed when a movement to an intermediate position is performed. When movement from the intermediate position to the return position is performed, the vector is restored; an intersection vector is generated between the block and the next block.

(1) G29 specified in offset mode (with movement to both an intermediate position and reference position performed)

(a) For specification made immediately after automatic reference position return

When CCN (bit 2 of parameter No.5003) = 0

When CCN (bit 2 of parameter No.5003) = 1
(b) For specification made other than immediately after automatic reference position return
When CCN (bit 2 of parameter No.5003)=0

When CCN (bit 2 of parameter No.5003)=1

(2) G29 specified in offset mode (with movement to an intermediate position not performed)
(a) For specification made immediately after automatic reference position return
When CCN (bit 2 of parameter No.5003)=0
When CCN (bit 2 of parameter No.5003)=1

(b) For specification made other than immediately after automatic reference position return

When CCN (bit 2 of parameter No.5003)=0

When CCN (bit 2 of parameter No.5003)=1
(3) G29 specified in offset mode (with movement to a reference position not performed)

(a) For specification made immediately after automatic reference position return

When CCN (bit 2 of parameter No. 5003) = 0

When CCN (bit 2 of parameter No. 5003) = 1
(b) For specification made other than immediately after automatic reference position return

When CCN (bit 2 of parameter No.5003)=1

---

---
(4) G29 specified in offset mode (with movement to an intermediate position and reference position not performed)

(a) For specification made immediately after automatic reference position return

When CCN (bit 2 of parameter No. 5003) = 0

When CCN (bit 2 of parameter No. 5003) = 1
(b) For specification made other than immediately after automatic reference position return

When CCN (bit 2 of parameter No.5003)=0

When CCN (bit 2 of parameter No.5003)=1

NOTE

When a G29 command is specified for an axis that is not in the cutter compensation C plane in cutter compensation C mode, a perpendicular vector is generated at the end point of the previous block, and the tool does not move. In the next block, an intersection vector is generated (in the same way as when two or more continuous blocks do not specify any move commands).
14.6.9 Corner Circular Interpolation (G39)

By specifying G39 in offset mode during cutter compensation C, corner circular interpolation can be performed. The radius of the corner circular interpolation equals the compensation value.

Format

In offset mode

\[
\text{G39} \\
\text{or} \\
\text{G39}\{I,J,K\} \\
\text{;}
\]

Explanations

- **Corner circular interpolation**
  When the command indicated above is specified, corner circular interpolation in which the radius equals compensation value can be performed. G41 or G42 preceding the command determines whether the arc is clockwise or counterclockwise. G39 is a one-shot G code.

- **G39 without I, J, or K**
  When G39; is programmed, the arc at the corner is formed so that the vector at the end point of the arc is perpendicular to the start point of the next block.

- **G39 with I, J, and K**
  When G39 is specified with I, J, and K, the arc at the corner is formed so that the vector at the end point of the arc is perpendicular to the vector defined by the I, J, and K values.

Limitations

- **Move command**
  In a block containing G39, no move command can be specified.

- **Non-move command**
  Two or more consecutive non-move blocks must not be specified after a block containing G39 without I, J, or K. (A single block specifying a travel distance of zero is assumed to be two or more consecutive non-move blocks.) If the non-move blocks are specified, the offset vector is temporarily lost. Then, offset mode is automatically restored.
Examples

- **G39 without I, J, or K**

  ```
  N1 Y10.0 ;
  N2 G39 ;
  N3 X-10.0 ;
  ```

- **G39 with I, J, and K**

  ```
  N1 Y10.0 ;
  N2 G39 I-1.0 J2.0 ;
  N3 X-10.0 Y20.0 ;
  ```
14.7 THREE-DIMENSIONAL TOOL COMPENSATION (G40, G41)

In cutter compensation C, two-dimensional offsetting is performed for a selected plane. In three-dimensional tool compensation, the tool can be shifted three-dimensionally when a three-dimensional offset direction is programmed.

Format

- **Start up** (Starting three-dimensional tool compensation)

  - When the following command is executed in the cutter compensation cancel mode, the three-dimensional tool compensation mode is set:

    ```
    G41  Xp_ Yp_ Zp_ I_ J_ K_ D_ ;
    Xp : X-axis or a parallel axis
    Yp : Y-axis or a parallel axis
    Zp : Z-axis or a parallel axis
    I
    J
    K
    D : Code for specifying as the cutter compensation value (1-3 digits) (D code)
    ```

  - When the following command is executed in the three-dimensional tool compensation mode, the cutter compensation cancel mode is set:

    ```
    G40  Xp_ Yp_ Zp_ ;
    or
    Xp_ Yp_ Zp_ D00 ;
    ```

- **Canceling three-dimensional tool compensation**

  - When only canceling the vector

    ```
    G40;
    or
    D00;
    ```

- **Selecting offset space**

  The three-dimensional space where three-dimensional tool compensation is to be executed is determined by the axis addresses specified in the startup block containing the G41 command. If Xp, Yp, or Zp is omitted, the corresponding axis, X-, Y-, or Z-axis (the basic three axis), is assumed.

  (Example)

  When the U-axis is parallel to the X-axis, the V-axis is parallel to the Y-axis, and the W-axis is parallel to the Z-axis

  ```
  G41  X_I_J_K_D_;   XYZ space
  G41  U_Y_Z_I_J_K_D_;   UVZ space
  G41  W_I_J_K_D_;   XYW space
  ```
Explanations

- Three–dimensional tool compensation vector

In three–dimensional tool compensation mode, the following three–dimensional compensation vector is generated at the end of each block:

\[ V_x = \frac{i \cdot r}{p} \]  
\[ V_y = \frac{j \cdot r}{p} \]  
\[ V_z = \frac{k \cdot r}{p} \]

The three–dimensional tool compensation vector is obtained from the following expressions:

- (Vector component along the Xp–axis)
- (Vector component along the Yp–axis)
- (Vector component along the Zp–axis)

In the above expressions, i, j, and k are the values specified in addresses I, J, and K in the block. r is the offset value corresponding to the specified offset number. p is the value obtained from the following expression:

\[ p = \sqrt{i^2 + j^2 + k^2} \]

When the user wants to program the magnitude of a three–dimensional tool compensation vector as well as its direction, the value of p in the expressions of Vx, Vy, and Vz can be set as a constant in parameter (No. 5011). If the parameter is set to 0, however, p is determined as follows:

\[ p = \sqrt{i^2 + j^2 + k^2} \]

- Relationship between three–dimensional tool compensation and other compensation functions

<table>
<thead>
<tr>
<th>Tool length offset</th>
<th>The specified path is shifted by three–dimensional tool compensation and the subsequent path is shifted by tool length offset.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tool offset</td>
<td>When tool offset is specified in the three–dimensional tool compensation mode, an alarm is issued (P/S alarm No. 042).</td>
</tr>
<tr>
<td>Cutter compensation C</td>
<td>When addresses I, J, and K are all specified at startup, three–dimensional tool compensation mode is set. When not all of the addresses are specified, cutter compensation C mode is set. Therefore, cutter compensation C cannot be specified in three–dimensional tool compensation mode and three–dimensional tool compensation cannot be specified in cutter compensation C mode.</td>
</tr>
</tbody>
</table>
Addresses I, J, and K must all be specified to start three–dimensional tool compensation. When even one of the three addresses is omitted, two–dimensional cutter compensation C is activated. When a block specified in three–dimensional tool compensation mode contains none of addresses I, J, and K, the same vector as the vector generated in the previous block is generated at the end of the block.

G42

Generally, G41 is specified to start three–dimensional tool compensation. Instead of G41, G42 can be specified for startup. With G42, three–dimensional tool compensation is performed in the opposite direction.

Offset vector in interpolation

When circular interpolation, helical interpolation (both specified with G02, G03), or involute interpolation (G02.2, G03.2) is specified, the vector generated in the previous block is maintained.

Reference position return check (G27)

Before specifying reference position return check (G27), cancel three–dimensional tool compensation. In the compensation mode, G27 brings the tool to a position shifted by the offset value. If the position the tool reached is not the reference position, the reference position return LED does not go on (the P/S alarm No.092 alarm is issued).

Return to a reference position (G28, G30, G30.1)

When return to the reference position (G28), to the second, third, or fourth reference position (G30), or to the floating reference position (G30.1) is specified, the vector is cleared at a middle point.

Alarm issued at startup

If one of the following conditions is present at the startup of three–dimensional tool compensation, an alarm is issued:

- Two or more axes are specified in the same direction. (P/S alarm No.047)
- Although Xp, Yp, or Zp is omitted, the basic three axes are not set. (P/S alarm No.048)

Alarm during three–dimensional tool compensation

If one of the following G codes is specified in the three–dimensional tool compensation mode, an alarm is issued:

- G05 High–speed cycle machining (P/S alarm 178)
- G31 Skip function (P/S alarm 036)
- G51 Scaling (P/S alarm 141)
When one of the following G codes is specified in three-dimensional tool compensation mode, the vector is cleared:

- G73 Peck drilling cycle
- G74 Reverse tapping cycle
- G76 Fine boring
- G80 Canned cycle cancel
- G81 Drill cycle, spot boring
- G82 Drill cycle, counterboring
- G83 Peck drilling cycle
- G84 Tapping cycle
- G85 Boring cycle
- G86 Boring cycle
- G87 Back boring cycle
- G88 Boring cycle
- G89 Boring cycle
- G53 Machine coordinate system selection

When one of the following G codes is specified in three-dimensional tool compensation mode, the same vector as the vector generated in the previous block is generated at the end point of the next movement:

- G02 Circular or helical interpolation (CW)
- G03 Circular or helical interpolation (CCW)
- G02.2 Involute interpolation (CW)
- G03.2 Involute interpolation (CCW)
- G04 Dwell
- G10 Data setting
- G22 Stored stroke check function enabled
Tool compensation values include tool geometry compensation values and tool wear compensation (Fig. 14.8 (a)).

![Fig. 14.8 (a) Geometric compensation and wear compensation](image)

Table 14.8 (a) shows the valid input range of tool compensation values.

<table>
<thead>
<tr>
<th>Increment system</th>
<th>Geometric compensation value</th>
<th>Wear compensation value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Metric input</td>
<td>Inch input</td>
</tr>
<tr>
<td>IS–B</td>
<td>±999.999 mm</td>
<td>±99.9999 inch</td>
</tr>
<tr>
<td>IS–C</td>
<td>±999.999 mm</td>
<td>±99.99999 inch</td>
</tr>
</tbody>
</table>

The memory can hold 32, 64, 99, 200, 400, 499, or 999 tool compensation values (option).

Address D or H is used in the program. The address used depends on which of the following functions is used: tool length compensation (see II–14.1), tool offset (see II–14.3), cutter compensation B (see II–14.4), or cutter compensation C (see II–14.6).

The range of the number that comes after the address (D or H) depends on the number of tool compensation values: 0 to 32, 0 to 64, 0 to 99, 0 to 200, 0 to 400, 0 to 499, or 0 to 999.
Tool compensation memory A, B, or C can be used. The tool compensation memory determines the tool compensation values that are entered (set) (Table 14.8 (b)).

<table>
<thead>
<tr>
<th>Tool compensation value</th>
<th>Tool compensation memory A</th>
<th>Tool compensation memory B</th>
<th>Tool compensation memory C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tool geometry compensation value for address D</td>
<td>Set tool geometry + tool wear compensation values for addresses D and H (values can be specified with either address).</td>
<td>set</td>
<td></td>
</tr>
<tr>
<td>Tool geometry compensation value for address H</td>
<td></td>
<td>Set tool geometry compensation values for addresses D and H (values can be specified with either address).</td>
<td>set</td>
</tr>
<tr>
<td>Tool wear compensation for value address D</td>
<td>Set tool wear compensation values for addresses D and H (values can be specified with either address).</td>
<td>set</td>
<td>set</td>
</tr>
<tr>
<td>Tool wear compensation value for address H</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The programming format depends on which tool compensation memory is used.

**Input of tool compensation value by programing**

The programming format depends on which tool compensation memory is used.

<table>
<thead>
<tr>
<th>Variety of tool compensation memory</th>
<th>Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>G10L11P_R_;</td>
</tr>
<tr>
<td>B</td>
<td>G10L10P_R_;</td>
</tr>
<tr>
<td>Geometry compensation value</td>
<td>G10L10P_R_;</td>
</tr>
<tr>
<td>Wear compensation value</td>
<td>G10L11P_R_;</td>
</tr>
<tr>
<td>C</td>
<td>G10L10P_R_;</td>
</tr>
<tr>
<td>Geometry compensation value for H code</td>
<td>G10L10P_R_;</td>
</tr>
<tr>
<td>Geometry compensation value for D code</td>
<td>G10L12P_R_;</td>
</tr>
<tr>
<td>Wear compensation value for H code</td>
<td>G10L11P_R_;</td>
</tr>
<tr>
<td>Wear compensation value for D code</td>
<td>G10L13P_R_;</td>
</tr>
</tbody>
</table>

P : Number of tool compensation
R : Tool compensation value in the absolute command (G90) mode
Value to be added to the specified tool compensation value in the incremental command (G91) mode (the sum is also a tool compensation value.)

**NOTE**
To provide compatibility with the format of older CNC programs, the system allows L1 to be specified instead of L11.
**14.9 SCALING**

(G50, G51)

A programmed figure can be magnified or reduced (scaling). The dimensions specified with \( X_\), \( Y_\), and \( Z_\) can each be scaled up or down with the same or different rates of magnification. The magnification rate can be specified in the program. Unless specified in the program, the magnification rate specified in the parameter is applied.

**Format**

<table>
<thead>
<tr>
<th>Format</th>
<th>Meaning of command</th>
</tr>
</thead>
<tbody>
<tr>
<td>G51( X_)( Y_)( Z_)( P_) ; Scaling start</td>
<td>X_\ Y_ Z_\ : Absolute command for center coordinate value of scaling ( P_) : Scaling magnification</td>
</tr>
<tr>
<td>( )) Scaling is effective. (Scaling mode) ( )) Scaling cancel</td>
<td></td>
</tr>
<tr>
<td>G50 ;</td>
<td>Scaling cancel</td>
</tr>
</tbody>
</table>

**SCALING UP OR DOWN ALONG ALL AXES AT THE SAME RATE OF MAGNIFICATION**

---

**WARNING**

Specify G51 in a separate block. After the figure is enlarged or reduced, specify G50 to cancel the scaling mode.
Explanations

• Scaling up or down along all axes at the same rate of magnification

• Scaling of each axis, programmable mirror image (negative magnification)

Least input increment of scaling magnification is: 0.001 or 0.00001 It is depended on parameter SCR (No. 5400#7) which value is selected. Then, set parameter SCLx (No. 5401#0) to enable scaling for each axis. If scaling P is not specified on the block of scaling (G51X_Y_Z_P_ ;), the scaling magnification set to parameter (No. 5411) is applicable. If X,Y,Z are omitted, the tool position where the G51 command was specified serves as the scaling center.

Each axis can be scaled by different magnifications. Also when a negative magnification is specified, a mirror image is applied. First of all, set a parameter XSC (No. 5400#6) which validates each axis scaling (mirror image).

Then, set parameter SCLx (No. 5401#0) to enable scaling along each axis. Least input increment of scaling magnification of each axis (I, J, K) is 0.001 or 0.00001 (set parameter SCR (No. 5400#7)).

Magnification is set to parameter 5421 within the range +0.00001 to +9.99999 or +0.001 to +999.999.

If a negative value is set, mirror image is effected.

If magnification I, J or K is not commanded, a magnification value set to parameter (No. 5421) is effective. However, a value other than 0 must be set to the parameter.

NOTE
Decimal point programming can not be used to specify the rate of magnification (I, J, K).

Fig. 14.9 (b) Scaling of each axis
**Scaling of circular interpolation**

Even if different magnifications are applied to each axis in circular interpolation, the tool will not trace an ellipse. When different magnifications are applied to axes and a circular interpolation is specified with radius R, it becomes as following figure 14.9 (c) (in the example shown below, a magnification of 2 is applied to the X–component and a magnification of 1 is applied to the Y–component.).

```
G90 G00 X0.0 Y100.0 ;
G51 X0.0 Y0.0 Z0.0 I2000 J1000;
G02 X100.0 Y0.0 R100.0 F500 ;
```

Above commands are equivalent to the following command:

```
G90 G00 X0.0 Y100.0 Z0.0 ;
G02 X200.0 Y0.0 R200.0 F500 ;
```

Magnification of radius R depends on I, or J whichever is larger.

![Fig. 14.9 (c) Scaling for circular interpolation 1](image1)

When different magnifications are applied to axes and a circular interpolation is specified with I, J and K, it becomes as following figure 14.9 (d) (In the example shown below, a magnification of 2 is applied to the X–component and a magnification of 1 is applied to the Y–component.).

```
G90 G00 X0.0 Y0.0 ;
G51 X0.0 Y0.0 I2000 J1000;
G02 X100.0 Y0.0 I0.0 J–100.0 F500 ;
```

Above commands are equivalent to the following commands.

```
G90 G00 X0.0 Y100.0 ;
G02 X200.0 Y0.0 I0.0 J–100.0 F500 ;
```

In this case, the end point does not meet the radius, a linear section is included.

![Fig. 14.9 (d) Scaling for circular interpolation 2](image2)
- **Tool compensation**

This scaling is not applicable to cutter compensation values, tool length offset values, and tool offset values (Fig. 14.9 (e)).

![Scaling during cutter compensation](image)

- **Invalid scaling**

Scaling is not applicable to the Z-axis movement in case of the following canned cycle.
- Cut-in value Q and retraction value d of peck drilling cycle (G83, G73).
- Fine boring cycle (G76)
- Shift value Q of X and Y axes in back boring cycle (G87).

In manual operation, the travel distance cannot be increased or decreased using the scaling function.

- **Commands related to reference position return and coordinate system**

In scaling mode, G28, G30, or commands related to the coordinate system (G52 to G59) must not be specified. When any of these G codes is necessary, specify it after canceling scaling mode.

**WARNING**

1. If a parameter setting value is employed as a scaling magnification without specifying P, the setting value at G51 command time is employed as the scaling magnification, and a change of this value, if any, is not effective.
2. Before specifying the G code for reference position return (G27, G28, G29, G30) or coordinate system setting (G92), cancel the scaling mode.
3. If scaling results are rounded by counting fractions of 5 and over as a unit and disregarding the rest, the move amount may become zero. In this case, the block is regarded as a no movement block, and therefore, it may affect the tool movement by cutter compensation C. See the description of blocks that do not move the tool at II–14.6.3.
NOTE
1 The position display represents the coordinate value after scaling.
2 When a mirror image was applied to one axis of the specified plane, the following results:
   (1) Circular command Direction of rotation is reversed.
   (2) Cutter compensation C Offset direction is reversed.
   (3) Coordinate system rotation Rotation angle is reversed.
   (4) Cutter compensation B Offset direction is reversed. (Including G39)

Examples
Example of a mirror image program
Subprogram
O9000;
G00 G90 X60.0 Y60.0;
G01 X100.0 F100;
G01 Y100.0;
G01 X60.0 Y60.0;
M99;
Main program
N10 G00 G90;
N20 M98 P9000;
N30 G51 X50.0 Y50.0 I–1000 J1000;
N40 M98 P9000;
N50 G51 X50.0 Y50.0 I–1000 J–1000;
N60 M98 P9000;
N70 G51 X50.0 Y50.0 I1000 J–1000
N80 M98 P9000;
N90 G50;

Fig. 14.9 (f) Example of a mirror image program
14.10
COORDINATE SYSTEM ROTATION (G68, G69)

A programmed shape can be rotated. By using this function it becomes possible, for example, to modify a program using a rotation command when a workpiece has been placed with some angle rotated from the programmed position on the machine. Further, when there is a pattern comprising some identical shapes in the positions rotated from a shape, the time required for programming and the length of the program can be reduced by preparing a subprogram of the shape and calling it after rotation.

![Coordinate system rotation diagram](image_url)

**Fig. 14.10 (a) Coordinate system rotation**

<table>
<thead>
<tr>
<th>Format</th>
<th>Meaning of command</th>
</tr>
</thead>
<tbody>
<tr>
<td>G17</td>
<td>Select the plane in which contains the figure to be rotated.</td>
</tr>
<tr>
<td>G18</td>
<td>Absolute command for two of the x, y, and Z axes that correspond to the current plane selected by a command (G17, G18, or G19). The command specifies the coordinates of the center of rotation for the values specified subsequent to G68.</td>
</tr>
<tr>
<td>G19</td>
<td>Angular displacement with a positive value indicates counter clockwise rotation. Bit 0 of parameter 5400 selects whether the specified angular displacement is always considered an absolute value or is considered an absolute or incremental value depending on the specified G code (G90 or G91).</td>
</tr>
<tr>
<td>G68 αβR_</td>
<td>Start rotation of a coordinate system.</td>
</tr>
<tr>
<td>G69 ;</td>
<td>Coordinate system rotation cancel command</td>
</tr>
</tbody>
</table>

**Least input increment:** 0.001 deg  
**Valid data range:** $-360,000$ to $360,000$
When a decimal fraction is used to specify angular displacement \((R)\), the 1’s digit corresponds to degree units.

**NOTE**

The G code for selecting a plane (G17, G18, or G19) can be specified before the block containing the G code for coordinate system rotation (G68). G17, G18 or G19 must not be designated in the mode of coordinate system rotation.

The center of rotation for an incremental command programmed after G68 but before an absolute command is the tool position when G68 was programmed (Fig. 14.10 (c)).

When \(\alpha, \beta\) is not programmed, the tool position when G68 was programmed is assumed as the center of rotation.

When \(R\) is not specified, the value specified in parameter 5410 is assumed as the angular displacement.

The G code used to cancel coordinate system rotation (G69) may be specified in a block in which another command is specified.

Cutter compensation, tool length compensation, tool offset, and other compensation operations are executed after the coordinate system is rotated.

Both coordinate system rotation and three-dimensional coordinate conversion use the same G codes: G68 and G69. The G code with I, J, and K is processed as a command for three-dimensional coordinate conversion. The G code without I, J, and K is processed as a command for two-dimensional coordinate system rotation.
Limitations

- **Commands related to reference position return and the coordinate system**

  In coordinate system rotation mode, G codes related to reference position return (G27, G28, G29, G30, etc.) and those for changing the coordinate system (G52 to G59, G92, etc.) must not be specified. If any of these G codes is necessary, specify it only after canceling coordinate system rotation mode.

- **Incremental command**

  The first move command after the coordinate system rotation cancel command (G69) must be specified with absolute values. If an incremental move command is specified, correct movement will not be performed.

Explanations

**Absolute/Incremental position commands**

```plaintext
N1 G92 X-5000 Y-5000 G69 G17 ;
N2 G68 X7000 Y3000 R60000 ;
N3 G90 G01 X0 Y0 F200 ;
   (G91X5000Y5000)
N4 G91 X10000 ;
N5 G02 Y10000 R100000 ;
N6 G03 X-10000 I-5000 J-5000 ;
N7 G01 Y-10000 ;
N8 G69 G90 X-5000 Y-5000 M02 ;
```

Tool path when the incremental command is designated in the N3 block (in parenthesis)

Original programmed tool path

Center of rotation (7000,3000)

60°

(-500.0,-500.0)

Tool path after rotation

Fig. 14.10 (c) Absolute/incremental command during coordinate system rotation
Examples

- Cutter compensation C and coordinate system rotation

It is possible to specify G68 and G69 in cutter compensation C mode. The rotation plane must coincide with the plane of cutter compensation C.

N1 G92 X0 Y0 G69 G01 ;
N2 G42 G90 X1000 Y1000 F1000 D01 ;
N3 G68 R 30000 ;
N4 G91 X2000 ;
N5 G03 Y1000 R1000 J500 ;
N6 G01 X − 2000 ;
N7 Y − 1000 ;
N8 G69 G40 G90 X0 Y0 M30 ;

Fig. 14.10 (d) Cutter compensation C and coordinate system rotation

- Scaling and coordinate system rotation

If a coordinate system rotation command is executed in the scaling mode (G51 mode), the coordinate value (α, β) of the rotation center will also be scaled, but not the rotation angle (R). When a move command is issued, the scaling is applied first and then the coordinates are rotated.

A coordinate system rotation command (G68) should not be issued in cutter compensation C mode (G41, G42) on scaling mode (G51). The coordinate system rotation command should always be specified prior to setting the cutter compensation C mode.

1. When the system is not in cutter compensation mode C, specify the commands in the following order:
   G51 ; scaling mode start
   G68 ; coordinate system rotation mode start
   ...
   ...
   G69 ; coordinate system rotation mode cancel
   G50 ; scaling mode cancel
2. When the system is in cutter compensation model C, specify the commands in the following order (Fig.14.10(e)):
(cutter compensation C cancel)
G51 ; scaling mode start
G68 ; coordinate system rotation start
G41 ; cutter compensation C mode start

G92 X0 Y0 ;
G51 X300.0 Y150.0 P500 ;
G68 X200.0 Y100.0 R45.0 ;
G01 X400.0 Y100.0 ;
Y100.0 ;
X–200.0 ;
Y–100.0 ;
X200.0 ;

Fig. 14.10 (e) Scaling and coordinate system rotation in cutter compensation C mode
It is possible to store one program as a subprogram and recall subprogram by changing the angle.

Sample program for when the RIN bit (bit 0 of parameter 5400) is set to 1.
The specified angular displacement is treated as an absolute or incremental value depending on the specified G code (G90 or G91).

```gcode
G92 X0 Y0 G69 G17;  
G01 F200 H01;  
M98 P2100;  
M98 P072200;  
G00 G90 X0 Y0 M30;  

O 2200 G68 X0 Y0 G91 R45.0 ;  
G90 M98 P2100 ;  
M99 ;  

O 2100 G90 G01 G42 X0 Y-10.0 ;  
X4.142 ;  
X7.071 Y-7.071 ;  
G40 ;  
M99 ;  
```

![Fig. 14.10 (f) Coordinate system rotation command](image-url)
When a tool with a rotation axis (C-axis) is moved in the XY plane during cutting, the normal direction control function can control the tool so that the C-axis is always perpendicular to the tool path (Fig. 14.11 (a)).

### Format

<table>
<thead>
<tr>
<th>G code</th>
<th>Function</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>G41.1 or G151</td>
<td>Normal direction control left</td>
<td>If the workpiece is to the right of the tool path looking toward the direction in which the tool advances, the normal direction control left (G41.1 or G151) function is specified. After G41.1 (or G151) is specified, the normal direction control function is enabled (normal direction control mode). When G40.1 (or G150) is specified, the normal direction control mode is canceled.</td>
</tr>
<tr>
<td>G42.1 or G152</td>
<td>Normal direction control right</td>
<td></td>
</tr>
<tr>
<td>G40.1 or G150</td>
<td>Normal direction control cancel</td>
<td></td>
</tr>
</tbody>
</table>
Explanations

- **Angle of the C axis**

  When viewed from the center of rotation around the C–axis, the angular displacement about the C–axis is determined as shown in Fig. 14.11 (d). The positive side of the X–axis is assumed to be 0°, the positive side of the Y–axis is 90°, the negative side of the X–axis is 180°, and the negative side of the Y–axis is 270°.

- **Normal direction control of the C axis**

  When the cancel mode is switched to the normal direction control mode, the C–axis becomes perpendicular to the tool path at the beginning of the block containing G41.1 or G42.1.

  In the interface between blocks in the normal direction control mode, a command to move the tool is automatically inserted so that the C–axis becomes perpendicular to the tool path at the beginning of each block. The tool is first oriented so that the C–axis becomes perpendicular to the tool path specified by the move command, then it is moved along the X– and Y–axes.

  In the cutter compensation mode, the tool is oriented so that the C–axis becomes perpendicular to the tool path created after compensation.

  In single–block operation, the tool is not stopped between a command for rotation of the tool and a command for movement along the X– and Y–axes. A single–block stop always occurs after the tool is moved along the X– and Y–axes.
Before circular interpolation is started, the C-axis is rotated so that the C-axis becomes normal to the arc at the start point. During circular interpolation, the tool is controlled so that the C-axis is always perpendicular to the tool path determined by circular interpolation.

NOTE
During normal direction control, the C axis always rotates through an angle less than 180 deg. I.e., it rotates in whichever direction provides the shorter route.
Movement of the tool inserted at the beginning of each block is executed at the feedrate set in parameter 5481. If dry run mode is on at that time, the dry run feedrate is applied. If the tool is to be moved along the X–and Y–axes in rapid traverse (G00) mode, the rapid traverse feedrate is applied.

The federate of the C axis during circular interpolation is defined by the following formula.

\[ F \times \frac{\text{Amount of movement of the C axis (deg)}}{\text{Length of arc (mm or inch)}} (\text{deg/min}) \]

\( F \) : Federate (mm/min or inch/min) specified by the corresponding block of the arc

Amount of movement of the C axis : The difference in angles at the beginning and the end of the block.

NOTE

If the federate of the C axis exceeds the maximum cutting speed of the C axis specified to parameter No. 1422, the federate of each of the other axes is clamped to keep the federate of the C axis below the maximum cutting speed of the C axis.

A C–axis to which normal–direction control is applied can be assigned to any axis with parameter No. 5480.

When the rotation angle to be inserted, calculated by normal–direction control, is smaller than the value set with parameter No. 5482, the corresponding rotation block is not inserted for the axis to which normal–direction control is applied. This ignored rotation angle is added to the next rotation angle to be inserted, the total angle being subject to the same check at the next block.

If an angle of 360 degrees or more is specified, the corresponding rotation block is not inserted.

If an angle of 180 degrees or more is specified in a block other than that for circular interpolation with a C–axis rotation angle of 180 degrees or more, the corresponding rotation block is not inserted.
Specify the maximum distance for which machining is performed with the same normal direction as that of the preceding block.

**Linear movement**
When distance $N_2$, shown below, is smaller than the set value, machining for block $N_2$ is performed using the same direction as that for block $N_1$.

**Circular movement**
When the diameter of block $N_2$, shown below, is smaller than the set value, machining for block $N_2$ is performed using the same normal direction as that for block $N_1$. The orientation of the axis to which normal–direction control is applied, relative to the normal direction of block $N_2$, does not change as machining proceeds along the arc.

**NOTE**
1. Do not specify any command to the C axis during normal direction control. Any command specified at this time is ignored.
2. Before processing starts, it is necessary to correlate the workpiece coordinate of the C axis with the actual position of the C axis on the machine using the coordinate system setting (G92) or the like.
3. The helical cutting option is required to use this function. Helical cutting cannot be specified in the normal direction control mode.
4. Normal direction control cannot be performed by the G53 move command.
5. The C–axis must be a rotation axis.
14.12 PROGRAMMABLE MIRROR IMAGE (G50.1, G51.1)

A mirror image of a programmed command can be produced with respect to a programmed axis of symmetry (Fig. 14.12 (a)).

Fig. 14.12 (a) Programmable Mirror image

Format

**G51.1** \( p \); Setting a programmable image

\[
\begin{align*}
\text{A mirror image of a command specified in these blocks is produced with respect to the axis of symmetry specified by G51.1 } p .
\end{align*}
\]

**G50.1** \( p \); Canceling a programmable mirror image

\[
\begin{align*}
\text{Point (position) and axis of symmetry for producing a mirror image when specified with G51.1.} \\
\text{Axis of symmetry for producing a mirror image when specified with G50.1. Point of symmetry is not specified.}
\end{align*}
\]
Explanations

• **Mirror image by setting**
  
  If the programmable mirror image function is specified when the command for producing a mirror image is also selected by a CNC external switch or CNC setting (see III–4.9), the programmable mirror image function is executed first.

• **Mirror image on a single axis in a specified plane**
  
  Applying a mirror image to one of the axes on a specified plane changes the following commands as follows:

<table>
<thead>
<tr>
<th>Command</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circular command</td>
<td>G02 and G03 are interchanged.</td>
</tr>
<tr>
<td>Cutter compensation</td>
<td>G41 and G42 are interchanged.</td>
</tr>
<tr>
<td>Coordinate rotation</td>
<td>CW and CCW (directions of rotation) are interchanged.</td>
</tr>
</tbody>
</table>

Limitations

• **Scaling/coordinate system rotation**
  
  Processing proceeds from program mirror image to scaling and coordinate rotation in the stated order. The commands should be specified in this order, and, for cancellation, in the reverse order. Do not specify G50.1 or G51.1 during scaling or coordinate rotation mode.

• **Commands related to reference position return and coordinate system**
  
  In programmable mirror image mode, G codes related to reference position return (G27, G28, G29, G30, etc.) and those for changing the coordinate system (G52 to G59, G92, etc.) must not be specified. If any of these G codes is necessary, specify it only after canceling the programmable mirror image mode.
The grinding wheel compensation function creates a compensation vector by extending the line between the specified compensation center and the specified end point, on the specified compensation plane.

### Format

- **Selecting the compensation center**
  - G41 P1; Select the first compensation center
  - G41 P2; Select the second compensation center
  - G41 P3; Select the third compensation center

- **Start-up**
  - D_; D code other than D0

- **Canceling compensation mode**
  - D0;

- **Holding the compensation vector**
  - G40;

### Explanations

- **Setting and selecting the compensation center**
  
  Three compensation centers can be specified by specifying their center coordinates with parameters No. 5081 to 5086. The G41Pn (n = 1, 2, or 3) command is used to specify which compensation center is to be used.

    G41 P1 ; . . . . . Select the first compensation center.
    G41 P2 ; . . . . . Select the second compensation center.
    G41 P3 ; . . . . . Select the third compensation center.

  
  When selecting the compensation center, specify P1, P2, or P3 at the same time with G41. If G41 has been specified without a P command or with a P command other than P1, P2, and P3, P/S alarm 5069 is issued.

  When specifying the compensation center with parameters, use the workpiece coordinates.

- **Start-up**
  
  To enter compensation mode, specify the compensation center, then specify a D code other than D0. A compensation vector is created and the tool is accordingly moved, even if the block in which the D code has been specified does not contain a move command.
A compensation vector is created by extending the line between the compensation center and the specified end point. The length of the compensation vector equals to the offset value corresponding to the offset number specified with the D code.

When the offset value is positive, the compensation vector is added to the specified end point. When the offset value is negative, the compensation vector is subtracted from the specified end point.

Specifying D0 cancels compensation mode, thus disabling the creation of a compensation vector.

Specifying G40 selects a mode for holding the current compensation vector. In this mode, the specified end point is shifted by the same vector length until a different compensation mode is specified.

Specifying D0 in compensation vector hold mode clears the compensation vector and cancels compensation mode.
Grinding wheel wear compensation can also be applied to circular interpolation and helical interpolation. If the radius at the start point differs from that at the end point, the figure does not become an arc; it becomes a helix.

The compensated values are still subject to arc radius error limit (parameter No. 3410) check.

Specifying an arc command in G40 mode causes the arc center to be shifted by the vector length, thus causing the figure to become an arc, not a helix.

Grinding wheel wear compensation can also be applied to exponential interpolation. Exponential interpolation is performed for the compensated positions.

A compensation vector is created only on the plane (compensation plane) corresponding to the axes specified with parameters No. 5071 and 5072 (compensation axes).

In compensation mode (including compensation vector hold mode), a compensation vector is always created on the compensation plane specified with parameters (No. 5071 and 5072), regardless of the plane selected with the G17, G18, or G19 command. For example, compensation can be performed using the YZ plane as the compensation plane while circular interpolation is performed on the XY plane (G17).

If a move command has been specified for either compensation axis, in compensation mode, the compensation vector component of the other axis may be changed during compensation vector creation, thus causing the tool to also move along that axis.
When the compensation axes are the Y– and Z–axes and linear interpolation is performed for the X– and Y–axes
Programmed path:  a → b, compensated path:  a' → b'

When the compensation axes are the Y– and Z–axes and circular interpolation is performed for the X– and Y–axes
Programmed path:  a → b, compensated path:  a' → b'

- **Compensation cancel mode**
  Compensation cancel mode is selected immediately after power–on or reset.

- **Changing the coordinate system**
  Before attempting to change the coordinate system, cancel compensation mode.

- **Reference position return (G28, G30)**
  Before attempting to return to the reference point (G28 or G30), cancel compensation mode.

**Limitations**

- **Changing the compensation axes**
  The compensation axes can be changed only in compensation cancel mode.

- **Relationship with other offset functions**
  Cutter compensation and three–dimensional tool compensation cannot be used when grinding wheel wear compensation is enabled on the system. The tool length offset and tool position offset functions can be used with grinding wheel wear compensation.

- **Relationship with the coordinate change function**
  The coordinates of the compensation center are not subject to programmable mirror image, scaling, or coordinate rotation.
14.14
ROTARY TABLE
DYNAMIC FIXTURE
OFFSET

The rotary table dynamic fixture offset function saves the operator the
trouble of re-setting the workpiece coordinate system when the rotary
table rotates before cutting is started. With this function the operator
simply sets the position of a workpiece placed at a certain position on the
rotary table as a reference fixture offset. If the rotary table rotates, the
system automatically obtains a current fixture offset from the angular
displacement of the rotary table and creates a suitable workpiece
coordinate system. After the reference fixture offset is set, the workpiece
coordinate system is prepared dynamically, wherever the rotary table is
located.

The zero point of the workpiece coordinate system is obtained by adding
the fixture offset to the offset from the workpiece reference point.

![Diagram](Image)

Fig.14.14 (a) Fixture offset

Format

- Fixture offset command

  G54.2 Pn ;
  n : Reference fixture offset value number (1 to 8)

- Fixture offset cancel command

  G54.2 P0 ;
When a command to move the tool about a rotation axis involved with a fixture offset is specified in the G54.2 mode, the coordinates about the rotation axis at the end of the block are used to calculate a vector. The tool is moved to the specified position on the workpiece coordinate system that is indicated by the vector.

Whether to cancel the fixture offset at a reset depends on the settings of bit 6 (CLR) of parameter No. 3402 and of bit 7 (C23) of parameter No. 3408.

When CLR is set to 0 or CLR and C23 are set to 1, the vector before the reset is saved.

When CLR is set to 1 and C23 is set to 0, the vector is cleared. The machine does not move by the cleared vector regardless of the setting of bit 0 (FTP) of parameter No. 7570, however.

When a move command is specified for a rotation axis in G54.2 mode

(1) Setting a group of three parameters which specify one rotation axis and two linear axes constituting the plane of rotation (Parameter No.7580 to 7588)

In each group, specify the number of the rotation axis as the first parameter and the numbers of the linear axes as the second and third parameters. The rotation in the normal direction about the rotation axis must agree with the rotation from the positive side of the linear axis set as the second parameter to the positive side of the linear axis set as the third parameter.

Example) Suppose that a machine has four axes, X, Y, Z, and C. The X–, Y–, and Z–axes form a right–handed coordinate system. The C–axis is a rotation axis. When viewed from the positive side of the Z–axis, a rotation in the normal direction about the C–axis is treated as the counterclockwise rotation around the Z–axis.

For this machine, specify the parameters as follows:

First parameter : 4 (C–axis)
Second parameter : 1 (X–axis)
Third parameter : 2 (Y–axis)

Up to three groups of parameters can be set. In calculation of the fixture offset, the data of the rotation axis specified in the first group is calculated first. Then, the data of the second and third groups are calculated.

If a machine has two or more rotation axes and the plane of rotation depends on the rotation about another rotation axis, the plane of rotation is set when the angular displacement about the rotation axis is 0.

(2) Setting the reference angle of the rotation axis and the corresponding reference fixture offset

Set the reference angle of the rotation axis and the fixture offset that corresponds to the reference angle.
Set the data on the fixture offset screen (See III–11.4). Eight groups of data items can be specified.

(3) Setting a parameter for enabling or disabling the fixture offset of each axis (bit 0 (FAX) of parameter 7575)
For the axis for which the fixture offset is enabled, set the parameter to 1. This need not be specified for a rotation axis.

(4) Setting the type of fixture offset (bit 1 (FTP) of parameter 6004)
Specify whether to cause a movement according to the increment or decrement of the fixture offset vector when the vector changes (when G54.2 is specified or when a rotation axis movement occurs in the G54.2 mode).
When 0 is set, the movement is made. (The current position on the workpiece coordinate system does not change. The position on the machine coordinate system changes.)
When 1 is set, the movement is not made. (The current position on the workpiece coordinate system changes. The position on the machine coordinate system does not change.)

\* Inputting and outputting the fixture offset

The setting of a program and external data can be input and output as described below:

(1) Setting the reference fixture offset by G10
G10 L21 Pn IP;

n : Number of fixture offset
IP : Reference fixture offset or reference angle of each axis

This command sets the reference fixture offset or reference angle in a program.
When the command is executed in the G90 mode, the specified value is set directly.
When the command is executed in the G91 mode, the specified value plus a value set before the execution is set.
The programmable data input function (G10) is required.

(2) Reading and writing the data by a system variable of a custom macro
System variable number = 5500 + 20\*n + m
The following system variable number can be used to read and write the reference fixture offset or reference angle. No data can be written in the system variable area (5500 to 5508) with n = 0, however.
\( n \) : Fixture offset number (1 to 8)
When \( n \) is 0, the current offset is indicated.
\( m \) : Axis number (1 to number of controlled axes)
System variable 5500 can be used to read the selected offset number.

The custom macro function is required.

(3) Reading and writing the data by the PMC window or open CNC
The window function can be used to read and write the custom macro system variable with the same number as for (2).

The NC window function and custom macro function are required.

(4) Outputting the data to an external device
By selecting <PUNCH> on the fixture offset screen, the data can be output to a Floppy Cassette, memory card or other external device via RS-232C.
The data is output in the G10 form without a program number.

The reader/punch interface function and programmable data input function (G10) are required.

(5) Input from an external device
Register the data output in step (4) into the CNC memory as a program and execute the program to input the data.

The reader/punch interface function and programmable data input function (G10) are required.
• Calculating the Fixture Offset

(1) Relationship between the rotation axis and linear axes
First group : 5(B-axis), 1(X-axis), 3(Z-axis)
Second group : 4(A-axis), 3(Z-axis), 2(Y-axis)
Third group : 0, 0, 0

(2) Reference angle and reference fixture offset
X : F_{0X}
Y : F_{0Y}
Z : F_{0Z}
A : \phi_0
B : \theta_0

The calculation method is shown below when data is set as above:
O : Rotary table center
W : Workpiece origin offset value
F_0 : Fixture offset value when A = \phi_0 and B = \theta_0
F_A : Fixture offset value when A = 0 and B = 0
F_1 : Fixture offset value when A = 0 and B = \theta
F : Fixture offset value when A = \phi and B = \theta

\[
\begin{align*}
F_A &= (F_{AX}, F_{AY}, F_{A Y}) \\
F_1 &= (F_{1X}, F_{1Y}, F_{1Z}) \\
F &= (F_X, F_Y, F_Z)
\end{align*}
\]

Then, the following expression is used for fixture offset calculation.

\[
\begin{align*}
F_{AX} &= \begin{bmatrix} \cos(-\theta_0) & 0 & -\sin(-\theta_0) \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos(\phi_0) & -\sin(\phi_0) \\ 0 & \sin(\phi_0) & \cos(\phi_0) \end{bmatrix} \begin{bmatrix} F_{0X} \\ F_{0Y} \\ F_{0Z} \end{bmatrix} \\
F_{AY} &= \begin{bmatrix} 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos(\phi_0) & -\sin(\phi_0) \\ 0 & \sin(\phi_0) & \cos(\phi_0) \end{bmatrix} \begin{bmatrix} F_{0X} \\ F_{0Y} \\ F_{0Z} \end{bmatrix} \\
F_{AZ} &= \begin{bmatrix} \sin(-\theta_0) & 0 & -\cos(-\theta_0) \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos(\phi_0) & -\sin(\phi_0) \\ 0 & \sin(\phi_0) & \cos(\phi_0) \end{bmatrix} \begin{bmatrix} F_{0X} \\ F_{0Y} \\ F_{0Z} \end{bmatrix} \\
F_{1X} &= \begin{bmatrix} \cos(\theta) & 0 & -\sin(\theta) \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos(\phi_0) & -\sin(\phi_0) \\ 0 & \sin(\phi_0) & \cos(\phi_0) \end{bmatrix} \begin{bmatrix} F_{0X} \\ F_{0Y} \\ F_{0Z} \end{bmatrix} \\
F_{1Y} &= \begin{bmatrix} 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos(\phi_0) & -\sin(\phi_0) \\ 0 & \sin(\phi_0) & \cos(\phi_0) \end{bmatrix} \begin{bmatrix} F_{0X} \\ F_{0Y} \\ F_{0Z} \end{bmatrix} \\
F_{1Z} &= \begin{bmatrix} \sin(\theta) & 0 & \cos(\theta) \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos(\phi_0) & -\sin(\phi_0) \\ 0 & \sin(\phi_0) & \cos(\phi_0) \end{bmatrix} \begin{bmatrix} F_{0X} \\ F_{0Y} \\ F_{0Z} \end{bmatrix} \\
F_X &= \begin{bmatrix} 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos(\phi_0) & -\sin(\phi_0) \\ 0 & \sin(\phi_0) & \cos(\phi_0) \end{bmatrix} \begin{bmatrix} F_{0X} \\ F_{0Y} \\ F_{0Z} \end{bmatrix} \\
F_Y &= \begin{bmatrix} 0 & \cos(-\phi) & -\sin(-\phi_0) \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos(\phi_0) & -\sin(\phi_0) \\ 0 & \sin(\phi_0) & \cos(\phi_0) \end{bmatrix} \begin{bmatrix} F_{0X} \\ F_{0Y} \\ F_{0Z} \end{bmatrix} \\
F_Z &= \begin{bmatrix} 0 & \sin(-\phi) & \cos(-\phi_0) \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos(\phi_0) & -\sin(\phi_0) \\ 0 & \sin(\phi_0) & \cos(\phi_0) \end{bmatrix} \begin{bmatrix} F_{0X} \\ F_{0Y} \\ F_{0Z} \end{bmatrix}
\end{align*}
\]
Limitation

- **When data is modified in G54.2 mode**
  In the G54.2 mode, a change made to the setting of parameter No. 7580 to 7588 or to the reference fixture offset becomes effective when the next G54.2Pn is specified.

- **Movement due to a fixture offset vector change**
  It depends on the current continuous–state code of the 01 group whether a change in the fixture offset vector causes a movement. If the system is in a mode other than the G00 or G01 mode (G02, G03, etc.), the movement is made temporarily in the G01 mode.

- **When a rotation axis is manually adjusted**
  When the automatic operation is stopped using the SBK stop function during the G54.2 mode and a manual movement is made about the rotation axis, the fixture offset vector does not change. The vector is calculated when a rotation axis command or G54.2 is specified for automatic operation or MDI operation.

  When manual intervention is performed in the manual absolute switch on status and a rotation axis command is specified in the incremental (G91) mode, however, the vector is calculated using the coordinates on which the manual intervention is reflected. This operation is not a specification of the FS15.

  If the ABS bit (bit 3 of parameter 2409) is set to 0 or the G90 mode is selected when N3 is specified, the coordinate of the C-axis is assumed to be 40.0(30.0+10.0), which is the specified value, in calculation.

- **When compensation is applied to a rotation axis**
  In calculation of the fixture offset, the coordinate of the rotation axis on the workpiece coordinate system is used. If a tool offset or another offset is applied, the coordinate before the offset is used.

- **Command for suppressing fixture offset calculation**
  If the following commands are specified for the rotation axis in the G54.2 mode, the fixture offset vector is not calculated:

    - Command related to the machine coordinate system : G53
    - Command specifying a change of the workpiece coordinate system : G54 to G59, G54.1, G92, G52
    - Command specifying a return to the reference position : G27, G28, G29, G30, G30.1

- **Rotation axis used for fixture offset**
  The rotation axis used for polar coordinate interpolation (G12.1) cannot be set as the rotation axis for the fixture offset.

- **Rotation axis roll over**
  When using the rotary axis roll over function, always specify 360 degrees for the amount of travel per revolution of the rotation axis.

- **Functions that cannot be specified**
  In the G54.2 mode, the functions listed below cannot be specified.

    - Program restart function
    - Mirror image function
    - Scaling function
    - Coordinate system rotation function
    - High-speed contour control function and AI/AI–nano contour control function
    - Figure copy function
**Example**

Parameter

Parameter 7580=4 (C-axis)
Parameter 7581=1 (X-axis)
Parameter 7582=2 (Y-axis)
Parameter 7583 to 7588=0
Parameter 7575#0(X)=1 (The offset is valid for the X-axis.)
7575#0(Y)=1 (The offset is valid for the Y-axis.)
7570#0=0 (When bit 0 of parameter 7570 is set to 1, the values in square brackets ([ ]) are calculated.)

Data of fixture offset 1 (n = 1)

C= 180.0 (reference angle)
X= −10.0
Y= 0.0

When these parameters and data are set, the machine operates as shown below:

**Table 14.14 Example of fixture offset**

<table>
<thead>
<tr>
<th>Program</th>
<th>Coordinates</th>
<th>Position on the workpiece coordinate system (ABSOLUTE)</th>
<th>Position on the machine coordinate system (MACHINE)</th>
<th>Fixture offset</th>
</tr>
</thead>
<tbody>
<tr>
<td>N1</td>
<td>G90 G00 X0 Y0 C90. ;</td>
<td>X Y C</td>
<td>X Y C</td>
<td>X Y C</td>
</tr>
<tr>
<td>N2</td>
<td>G54.2 P1 ;</td>
<td>0.0</td>
<td>0.0</td>
<td>90.0</td>
</tr>
<tr>
<td>N3</td>
<td>G01 X10. Y2. F100. ;</td>
<td>10.0</td>
<td>2.0</td>
<td>90.0</td>
</tr>
<tr>
<td>N4</td>
<td>G02 X2. Y10. R10. ;</td>
<td>2.0</td>
<td>10.0</td>
<td>90.0</td>
</tr>
<tr>
<td>N5</td>
<td>G01 X0 Y0 ;</td>
<td>0.0</td>
<td>0.0</td>
<td>90.0</td>
</tr>
</tbody>
</table>

The values enclosed in brackets ([ ]) apply when bit 0 (FTP) of parameter No. 7570 is set to 1.
When G54.2 P1 is specified in the N2 block, the fixture offset vector (0, 10.0) is calculated. The vector is handled in the same way as the offset from the workpiece reference point. The current position on the workpiece coordinate system is (0, –10.0). If bit 0 (FTP) of parameter 7570 is set to 0, the tool is moved according to the vector. The resultant position on the workpiece coordinate system is (0, 0), the position before the command is specified.
Although subprograms are useful for repeating the same operation, the custom macro function also allows use of variables, arithmetic and logic operations, and conditional branches for easy development of general programs such as pocketing and user-defined canned cycles. A machining program can call a custom macro with a simple command, just like a subprogram.
15.1 VARIABLES

An ordinary machining program specifies a G code and the travel distance directly with a numeric value; examples are G100 and X100.0. With a custom macro, numeric values can be specified directly or using a variable number. When a variable number is used, the variable value can be changed by a program or using operations on the MDI panel.

```
#1=#2+100 ;
G01 X#1 F300 ;
```

Explanation

- **Variable representation**

When specifying a variable, specify a number sign (#) followed by a variable number. General–purpose programming languages allow a name to be assigned to a variable, but this capability is not available for custom macros.

Example: #1

An expression can be used to specify a variable number. In such a case, the expression must be enclosed in brackets.

Example: [#1+#2–12]

- **Types of variables**

Variables are classified into four types by variable number.

<table>
<thead>
<tr>
<th>Variable number</th>
<th>Type of variable</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>#0</td>
<td>Always null</td>
<td>This variable is always null. No value can be assigned to this variable.</td>
</tr>
<tr>
<td>#1 – #33</td>
<td>Local variables</td>
<td>Local variables can only be used within a macro to hold data such as the results of operations. When the power is turned off, local variables are initialized to null. When a macro is called, arguments are assigned to local variables.</td>
</tr>
<tr>
<td>#100 – #149 (#199) #500 – #531 (#999)</td>
<td>Common variables</td>
<td>Common variables can be shared among different macro programs. When the power is turned off, variables #100 to #149 are initialized to null. Variables #500 to #531 hold data even when the power is turned off. As an option, common variables #150 to #199 and #532 to #999 are also available. However, when these values are using.</td>
</tr>
<tr>
<td>#1000 –</td>
<td>System variables</td>
<td>System variables are used to read and write a variety of NC data items such as the current position and tool compensation values.</td>
</tr>
</tbody>
</table>

**NOTE**

Common variables #150 to #199 and #532 to #999 are optional.
• **Range of variable values**

Local and common variables can have value 0 or a value in the following ranges:

- $-10^{47}$ to $-10^{-29}$
- $0$
- $10^{-29}$ to $10^{47}$

If the result of calculation turns out to be invalid, an P/S alarm No. 111 is issued.

• **Omission of the decimal point**

When a variable value is defined in a program, the decimal point can be omitted.

Example:

When #1=123; is defined, the actual value of variable #1 is 123.000.

• **Referencing variables**

To reference the value of a variable in a program, specify a word address followed by the variable number. When an expression is used to specify a variable, enclose the expression in brackets.

Example: G01X[#1+#2]F#3;

A referenced variable value is automatically rounded according to the least input increment of the address.

Example:

When G00X#1; is executed on a 1/1000–mm CNC with 12.3456 assigned to variable #1, the actual command is interpreted as G00X12.346;.

To reverse the sign of a referenced variable value, prefix a minus sign (−) to #.

Example: G00X−#1;

When an undefined variable is referenced, the variable is ignored up to an address word.

Example:

When the value of variable #1 is 0, and the value of variable #2 is null, execution of G00X#1Y#2; results in G00X0;.

• **Common custom macro variables for two paths (two–path control)**

For two–path control, macro variables are provided for each path. Some common variables, however, can be used for both paths, by setting parameters No. 6036 and 6037 accordingly.

• **Undefined variable**

When the value of a variable is not defined, such a variable is referred to as a “null” variable. Variable #0 is always a null variable. It cannot be written to, but it can be read.

(a) Quotation

When an undefined variable is quotated, the address itself is also ignored.

<table>
<thead>
<tr>
<th>When #1 = &lt; vacant &gt;</th>
<th>When #1 = 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>G90 X100 Y #1</td>
<td>G90 X100 Y #1</td>
</tr>
<tr>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td>G90 X100</td>
<td>G90 X100 Y0</td>
</tr>
</tbody>
</table>
(b) Operation

\(<\text{vacant}>\) is the same as 0 except when replaced by \(<\text{vacant}>\)

<table>
<thead>
<tr>
<th>When #1 = (&lt;\text{vacant}&gt;)</th>
<th>When #1 = 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>#2 = #1</td>
<td>#2 = #1</td>
</tr>
<tr>
<td>\text{↓}</td>
<td>\text{↓}</td>
</tr>
<tr>
<td>#2 = (&lt;\text{vacant}&gt;)</td>
<td>#2 = 0</td>
</tr>
<tr>
<td>#2 = #1*5</td>
<td>#2 = #1*5</td>
</tr>
<tr>
<td>\text{↓}</td>
<td>\text{↓}</td>
</tr>
<tr>
<td>#2 = 0</td>
<td>#2 = 0</td>
</tr>
<tr>
<td>#2 = #1 + #1</td>
<td>#2 = #1 + #1</td>
</tr>
<tr>
<td>\text{↓}</td>
<td>\text{↓}</td>
</tr>
<tr>
<td>#2 = 0</td>
<td>#2 = 0</td>
</tr>
</tbody>
</table>

(c) Conditional expressions

\(<\text{vacant}>\) differs from 0 only for EQ and NE.

<table>
<thead>
<tr>
<th>When #1 = (&lt;\text{vacant}&gt;)</th>
<th>When #1 = 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1 EQ #0</td>
<td>#1 EQ #0</td>
</tr>
<tr>
<td>Established</td>
<td>Not established</td>
</tr>
<tr>
<td>#1 NE 0</td>
<td>#1 NE 0</td>
</tr>
<tr>
<td>Established</td>
<td>Not established</td>
</tr>
<tr>
<td>#1 GE #0</td>
<td>#1 GE #0</td>
</tr>
<tr>
<td>Established</td>
<td>Established</td>
</tr>
<tr>
<td>#1 GT 0</td>
<td>#1 GT 0</td>
</tr>
<tr>
<td>Not established</td>
<td>Not established</td>
</tr>
</tbody>
</table>

- Custom macro variables common to tool posts (two-path control)
- Displaying variable Values

With the two-path control, macro variables are provided for each path. Specifying parameter Nos. 6036 and 6037 allows some of the common variables to be used for all paths.

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>ID</th>
<th>DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>123.456</td>
<td></td>
</tr>
<tr>
<td>101</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>102</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>103</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>104</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>105</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>106</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>107</td>
<td>0.000</td>
<td></td>
</tr>
</tbody>
</table>

ACTUAL POSITION (RELATIVE)

- X 0.000
- Y 0.000
- Z 0.000

MEM **** *** *** 18:42:15

- When the value of a variable is blank, the variable is null.
The mark ******* indicates an overflow (when the absolute value of a variable is greater than 99999999) or an underflow (when the absolute value of a variable is less than 0.0000001).

**Limitations**

Program numbers, sequence numbers, and optional block skip numbers cannot be referenced using variables.

Example:

Variables cannot be used in the following ways:

- O#1;
- /#2G00X100.0;
- N#3Y200.0;
### 15.2 SYSTEM VARIABLES

System variables can be used to read and write internal NC data such as tool compensation values and current position data. Note, however, that some system variables can only be read. System variables are essential for automation and general-purpose program development.

**Explanations**

- **Interface signals**

Signals can be exchanged between the programmable machine controller (PMC) and custom macros.

#### Table 15.2 (a) System variables for interface signals

<table>
<thead>
<tr>
<th>Variable number</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1000–#1015</td>
<td>A 16-bit signal can be sent from the PMC to a custom macro. Variables #1000 to #1015 are used to read a signal bit by bit. Variable #1032 is used to read all 16 bits of a signal at one time.</td>
</tr>
<tr>
<td>#1100–#1115</td>
<td>A 16-bit signal can be sent from a custom macro to the PMC. Variables #1100 to #1115 are used to write a signal bit by bit. Variable #1132 is used to write all 16 bits of a signal at one time.</td>
</tr>
<tr>
<td>#1133</td>
<td>Variable #1133 is used to write all 32 bits of a signal at one time from a custom macro to the PMC. Note, that values from –99999999 to +99999999 can be used for #1133.</td>
</tr>
</tbody>
</table>

For detailed information, refer to the connection manual (B–63523EN–1).

- **Tool compensation values**

Tool compensation values can be read and written using system variables. Usable variable numbers depend on the number of compensation pairs, whether a distinction is made between geometric compensation and wear compensation, and whether a distinction is made between tool length compensation and cutter compensation. When the number of compensation pairs is not greater than 200, variables #2001 to #2400 can also be used.

#### Table 15.2 (b) System variables for tool compensation memory A

<table>
<thead>
<tr>
<th>Compensation number</th>
<th>System variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>#10001 (#2001)</td>
</tr>
<tr>
<td>:</td>
<td></td>
</tr>
<tr>
<td>200</td>
<td>#10200 (#2200)</td>
</tr>
<tr>
<td>:</td>
<td></td>
</tr>
<tr>
<td>999</td>
<td>#10999</td>
</tr>
</tbody>
</table>

#### Table 15.2 (c) System variables for tool compensation memory B

<table>
<thead>
<tr>
<th>Compensation number</th>
<th>Geometry compensation</th>
<th>Wear compensation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>#11001 (#2201)</td>
<td>#10001 (#2001)</td>
</tr>
<tr>
<td>:</td>
<td></td>
<td>:</td>
</tr>
<tr>
<td>200</td>
<td>#11200 (#2400)</td>
<td>#10200 (#2200)</td>
</tr>
<tr>
<td>:</td>
<td></td>
<td>:</td>
</tr>
<tr>
<td>999</td>
<td>#11999</td>
<td>#10999</td>
</tr>
</tbody>
</table>
Table 15.2 (d) System variables for tool compensation memory C

<table>
<thead>
<tr>
<th>Compensation number</th>
<th>Tool length compensation (H)</th>
<th>Cutter compensation (D)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Geometric compensation</td>
<td>Wear compensation</td>
</tr>
<tr>
<td>1</td>
<td>#11001(#2201)</td>
<td>#10001(#2001)</td>
</tr>
<tr>
<td>: 200</td>
<td>:</td>
<td>:</td>
</tr>
<tr>
<td>: 999</td>
<td>#11999</td>
<td>#10999</td>
</tr>
</tbody>
</table>

- Macro alarms

Table 15.2 (e) System variable for macro alarms

<table>
<thead>
<tr>
<th>Variable number</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>#3000</td>
<td>When a value from 0 to 200 is assigned to variable #3000, the CNC stops with an alarm. After an expression, an alarm message not longer than 26 characters can be described. The CRT screen displays alarm numbers by adding 3000 to the value in variable #3000 along with an alarm message.</td>
</tr>
</tbody>
</table>

Example:
#3000=1(TOOL NOT FOUND);
→ The alarm screen displays "3001 TOOL NOT FOUND."

- Stop with a message

Execution of the program can be stopped, and then a message can be displayed.

<table>
<thead>
<tr>
<th>Variable number</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>#3006</td>
<td>When &quot;#3006=1 (MESSAGE);&quot; is commanded in the macro, the program executes blocks up to the immediately previous one and then stops. When a message of up to 26 characters, which is enclosed by a control–in character (&quot;(&quot;) and control–out character &quot;)&quot;, is programmed in the same block, the message is displayed on the external operator message screen.</td>
</tr>
</tbody>
</table>
- **Time information**

  Time information can be read and written.

  **Table 15.2 (f) System variables for time information**

<table>
<thead>
<tr>
<th>Variable number</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>#3001</td>
<td>This variable functions as a timer that counts in 1-millisecond increments at all times. When the power is turned on, the value of this variable is reset to 0. When 2147483648 milliseconds is reached, the value of this timer returns to 0.</td>
</tr>
<tr>
<td>#3002</td>
<td>This variable functions as a timer that counts in 1-hour increments when the cycle start lamp is on. This timer preserves its value even when the power is turned off. When 9544.371767 hours is reached, the value of this timer returns to 0.</td>
</tr>
<tr>
<td>#3011</td>
<td>This variable can be used to read the current date (year/month/day). Year/month/day information is converted to an apparent decimal number. For example, September 28, 2001 is represented as 20010928.</td>
</tr>
<tr>
<td>#3012</td>
<td>This variable can be used to read the current time (hours/minutes/seconds). Hours/minutes/seconds information is converted to an apparent decimal number. For example, 34 minutes and 56 seconds after 3 p.m. is represented as 153456.</td>
</tr>
</tbody>
</table>

- **Automatic operation control**

  The control state of automatic operation can be changed.

  **Table 15.2 (g) System variable (#3003) for automatic operation control**

<table>
<thead>
<tr>
<th>#3003</th>
<th>Single block</th>
<th>Completion of an auxiliary function</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Enabled</td>
<td>To be awaited</td>
</tr>
<tr>
<td>1</td>
<td>Disabled</td>
<td>To be awaited</td>
</tr>
<tr>
<td>2</td>
<td>Enabled</td>
<td>Not to be awaited</td>
</tr>
<tr>
<td>3</td>
<td>Disabled</td>
<td>Not to be awaited</td>
</tr>
</tbody>
</table>

  - When the power is turned on, the value of this variable is 0.
  - When single block stop is disabled, single block stop operation is not performed even if the single block switch is set to ON.
  - When a wait for the completion of auxiliary functions (M, S, and T functions) is not specified, program execution proceeds to the next block before completion of auxiliary functions. Also, distribution completion signal DEN is not output.
Table 15.2 (h) System variable (#3004) for automatic operation control

<table>
<thead>
<tr>
<th>#3004</th>
<th>Feed hold</th>
<th>Feedrate Override</th>
<th>Exact stop</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Enabled</td>
<td>Enabled</td>
<td>Enabled</td>
</tr>
<tr>
<td>1</td>
<td>Disabled</td>
<td>Enabled</td>
<td>Enabled</td>
</tr>
<tr>
<td>2</td>
<td>Enabled</td>
<td>Disabled</td>
<td>Enabled</td>
</tr>
<tr>
<td>3</td>
<td>Disabled</td>
<td>Disabled</td>
<td>Enabled</td>
</tr>
<tr>
<td>4</td>
<td>Enabled</td>
<td>Enabled</td>
<td>Disabled</td>
</tr>
<tr>
<td>5</td>
<td>Disabled</td>
<td>Enabled</td>
<td>Disabled</td>
</tr>
<tr>
<td>6</td>
<td>Enabled</td>
<td>Disabled</td>
<td>Disabled</td>
</tr>
<tr>
<td>7</td>
<td>Disabled</td>
<td>Disabled</td>
<td>Disabled</td>
</tr>
</tbody>
</table>

- When the power is turned on, the value of this variable is 0.
- When feed hold is disabled:
  1. When the feed hold button is held down, the machine stops in the single block stop mode. However, single block stop operation is not performed when the single block mode is disabled with variable #3003.
  2. When the feed hold button is pressed then released, the feed hold lamp comes on, but the machine does not stop; program execution continues and the machine stops at the first block where feed hold is enabled.
- When feedrate override is disabled, an override of 100% is always applied regardless of the setting of the feedrate override switch on the machine operator’s panel.
- When exact stop check is disabled, no exact stop check (position check) is made even in blocks including those which do not perform cutting.

O0001;
N1  G00 G91 X#24 Y#25;
N2  Z#18;
G04;
N3  #3003=3;
N4  #3004=7;
N5  G01 Z#26 F#9;
N6  M04;
N7  G01
Z-[ROUND[#18]+ROUND[#26]];
G04;
N8  #3004=0;
N9  #3003=0;
N10 M03;
M99;

Fig. 15.2 (a) Example of using variable #3004 in a tapping cycle
• **Settings**

Settings can be read and written. Binary values are converted to decimals.

<table>
<thead>
<tr>
<th>#3005</th>
</tr>
</thead>
<tbody>
<tr>
<td>Setting</td>
</tr>
<tr>
<td>Setting</td>
</tr>
<tr>
<td>FCV</td>
</tr>
</tbody>
</table>

- **#9 (FCV)**: Whether to use the FS15 tape format conversion capability
- **#5 (SEQ)**: Whether to automatically insert sequence numbers
- **#2 (INI)**: Millimeter input or inch input
- **#1 (ISO)**: Whether to use EIA or ISO as the output code
- **#0 (TVC)**: Whether to make a TV check

• **Mirror image**

The mirror–image status for each axis set using an external switch or setting operation can be read through the output signal (mirror–image check signal). The mirror–image status present at that time can be checked. (See III–4.9)

The value obtained in binary is converted into decimal notation.

<table>
<thead>
<tr>
<th>#3007</th>
</tr>
</thead>
<tbody>
<tr>
<td>Setting</td>
</tr>
<tr>
<td>Setting</td>
</tr>
</tbody>
</table>

For each bit,

\[
\begin{cases} 
0 \text{ (mirror–image function is disabled)} \\
1 \text{ (mirror–image function is enabled)} 
\end{cases}
\]

is indicated.

Example: If #3007 is 3, the mirror–image function is enabled for the first and second axes.

- When the mirror–image function is set for a certain axis by both the mirror–image signal and setting, the signal value and setting value are ORed and then output.
- When mirror–image signals for axes other than the controlled axes are turned on, they are still read into system variable #3007.
- System variable #3007 is a write–protected system variable. If an attempt is made to write data in the variable, P/S 116 alarm “WRITE PROTECTED VARIABLE” is issued.
• **Number of machined parts**

The number (target number) of parts required and the number (completion number) of machined parts can be read and written.

**Table 15.2(i) System variables for the number of parts required and the number of machined parts**

<table>
<thead>
<tr>
<th>Variable number</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>#3901</td>
<td>Number of machined parts (completion number)</td>
</tr>
<tr>
<td>#3902</td>
<td>Number of required parts (target number)</td>
</tr>
</tbody>
</table>

**NOTE**

Do not substitute a negative value.

• **Modal information**

Modal information specified in blocks up to the immediately preceding block can be read.

**Table 15.2 (j) System variables for modal information**

<table>
<thead>
<tr>
<th>Variable number</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>#4001</td>
<td>G00, G01, G02, G03, G33 (Group 01)</td>
</tr>
<tr>
<td>#4002</td>
<td>G17, G18, G19 (Group 02)</td>
</tr>
<tr>
<td>#4003</td>
<td>G90, G91 (Group 03)</td>
</tr>
<tr>
<td>#4004</td>
<td>(Group 04)</td>
</tr>
<tr>
<td>#4005</td>
<td>G94, G95 (Group 05)</td>
</tr>
<tr>
<td>#4006</td>
<td>G20, G21 (Group 06)</td>
</tr>
<tr>
<td>#4007</td>
<td>G40, G41, G42 (Group 07)</td>
</tr>
<tr>
<td>#4008</td>
<td>G43, G44, G49 (Group 08)</td>
</tr>
<tr>
<td>#4009</td>
<td>G73, G74, G76, G80–G89 (Group 09)</td>
</tr>
<tr>
<td>#4010</td>
<td>G98, G99 (Group 10)</td>
</tr>
<tr>
<td>#4011</td>
<td>G50, G51 (Group 11)</td>
</tr>
<tr>
<td>#4012</td>
<td>G65, G66, G67 (Group 12)</td>
</tr>
<tr>
<td>#4013</td>
<td>G96,G97 (Group 13)</td>
</tr>
<tr>
<td>#4014</td>
<td>G54–G59 (Group 14)</td>
</tr>
<tr>
<td>#4015</td>
<td>G61–G64 (Group 15)</td>
</tr>
<tr>
<td>#4016</td>
<td>G68, G69 (Group 16)</td>
</tr>
<tr>
<td></td>
<td>:</td>
</tr>
<tr>
<td>#4022</td>
<td>(Group 22)</td>
</tr>
<tr>
<td>#4102</td>
<td>B code</td>
</tr>
<tr>
<td>#4107</td>
<td>D code</td>
</tr>
<tr>
<td>#4109</td>
<td>F code</td>
</tr>
<tr>
<td>#4111</td>
<td>H code</td>
</tr>
<tr>
<td>#4113</td>
<td>M code</td>
</tr>
<tr>
<td>#4114</td>
<td>Sequence number</td>
</tr>
<tr>
<td>#4115</td>
<td>Program number</td>
</tr>
<tr>
<td>#4119</td>
<td>S code</td>
</tr>
<tr>
<td>#4120</td>
<td>T code</td>
</tr>
<tr>
<td>#4130</td>
<td>P code (number of the currently selected additional workpiece coordinate system)</td>
</tr>
</tbody>
</table>

Example:

When #1=#4001; is executed, the resulting value in #1 is 0, 1, 2, 3, or 33.

If the specified system variable for reading modal information corresponds to a G code group which cannot be used, a P/S alarm is issued.
Position information cannot be written but can be read.

**Table 15.2 (k) System variables for position information**

<table>
<thead>
<tr>
<th>Variable number</th>
<th>Position information</th>
<th>Coordinate system</th>
<th>Tool compensation value</th>
<th>Read operation during movement</th>
</tr>
</thead>
<tbody>
<tr>
<td>#5001–#5008</td>
<td>Block end point</td>
<td>Workpiece coordinate system</td>
<td>Not included</td>
<td>Enabled</td>
</tr>
<tr>
<td>#5021–#5028</td>
<td>Current position</td>
<td>Machine coordinate system</td>
<td>Included</td>
<td>Disabled</td>
</tr>
<tr>
<td>#5041–#5048</td>
<td>Current position</td>
<td>Workpiece coordinate system</td>
<td></td>
<td></td>
</tr>
<tr>
<td>#5061–#5068</td>
<td>Skip signal position</td>
<td>Workpiece coordinate system</td>
<td></td>
<td>Enabled</td>
</tr>
<tr>
<td>#5081–#5088</td>
<td>Tool length offset value</td>
<td></td>
<td></td>
<td>Disabled</td>
</tr>
<tr>
<td>#5101–#5108</td>
<td>Deviated servo position</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- The first digit (from 1 to 8) represents an axis number.
- The tool length offset value currently used for execution rather than the immediately preceding tool offset value is held in variables #5081 to 5088.
- The tool position where the skip signal is turned on in a G31 (skip function) block is held in variables #5061 to #5068. When the skip signal is not turned on in a G31 block, the end point of the specified block is held in these variables.
- When read during movement is “disabled,” this means that expected values cannot be read due to the buffering (preread) function.
Workpiece zero point offset values can be read and written.

### Table 15.2 (I) System variables for workpiece zero point offset values

<table>
<thead>
<tr>
<th>Variable number</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>#5201</td>
<td>First-axis external workpiece zero point offset value</td>
</tr>
<tr>
<td>#5208</td>
<td>Eighth-axis external workpiece zero point offset value</td>
</tr>
<tr>
<td>#5221</td>
<td>First-axis G54 workpiece zero point offset value</td>
</tr>
<tr>
<td>#5228</td>
<td>Eighth-axis G54 workpiece zero point offset value</td>
</tr>
<tr>
<td>#5241</td>
<td>First-axis G55 workpiece zero point offset value</td>
</tr>
<tr>
<td>#5248</td>
<td>Eighth-axis G55 workpiece zero point offset value</td>
</tr>
<tr>
<td>#5261</td>
<td>First-axis G56 workpiece zero point offset value</td>
</tr>
<tr>
<td>#5268</td>
<td>Eighth-axis G56 workpiece zero point offset value</td>
</tr>
<tr>
<td>#5281</td>
<td>First-axis G57 workpiece zero point offset value</td>
</tr>
<tr>
<td>#5288</td>
<td>Eighth-axis G57 workpiece zero point offset value</td>
</tr>
<tr>
<td>#5301</td>
<td>First-axis G58 workpiece zero point offset value</td>
</tr>
<tr>
<td>#5308</td>
<td>Eighth-axis G58 workpiece zero point offset value</td>
</tr>
<tr>
<td>#5321</td>
<td>First-axis G59 workpiece zero point offset value</td>
</tr>
<tr>
<td>#5328</td>
<td>Eighth-axis G59 workpiece zero point offset value</td>
</tr>
<tr>
<td>#7001</td>
<td>First-axis workpiece zero point offset value (G54.1 P1)</td>
</tr>
<tr>
<td>#7008</td>
<td>Eighth-axis workpiece zero point offset value</td>
</tr>
<tr>
<td>#7021</td>
<td>First-axis workpiece zero point offset value (G54.1 P2)</td>
</tr>
<tr>
<td>#7028</td>
<td>Eighth-axis workpiece zero point offset value</td>
</tr>
<tr>
<td>#7941</td>
<td>First-axis workpiece zero point offset value (G54.1 P48)</td>
</tr>
<tr>
<td>#7948</td>
<td>Eighth-axis workpiece zero point offset value</td>
</tr>
<tr>
<td>#14001</td>
<td>First-axis workpiece zero point offset value (G54.1 P1)</td>
</tr>
<tr>
<td>#14008</td>
<td>Eighth-axis workpiece zero point offset value</td>
</tr>
<tr>
<td>#14021</td>
<td>First-axis workpiece zero point offset value (G54.1 P2)</td>
</tr>
<tr>
<td>#14028</td>
<td>Eighth-axis workpiece zero point offset value</td>
</tr>
<tr>
<td>#19980</td>
<td>First-axis workpiece zero point offset value (G54.1 P300)</td>
</tr>
<tr>
<td>#19988</td>
<td>Eighth-axis workpiece zero point offset value</td>
</tr>
</tbody>
</table>
The following variables can also be used:

<table>
<thead>
<tr>
<th>Axis</th>
<th>Function</th>
<th>Variable number</th>
</tr>
</thead>
<tbody>
<tr>
<td>First axis</td>
<td>External workpiece zero point offset</td>
<td>#2500</td>
</tr>
<tr>
<td></td>
<td>G54 workpiece zero point offset</td>
<td>#2501</td>
</tr>
<tr>
<td></td>
<td>G55 workpiece zero point offset</td>
<td>#2502</td>
</tr>
<tr>
<td></td>
<td>G56 workpiece zero point offset</td>
<td>#2503</td>
</tr>
<tr>
<td></td>
<td>G57 workpiece zero point offset</td>
<td>#2504</td>
</tr>
<tr>
<td></td>
<td>G58 workpiece zero point offset</td>
<td>#2505</td>
</tr>
<tr>
<td></td>
<td>G59 workpiece zero point offset</td>
<td>#2506</td>
</tr>
<tr>
<td>Second axis</td>
<td>External workpiece zero point offset</td>
<td>#2600</td>
</tr>
<tr>
<td></td>
<td>G54 workpiece zero point offset</td>
<td>#2601</td>
</tr>
<tr>
<td></td>
<td>G55 workpiece zero point offset</td>
<td>#2602</td>
</tr>
<tr>
<td></td>
<td>G56 workpiece zero point offset</td>
<td>#2603</td>
</tr>
<tr>
<td></td>
<td>G57 workpiece zero point offset</td>
<td>#2604</td>
</tr>
<tr>
<td></td>
<td>G58 workpiece zero point offset</td>
<td>#2605</td>
</tr>
<tr>
<td></td>
<td>G59 workpiece zero point offset</td>
<td>#2606</td>
</tr>
<tr>
<td>Third axis</td>
<td>External workpiece zero point offset</td>
<td>#2700</td>
</tr>
<tr>
<td></td>
<td>G54 workpiece zero point offset</td>
<td>#2701</td>
</tr>
<tr>
<td></td>
<td>G55 workpiece zero point offset</td>
<td>#2702</td>
</tr>
<tr>
<td></td>
<td>G56 workpiece zero point offset</td>
<td>#2703</td>
</tr>
<tr>
<td></td>
<td>G57 workpiece zero point offset</td>
<td>#2704</td>
</tr>
<tr>
<td></td>
<td>G58 workpiece zero point offset</td>
<td>#2705</td>
</tr>
<tr>
<td></td>
<td>G59 workpiece zero point offset</td>
<td>#2706</td>
</tr>
<tr>
<td>Fourth axis</td>
<td>External workpiece zero point offset</td>
<td>#2800</td>
</tr>
<tr>
<td></td>
<td>G54 workpiece zero point offset</td>
<td>#2801</td>
</tr>
<tr>
<td></td>
<td>G55 workpiece zero point offset</td>
<td>#2802</td>
</tr>
<tr>
<td></td>
<td>G56 workpiece zero point offset</td>
<td>#2803</td>
</tr>
<tr>
<td></td>
<td>G57 workpiece zero point offset</td>
<td>#2804</td>
</tr>
<tr>
<td></td>
<td>G58 workpiece zero point offset</td>
<td>#2805</td>
</tr>
<tr>
<td></td>
<td>G59 workpiece zero point offset</td>
<td>#2806</td>
</tr>
</tbody>
</table>

**NOTE**

To use variables #2500 to #2806 and #5201 to #5328, optional variables for the workpiece coordinate systems are necessary.

Optional variables for 48 additional workpiece coordinate systems are #7001 to #7948 (G54.1 P1 to G54.1 P48).

Optional variables for 300 additional workpiece coordinate systems are #14001 to #19988 (G54.1 P1 to G54.1 P300).

With these variables, #7001 to #7948 can also be used.
The operations listed in Table 15.3(a) can be performed on variables. The expression to the right of the operator can contain constants and/or variables combined by a function or operator. Variables #j and #K in an expression can be replaced with a constant. Variables on the left can also be replaced with an expression.

<table>
<thead>
<tr>
<th>Function</th>
<th>Format</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Definition</td>
<td>#i=#j</td>
<td></td>
</tr>
<tr>
<td>Sum</td>
<td>#i=#j+#k</td>
<td></td>
</tr>
<tr>
<td>Difference</td>
<td>#i=#j–#k</td>
<td></td>
</tr>
<tr>
<td>Product</td>
<td>#i=#j*#k</td>
<td></td>
</tr>
<tr>
<td>Quotient</td>
<td>#i=#j/#k</td>
<td></td>
</tr>
<tr>
<td>Sine</td>
<td>#i=SIN[#j]</td>
<td>An angle is specified in degrees. 90 degrees and 30 minutes is represented as 90.5 degrees.</td>
</tr>
<tr>
<td>Arcsine</td>
<td>#i=ASIN[#j]</td>
<td></td>
</tr>
<tr>
<td>Cosine</td>
<td>#i=COS[#j]</td>
<td></td>
</tr>
<tr>
<td>Arcosine</td>
<td>#i=ACOS[#j]</td>
<td></td>
</tr>
<tr>
<td>Tangent</td>
<td>#i=TAN[#j]</td>
<td></td>
</tr>
<tr>
<td>Arctangent</td>
<td>#i=ATAN[#j]/[#k]</td>
<td></td>
</tr>
<tr>
<td>Square root</td>
<td>#i=SQRT[#j]</td>
<td></td>
</tr>
<tr>
<td>Absolute value</td>
<td>#i=ABS[#j]</td>
<td></td>
</tr>
<tr>
<td>Rounding off</td>
<td>#i=ROUND[#j]</td>
<td></td>
</tr>
<tr>
<td>Rounding down</td>
<td>#i=FUP[#j]</td>
<td></td>
</tr>
<tr>
<td>Rounding up</td>
<td>#i=FIX[#j]</td>
<td></td>
</tr>
<tr>
<td>Natural logarithm</td>
<td>#i=LN[#j]</td>
<td></td>
</tr>
<tr>
<td>Exponential function</td>
<td>#i=EXP[#j]</td>
<td></td>
</tr>
<tr>
<td>OR</td>
<td>#i=#j OR #k</td>
<td>A logical operation is performed on binary numbers bit by bit.</td>
</tr>
<tr>
<td>XOR</td>
<td>#i=#j XOR #k</td>
<td></td>
</tr>
<tr>
<td>AND</td>
<td>#i=#j AND #k</td>
<td></td>
</tr>
<tr>
<td>Conversion from BCD to BIN</td>
<td>#i=BIN[#j];</td>
<td>Used for signal exchange to and from the PMC</td>
</tr>
<tr>
<td>Conversion from BIN to BCD</td>
<td>#i=BCD[#j];</td>
<td></td>
</tr>
</tbody>
</table>

Explanations

- **Angle units**

  The units of angles used with the SIN, COS, ASIN, ACOS, TAN, and ATAN functions are degrees. For example, 90 degrees and 30 minutes is represented as 90.5 degrees.

- **ARCSIN #i = ASIN[#j]**;

  - The solution ranges are as indicated below:
    When the NAT bit (bit 0 of parameter 6004) is set to 0: 270° to 90°
    When the NAT bit (bit 0 of parameter 6004) is set to 1: −90° to 90°

  - When #j is beyond the range of −1 to 1, P/S alarm No. 111 is issued.

  - A constant can be used instead of the #j variable.

- **ARCCOS #i = ACOS[#j]**;

  - The solution ranges from 180° to 0°.

  - When #j is beyond the range of −1 to 1, P/S alarm No. 111 is issued.

  - A constant can be used instead of the #j variable.
Specify the lengths of two sides, separated by a slash (/).

The solution ranges are as follows:

When the NAT bit (bit 0 of parameter 6004) is set to 0:  0° to 360°

[Example] When #1 = ATAN[1]/[1]; is specified, #1 is 225.0.

When the NAT bit (bit 0 of parameter 6004) is set to 1: −180° to 180°

[Example] When #1 = ATAN[1]/[1]; is specified, #1 is −135.0.0.

A constant can be used instead of the #j variable.

Note that the relative error may become 10⁻⁸ or greater.

When the antilogarithm (#j) is zero or smaller, P/S alarm No. 111 is issued.

A constant can be used instead of the #j variable.

When the result of the operation exceeds 3.65 X 10⁴⁷ (j is about 110), an overflow occurs and P/S alarm No. 111 is issued.

A constant can be used instead of the #j variable.

When the ROUND function is included in an arithmetic or logic operation command, IF statement, or WHILE statement, the ROUND function rounds off at the first decimal place.

Example:
When #1=ROUND[#2]; is executed where #2 holds 1.2345, the value of variable #1 is 1.0.

When the ROUND function is used in NC statement addresses, the ROUND function rounds off the specified value according to the least input increment of the address.

Example:
Creation of a drilling program that cuts according to the values of variables #1 and #2, then returns to the original position
Suppose that the increment system is 1/1000 mm, variable #1 holds 1.2345, and variable #2 holds 2.3456. Then,
G00 G91 X=#1; Moves 1.235 mm.
G01 X=#2 F300; Moves 2.346 mm.
G00 X[#1+#2]; Since 1.2345 + 2.3456 = 3.5801, the travel distance is 3.580, which does not return the tool to the original position.

This difference comes from whether addition is performed before or after rounding off. G00X=[ROUND[#1]+ROUND[#2]] must be specified to return the tool to the original position.
• Rounding up and down to an integer

With CNC, when the absolute value of the integer produced by an operation on a number is greater than the absolute value of the original number, such an operation is referred to as rounding up to an integer. Conversely, when the absolute value of the integer produced by an operation on a number is less than the absolute value of the original number, such an operation is referred to as rounding down to an integer. Be particularly careful when handling negative numbers.

Example:
Suppose that \( #1=1.2 \) and \( #2=-1.2 \).
When \( #3=\text{FUP}[#1] \) is executed, 2.0 is assigned to \( #3 \).
When \( #3=\text{FIX}[#1] \) is executed, 1.0 is assigned to \( #3 \).
When \( #3=\text{FUP}[#2] \) is executed, \(-2.0\) is assigned to \( #3 \).
When \( #3=\text{FIX}[#2] \) is executed, \(-1.0\) is assigned to \( #3 \).

• Abbreviations of arithmetic and logic operation commands

When a function is specified in a program, the first two characters of the function name can be used to specify the function (See III–9.7).

Example:
\[
\text{ROUND} \rightarrow \text{RO} \\
\text{FIX} \rightarrow \text{FI}
\]

• Priority of operations

1. Functions
2. Operations such as multiplication and division (*, /, AND)
3. Operations such as addition and subtraction (+, –, OR, XOR)

Example) \( #1=#2+\#3\ast\text{SIN}[\#4]; \)

\[
\begin{array}{c}
1 \\
2 \\
3 \\
1, 2 \text{ and } 3 \text{ indicate the order of operations.}
\end{array}
\]

• Bracket nesting

Brackets are used to change the order of operations. Brackets can be used to a depth of five levels including the brackets used to enclose a function. When a depth of five levels is exceeded, P/S alarm No. 118 occurs.

Example) \( #1=\text{SIN}[([\#2+\#3]\ast\#4+\#5]\ast\#6); \)

\[
\begin{array}{c}
1 \\
2 \\
3 \\
4 \\
5 \\
1 \text{ to } 5 \text{ indicate the order of operations.}
\end{array}
\]
Limitations

- **Brackets**

  Brackets ([, ]) are used to enclose an expression. Note that parentheses are used for comments.

- **Operation error**

  Errors may occur when operations are performed.

<table>
<thead>
<tr>
<th>Operation</th>
<th>Average error</th>
<th>Maximum error</th>
<th>Type of error</th>
</tr>
</thead>
<tbody>
<tr>
<td>a = b*c</td>
<td>1.55×10^{-10}</td>
<td>4.66×10^{-10}</td>
<td>Relative error(*)1</td>
</tr>
<tr>
<td>a = b / c</td>
<td>4.66×10^{-10}</td>
<td>1.88×10^{-9}</td>
<td></td>
</tr>
<tr>
<td>a = b - c</td>
<td>1.24×10^{-9}</td>
<td>3.73×10^{-9}</td>
<td></td>
</tr>
<tr>
<td>a = b + c</td>
<td>2.33×10^{-10}</td>
<td>5.32×10^{-10}</td>
<td>Min ( \frac{\epsilon}{b} )  ( \frac{\epsilon}{c} ) (**)</td>
</tr>
<tr>
<td>a = SIN [ b ]</td>
<td>5.0×10^{-9}</td>
<td>1.0×10^{-8}</td>
<td>Absolute error(***3)</td>
</tr>
<tr>
<td>a = COS [ b ]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a = ATAN [ b ]/ [ c ]</td>
<td>1.8×10^{-6}</td>
<td>3.6×10^{-6}</td>
<td>( \epsilon ) degrees (****)</td>
</tr>
</tbody>
</table>

**NOTE**

1. The relative error depends on the result of the operation.
2. Smaller of the two types of errors is used.
3. The absolute error is constant, regardless of the result of the operation.
4. Function TAN performs SIN/COS.
5. If the result of the operation by the SIN, COS, or TAN function is less than 1.0 x 10^{-8} or is not 0 because of the precision of the operation, the result of the operation can be normalized to 0 by setting bit 1 (MFZ) of parameter No. 6004 to 1.

- The precision of variable values is about 8 decimal digits. When very large numbers are handled in an addition or subtraction, the expected results may not be obtained.

Example:

When an attempt is made to assign the following values to variables #1 and #2:

- #1=9876543210123.456
- #2=9876543277777.777

the values of the variables become:

- #1=9876543200000.000
- #2=9876543300000.000

In this case, when #3=#2−#1; is calculated, #3=100000.000 results. (The actual result of this calculation is slightly different because it is performed in binary.)
• Also be aware of errors that can result from conditional expressions using EQ, NE, GE, GT, LE, and LT.

Example:
IF[#1 EQ #2] is effected by errors in both #1 and #2, possibly resulting in an incorrect decision.
Therefore, instead find the difference between the two variables with IF[ABS[#1–#2]LT0.001].
Then, assume that the values of the two variables are equal when the difference does not exceed an allowable limit (0.001 in this case).

• Also, be careful when rounding down a value.

Example:
When #2=#1*1000; is calculated where #1=0.002;, the resulting value of variable #2 is not exactly 2 but 1.99999997.
Here, when #3=FIX[#2]; is specified, the resulting value of variable #1 is not 2.0 but 1.0. In this case, round down the value after correcting the error so that the result is greater than the expected number, or round it off as follows:
#3=FIX[#2+0.001]
#3=ROUND[#2]

• Divisor

When a divisor of zero is specified in a division or TAN[90], P/S alarm No. 112 occurs.
15.4
MACRO STATEMENTS AND NC STATEMENTS

The following blocks are referred to as macro statements:
- Blocks containing an arithmetic or logic operation (=)
- Blocks containing a control statement (such as GOTO, DO, END)
- Blocks containing a macro call command (such as macro calls by G65, G66, G67, or other G codes, or by M codes)

Any block other than a macro statement is referred to as an NC statement.

Explanations

- Differences from NC statements
  - Even when single block mode is on, the machine does not stop. Note, however, that the machine stops in the single block mode when bit 5 of parameter SBM No. 6000 is 1.
  - Macro blocks are not regarded as blocks that involve no movement in the cutter compensation mode (see II–15.7).

- NC statements that have the same property as macro statements
  - NC statements that include a subprogram call command (such as subprogram calls by M98 or other M codes, or by T codes) and not include other command addresses except an O,N or L address have the same property as macro statements.
  - The blocks not include other command addresses except an O,N,P or L address have the same property as macro statements.
15.5 BRANCH AND REPETITION

In a program, the flow of control can be changed using the GOTO statement and IF statement. Three types of branch and repetition operations are used:

<table>
<thead>
<tr>
<th>Branch and repetition</th>
<th>GOTO statement (unconditional branch)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IF statement (conditional branch: if ..., then...)</td>
</tr>
<tr>
<td></td>
<td>WHILE statement (repetition while ...)</td>
</tr>
</tbody>
</table>

15.5.1 Unconditional Branch (GOTO Statement)

A branch to sequence number n occurs. When a sequence number outside of the range 1 to 99999 is specified, P/S alarm No. 128 occurs. A sequence number can also be specified using an expression.

GOTO n ;  n: Sequence number (1 to 99999)

Example:
GOTO1;
GOTO#10;

15.5.2 Conditional Branch (IF Statement)

Specify a conditional expression after IF.

IF[<conditional expression>]GOTOn

If the specified conditional expression is satisfied, a branch to sequence number n occurs. If the specified condition is not satisfied, the next block is executed.

IF [#1 GT 10] GOTO 2 ;  
N2 G00 G91 X10.0 ;

IF[<conditional expression>]THEN

If the specified conditional expression is satisfied, a predetermined macro statement is executed. Only a single macro statement is executed.

IF [#1 EQ #2] THEN#3=0 ;

Explanations

• Conditional expression

A conditional expression must include an operator inserted between two variables or between a variable and constant, and must be enclosed in brackets ([, ]). An expression can be used instead of a variable.
Operators each consist of two letters and are used to compare two values to determine whether they are equal or one value is smaller or greater than the other value. Note that the inequality sign cannot be used.

<table>
<thead>
<tr>
<th>Operator</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>EQ</td>
<td>Equal to (=)</td>
</tr>
<tr>
<td>NE</td>
<td>Not equal to (≠)</td>
</tr>
<tr>
<td>GT</td>
<td>Greater than (&gt;)</td>
</tr>
<tr>
<td>GE</td>
<td>Greater than or equal to (≥)</td>
</tr>
<tr>
<td>LT</td>
<td>Less than (&lt;)</td>
</tr>
<tr>
<td>LE</td>
<td>Less than or equal to (≤)</td>
</tr>
</tbody>
</table>

The sample program below finds the total of numbers 1 to 10.

```
O9500;
#1=0;                      Initial value of the variable to hold the sum
#2=1;                      Initial value of the variable as an addend
N1 IF[#2 GT 10] GOTO 2;    Branch to N2 when the addend is greater than 10
#1=#1+#2;                  Calculation to find the sum
#2=#2+1;                   Next addend
GOTO 1;                    Branch to N1
N2 M30;                    End of program
```

Specify a conditional expression after WHILE. While the specified condition is satisfied, the program from DO to END is executed. If the specified condition is not satisfied, program execution proceeds to the block after END.

While the specified condition is satisfied, the program from DO to END after WHILE is executed. If the specified condition is not satisfied, program execution proceeds to the block after END. The same format as for the IF statement applies. A number after DO and a number after END are identification numbers for specifying the range of execution. The numbers 1, 2, and 3 can be used. When a number other than 1, 2, and 3 is used, P/S alarm No. 126 occurs.
## Nesting

The identification numbers (1 to 3) in a DO–END loop can be used as many times as desired. Note, however, when a program includes crossing repetition loops (overlapped DO ranges), P/S alarm No. 124 occurs.

<table>
<thead>
<tr>
<th>1. The identification numbers (1 to 3) can be used as many times as required.</th>
</tr>
</thead>
<tbody>
<tr>
<td>WHILE […] DO 1 ;</td>
</tr>
<tr>
<td>Processing</td>
</tr>
<tr>
<td>END 1 ;</td>
</tr>
<tr>
<td>WHILE […] DO 1 ;</td>
</tr>
<tr>
<td>Processing</td>
</tr>
<tr>
<td>END 1 ;</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2. DO ranges cannot overlap.</th>
</tr>
</thead>
<tbody>
<tr>
<td>WHILE […] DO 1 ;</td>
</tr>
<tr>
<td>Processing</td>
</tr>
<tr>
<td>WHILE […] DO 2 ;</td>
</tr>
<tr>
<td>Processing</td>
</tr>
<tr>
<td>END 1 ;</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3. DO loops can be nested to a maximum depth of three levels.</th>
</tr>
</thead>
<tbody>
<tr>
<td>WHILE […] DO 1 ;</td>
</tr>
<tr>
<td>WHILE […] DO 2 ;</td>
</tr>
<tr>
<td>WHILE […] DO 3 ;</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>4. Control can be transferred to the outside of a loop.</th>
</tr>
</thead>
<tbody>
<tr>
<td>WHILE […] DO 1 ;</td>
</tr>
<tr>
<td>IF […] GOTO n ;</td>
</tr>
<tr>
<td>Nn</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>5. Branches cannot be made to a location within a loop.</th>
</tr>
</thead>
<tbody>
<tr>
<td>IF […] GOTO n ;</td>
</tr>
<tr>
<td>WHILE […] DO 1 ;</td>
</tr>
</tbody>
</table>

### Limitations

- **Infinite loops**
  
  When DO m is specified without specifying the WHILE statement, an infinite loop ranging from DO to END is produced.

- **Processing time**
  
  When a branch to the sequence number specified in a GOTO statement occurs, the sequence number is searched for. For this reason, processing in the reverse direction takes a longer time than processing in the forward direction. Using the WHILE statement for repetition reduces processing time.

- **Undefined variable**
  
  In a conditional expression that uses EQ or NE, a <vacant> and zero have different effects. In other types of conditional expressions, a <vacant> is regarded as zero.
Sample program

The sample program below finds the total of numbers 1 to 10.

```
O0001;
#1=0;
#2=1;
WHILE[#2 LE 10]DO 1;
#1=#1+#2;
#2=#2+1;
END 1;
M30;
```
15.6
MACRO CALL

A macro program can be called using the following methods:

<table>
<thead>
<tr>
<th>Macro call</th>
<th>Simple call (G65)</th>
</tr>
</thead>
<tbody>
<tr>
<td>modal call (G66, G67)</td>
<td></td>
</tr>
<tr>
<td>Macro call with G code</td>
<td></td>
</tr>
<tr>
<td>Macro call with M code</td>
<td></td>
</tr>
<tr>
<td>Subprogram call with M code</td>
<td></td>
</tr>
<tr>
<td>Subprogram call with T code</td>
<td></td>
</tr>
</tbody>
</table>

Limitations

- Differences between macro calls and subprogram calls

Macro call (G65) differs from subprogram call (M98) as described below.

- With G65, an argument (data passed to a macro) can be specified. M98 does not have this capability.

- When an M98 block contains another NC command (for example, G01 X100.0 M98Pp), the subprogram is called after the command is executed. On the other hand, G65 unconditionally calls a macro.

- When an M98 block contains another NC command (for example, G01 X100.0 M98Pp), the machine stops in the single block mode. On the other hand, G65 does not stop the machine.

- With G65, the level of local variables changes. With M98, the level of local variables does not change.
15.6.1 Simple Call (G65)

When G65 is specified, the custom macro specified at address P is called. Data (argument) can be passed to the custom macro program.

```
G65 P p L <argument-specified> ;
```

- P: Number of the program to call
- L: Repetition count (1 by default)
- Argument: Data passed to the macro

Example:

```
O0001 ;
G65 P9010 L2 A1.0 B2.0 ;
M30 ;
```

### Explanations

- **Call**
  - After G65, specify at address P the program number of the custom macro to call.
  - When a number of repetitions is required, specify a number from 1 to 9999 after address L. When L is omitted, 1 is assumed.
  - By using argument specification, values are assigned to corresponding local variables.

- **Argument specification**
  - Two types of argument specification are available. Argument specification I uses letters other than G, L, O, N, and P once each. Argument specification II uses A, B, and C once each and also uses I, J, and K up to ten times. The type of argument specification is determined automatically according to the letters used.

#### Argument specification I

<table>
<thead>
<tr>
<th>Address</th>
<th>Variable number</th>
<th>Address</th>
<th>Variable number</th>
<th>Address</th>
<th>Variable number</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>#1</td>
<td>I</td>
<td>#4</td>
<td>T</td>
<td>#20</td>
</tr>
<tr>
<td>B</td>
<td>#2</td>
<td>J</td>
<td>#5</td>
<td>U</td>
<td>#21</td>
</tr>
<tr>
<td>C</td>
<td>#3</td>
<td>K</td>
<td>#6</td>
<td>V</td>
<td>#22</td>
</tr>
<tr>
<td>D</td>
<td>#7</td>
<td>M</td>
<td>#13</td>
<td>W</td>
<td>#23</td>
</tr>
<tr>
<td>E</td>
<td>#8</td>
<td>Q</td>
<td>#17</td>
<td>X</td>
<td>#24</td>
</tr>
<tr>
<td>F</td>
<td>#9</td>
<td>R</td>
<td>#18</td>
<td>Y</td>
<td>#25</td>
</tr>
<tr>
<td>H</td>
<td>#11</td>
<td>S</td>
<td>#19</td>
<td>Z</td>
<td>#26</td>
</tr>
</tbody>
</table>

- Addresses G, L, N, O, and P cannot be used in arguments.
- Addresses that need not be specified can be omitted. Local variables corresponding to an omitted address are set to null.
- Addresses do not need to be specified alphabetically. They conform to word address format. I, J, and K need to be specified alphabetically, however.

**Example**

B_A_D_ … J_K_ Correct
B_A_D_ … J_J_ Incorrect
Argument specification II

Argument specification II uses A, B, and C once each and uses I, J, and K up to ten times. Argument specification II is used to pass values such as three-dimensional coordinates as arguments.

<table>
<thead>
<tr>
<th>Address</th>
<th>Variable number</th>
<th>Address</th>
<th>Variable number</th>
<th>Address</th>
<th>Variable number</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>#1</td>
<td>K₃</td>
<td>#12</td>
<td>J₇</td>
<td>#23</td>
</tr>
<tr>
<td>B</td>
<td>#2</td>
<td>I₄</td>
<td>#13</td>
<td>K₇</td>
<td>#24</td>
</tr>
<tr>
<td>C</td>
<td>#3</td>
<td>J₄</td>
<td>#14</td>
<td>I₈</td>
<td>#25</td>
</tr>
<tr>
<td>I₁</td>
<td>#4</td>
<td>K₄</td>
<td>#15</td>
<td>J₈</td>
<td>#26</td>
</tr>
<tr>
<td>J₁</td>
<td>#5</td>
<td>I₅</td>
<td>#16</td>
<td>K₈</td>
<td>#27</td>
</tr>
<tr>
<td>K₁</td>
<td>#6</td>
<td>I₆</td>
<td>#17</td>
<td>I₉</td>
<td>#28</td>
</tr>
<tr>
<td>I₂</td>
<td>#7</td>
<td>J₅</td>
<td>#18</td>
<td>J₉</td>
<td>#29</td>
</tr>
<tr>
<td>J₂</td>
<td>#8</td>
<td>K₅</td>
<td>#19</td>
<td>K₉</td>
<td>#30</td>
</tr>
<tr>
<td>K₂</td>
<td>#9</td>
<td>I₆</td>
<td>#20</td>
<td>I₁₀</td>
<td>#31</td>
</tr>
<tr>
<td>I₃</td>
<td>#10</td>
<td>J₆</td>
<td>#21</td>
<td>J₁₀</td>
<td>#32</td>
</tr>
<tr>
<td>J₃</td>
<td>#11</td>
<td>K₆</td>
<td>#22</td>
<td>K₁₀</td>
<td>#33</td>
</tr>
</tbody>
</table>

- Subscripts of I, J, and K for indicating the order of argument specification are not written in the actual program.

Limitations

- Format

G65 must be specified before any argument.

- Mixture of argument specifications I and II

The CNC internally identifies argument specification I and argument specification II. If a mixture of argument specification I and argument specification II is specified, the type of argument specification specified later takes precedence.

Example

G65 A1.0 B2.0 I-3.0 I4.0 D5.0 P1000;

<Variables>

#1:1.0
#2:2.0
#3:
#4:-3.0
#5:
#6:
#7:

When both the I4.0 and D5.0 arguments are commanded for variable #7 in this example, the latter, D5.0, is valid.

- Position of the decimal point

The units used for argument data passed without a decimal point correspond to the least input increment of each address. The value of an argument passed without a decimal point may vary according to the system configuration of the machine. It is good practice to use decimal points in macro call arguments to maintain program compatibility.

- Call nesting

Calls can be nested to a depth of four levels including simple calls (G65) and modal calls (G66). This does not include subprogram calls (M98).
• **Local variable levels**

- Local variables from level 0 to 4 are provided for nesting.
- The level of the main program is 0.
- Each time a macro is called (with G65 or G66), the local variable level is incremented by one. The values of the local variables at the previous level are saved in the CNC.
- When M99 is executed in a macro program, control returns to the calling program. At that time, the local variable level is decremented by one; the values of the local variables saved when the macro was called are restored.

```
O0001 ;
  #1=1 ;
  G65 P2 A2 ;
  M30 ;

O0002 ;
  #1=2; 
  G65 P3 A3 ;
  M99 ;

O0003 ;
  #1=3; 
  G65 P4 A4 ;
  M99 ;

O0004 ;
  #1=4; 
  G65 P5 A5 ;
  M99 ;

O0005 ;
  #1=5; 

O0006 ;
  #1=6;
```

<table>
<thead>
<tr>
<th>Main program (level 0)</th>
<th>Macro (level 1)</th>
<th>Macro (level 2)</th>
<th>Macro (level 3)</th>
<th>Macro (level 4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>O0001 ;</td>
<td>O0002 ;</td>
<td>O0003 ;</td>
<td>O0004 ;</td>
<td>O0005 ;</td>
</tr>
<tr>
<td>:</td>
<td>:</td>
<td>:</td>
<td>:</td>
<td>:</td>
</tr>
<tr>
<td>#1=1 ;</td>
<td>#1=2;</td>
<td>#1=3;</td>
<td>#1=4;</td>
<td>#1=5;</td>
</tr>
<tr>
<td>G65 P2 A2 ;</td>
<td>G65 P3 A3 ;</td>
<td>G65 P4 A4 ;</td>
<td>G65 P5 A5 ;</td>
<td>:</td>
</tr>
<tr>
<td>:</td>
<td>:</td>
<td>:</td>
<td>:</td>
<td>:</td>
</tr>
<tr>
<td>M30 ;</td>
<td>M99 ;</td>
<td>M99 ;</td>
<td>M99 ;</td>
<td>M99 ;</td>
</tr>
</tbody>
</table>

**Local variables**

<table>
<thead>
<tr>
<th>Level 0</th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
<th>Level 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>#1</td>
<td>#1</td>
<td>#1</td>
<td>#1</td>
</tr>
<tr>
<td>:</td>
<td>:</td>
<td>:</td>
<td>:</td>
<td>:</td>
</tr>
<tr>
<td>#33</td>
<td>#33</td>
<td>#33</td>
<td>#33</td>
<td>#33</td>
</tr>
</tbody>
</table>

**Common variables**

#100–, #500– Variables that can be read from and written to by macros at different levels
A macro is created which drills H holes at intervals of B degrees after a start angle of A degrees along the periphery of a circle with radius I. The center of the circle is (X,Y). Commands can be specified in either the absolute or incremental mode. To drill in the clockwise direction, specify a negative value for B.

---

**Calling format**

```
G65 P9100 X x Y y Z z R r F f I i A a B b H h ;
```

- **X**: X coordinate of the center of the circle (absolute or incremental specification) (#24)
- **Y**: Y coordinate of the center of the circle (absolute or incremental specification) (#25)
- **Z**: Hole depth (#26)
- **R**: Coordinates of an approach point (#18)
- **F**: Cutting feedrate (#9)
- **I**: Radius of the circle (#4)
- **A**: Drilling start angle (#1)
- **B**: Incremental angle (clockwise when a negative value is specified) (#2)
- **H**: Number of holes (#11)

---

**Program calling a macro program**

```
O0002;
G90 G92 X0 Y0 Z100.0;
G65 P9100 X100.0 Y50.0 R30.0 Z–50.0 F500 I100.0 A0 B45.0 H5;
M30;
```
Macro program (called program)

O9100;
#3=#4003; Stores G code of group 3.
G81 Z#26 R#18 F#9 K0; (Note) Drilling cycle.
Note: L0 can also be used.
IF[#3 EQ 90]GOTO 1; ....... Branches to N1 in the G90 mode.
#24=#5001+#24; .......... Calculates the X coordinate of the center.
#25=#5002+#25; .......... Calculates the Y coordinate of the center.
N1 WHILE[#11 GT 0]DO 1;
......................... Until the number of remaining holes reaches 0
#5=#24+#4*COS[#1]; ..... Calculates a drilling position on the X–axis.
#6=#25+#4*SIN[#1]; ..... Calculates a drilling position on the Y–axis.
G90 X#5 Y#6; ............. Performs drilling after moving to the target position.
#1=#1+#2; ............... Updates the angle.
#11=#11–1; ............... Decrements the number of holes.
END 1;
G#3 G80; ................. Returns the G code to the original state.
M99;

Meaning of variables:
#3: Stores the G code of group 3.
#5: X coordinate of the next hole to drill
#6: Y coordinate of the next hole to drill

15.6.2 Modal Call (G66)

Once G66 is issued to specify a modal call a macro is called after a block specifying movement along axes is executed. This continues until G67 is issued to cancel a modal call.

G66 P p L ℓ <argument–specification> ;
P : Number of the program to call
ℓ : Repetition count (1 by default)
Argument : Data passed to the macro
Explanations

- **Call**
  - After G66, specify at address P a program number subject to a modal call.
  - When a number of repetitions is required, a number from 1 to 9999 can be specified at address L.
  - As with a simple call (G65), data passed to a macro program is specified in arguments.

- **Cancellation**
  - When a G67 code is specified, modal macro calls are no longer performed in subsequent blocks.

- **Call nesting**
  - Calls can be nested to a depth of four levels including simple calls (G65) and modal calls (G66). This does not include subprogram calls (M98).

- **Modal call nesting**
  - Modal calls can be nested by specifying another G66 code during a modal call.

Limitations

- In a G66 block, no macros can be called.

- G66 needs to be specified before any arguments.

- No macros can be called in a block which contains a code such as a miscellaneous function that does not involve movement along an axis.

- Local variables (arguments) can only be set in G66 blocks. Note that local variables are not set each time a modal call is performed.

Sample program

The same operation as the drilling canned cycle G81 is created using a custom macro and the machining program makes a modal macro call. For program simplicity, all drilling data is specified using absolute values.

The canned cycle consists of the following basic operations:

- **Operation 1:** Positioning along the X-axis and Y-axis
- **Operation 2:** Rapid traverse to point R
- **Operation 3:** Cutting feed to point Z
- **Operation 4:** Rapid traverse to point R or I

---

**Sample program**

The same operation as the drilling canned cycle G81 is created using a custom macro and the machining program makes a modal macro call. For program simplicity, all drilling data is specified using absolute values.

<table>
<thead>
<tr>
<th>Operation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Positioning along the X-axis and Y-axis</td>
</tr>
<tr>
<td>2</td>
<td>Rapid traverse to point R</td>
</tr>
<tr>
<td>3</td>
<td>Cutting feed to point Z</td>
</tr>
<tr>
<td>4</td>
<td>Rapid traverse to point R or I</td>
</tr>
</tbody>
</table>

---

**Sample program**

The same operation as the drilling canned cycle G81 is created using a custom macro and the machining program makes a modal macro call. For program simplicity, all drilling data is specified using absolute values.
15. CUSTOM MACRO

• Calling format

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>G65 P9110 X x Y y Z z R r F f L l ;</td>
<td>Custom macro command</td>
</tr>
</tbody>
</table>

X: X coordinate of the hole (absolute specification only) ...... (#24)
Y: Y coordinate of the hole (absolute specification only) ...... (#25)
Z: Coordinates of position Z (absolute specification only) ...... (#26)
R: Coordinates of position R (absolute specification only) ...... (#18)
F: Cutting feedrate ............................................. (#9)
L: Repetition count

• Program that calls a macro program

O0001;
G28 G91 X0 Y0 Z0;
G92 X0 Y0 Z50.0;
G00 G90 X100.0 Y50.0;
G66 P9110 Z–20.0 R5.0 F500;
G90 X20.0 Y20.0;
X50.0;
Y50.0;
X70.0 Y80.0;
G67;
M30;

• Macro program (program called)

O9110;
#1=#4001; ................ Stores G00/G01.
#3=#4003; ................ Stores G90/G91.
#4=#4109; ................ Stores the cutting feedrate.
#5=#5003; ................ Stores the Z coordinate at the start of drilling.
G00 G90 Z#18; ............ Positioning at position R
G01 Z#26 F#9; ............ Cutting feed to position Z
IF[#4010 EQ 98]GOTO 1; Return to position I
G00 Z#18; ............... Positioning at position R
GOTO 2;
N1 G00 Z#5; .............. Positioning at position I
N2 G#1 G#3 F#4; ........ Restores modal information.
M99;

15.6.3 Macro Call Using G Code

By setting a G code number used to call a macro program in a parameter, the macro program can be called in the same way as for a simple call (G65).

<table>
<thead>
<tr>
<th>Parameter No.6050 = 81</th>
</tr>
</thead>
<tbody>
<tr>
<td>O0001 ;</td>
</tr>
<tr>
<td>G81 X10.0 Y20.0 Z=10.0 ;</td>
</tr>
</tbody>
</table>

Explanations

By setting a G code number from 1 to 9999 used to call a custom macro program (O9010 to O9019) in the corresponding parameter (N0.6050 to No.6059), the macro program can be called in the same way as with G65. For example, when a parameter is set so that macro program O9010 can be called with G81, a user-specific cycle created using a custom macro can be called without modifying the machining program.
15. CUSTOM MACRO

- Correspondence between parameter numbers and program numbers

<table>
<thead>
<tr>
<th>Program number</th>
<th>Parameter number</th>
</tr>
</thead>
<tbody>
<tr>
<td>O9010</td>
<td>6050</td>
</tr>
<tr>
<td>O9011</td>
<td>6051</td>
</tr>
<tr>
<td>O9012</td>
<td>6052</td>
</tr>
<tr>
<td>O9013</td>
<td>6053</td>
</tr>
<tr>
<td>O9014</td>
<td>6054</td>
</tr>
<tr>
<td>O9015</td>
<td>6055</td>
</tr>
<tr>
<td>O9016</td>
<td>6056</td>
</tr>
<tr>
<td>O9017</td>
<td>6057</td>
</tr>
<tr>
<td>O9018</td>
<td>6058</td>
</tr>
<tr>
<td>O9019</td>
<td>6059</td>
</tr>
</tbody>
</table>

- Repetition
As with a simple call, a number of repetitions from 1 to 9999 can be specified at address L.

- Argument specification
As with a simple call, two types of argument specification are available: Argument specification I and argument specification II. The type of argument specification is determined automatically according to the addresses used.

Limitations

- Nesting of calls using G codes
In a program called with a G code, no macros can be called using a G code. A G code in such a program is treated as an ordinary G code. In a program called as a subprogram with an M or T code, no macros can be called using a G code. A G code in such a program is also treated as an ordinary G code.

15.6.4
Macro Call Using an M Code

By setting an M code number used to call a macro program in a parameter, the macro program can be called in the same way as with a simple call (G65).

Explanations
By setting an M code number from 1 to 99999999 used to call a custom macro program (9020 to 9029) in the corresponding parameter (No.6080 to No.6089), the macro program can be called in the same way as with G65.
• Correspondence between parameter numbers and program numbers

<table>
<thead>
<tr>
<th>Program number</th>
<th>Parameter number</th>
</tr>
</thead>
<tbody>
<tr>
<td>O9020</td>
<td>6080</td>
</tr>
<tr>
<td>O9021</td>
<td>6081</td>
</tr>
<tr>
<td>O9022</td>
<td>6082</td>
</tr>
<tr>
<td>O9023</td>
<td>6083</td>
</tr>
<tr>
<td>O9024</td>
<td>6084</td>
</tr>
<tr>
<td>O9025</td>
<td>6085</td>
</tr>
<tr>
<td>O9026</td>
<td>6086</td>
</tr>
<tr>
<td>O9027</td>
<td>6087</td>
</tr>
<tr>
<td>O9028</td>
<td>6088</td>
</tr>
<tr>
<td>O9029</td>
<td>6089</td>
</tr>
</tbody>
</table>

• Repetition

As with a simple call, a number of repetitions from 1 to 9999 can be specified at address L.

• Argument specification

As with a simple call, two types of argument specification are available: Argument specification I and argument specification II. The type of argument specification is determined automatically according to the addresses used.

Limitations

• An M code used to call a macro program must be specified at the start of a block.
• In a macro called with a G code or in a program called as a subprogram with an M or T code, no macros can be called using an M code. An M code in such a macro or program is treated as an ordinary M code.

15.6.5 Subprogram Call Using an M Code

By setting an M code number used to call a subprogram (macro program) in a parameter, the macro program can be called in the same way as with a subprogram call (M98).

Explanations

By setting an M code number from 1 to 99999999 used to call a subprogram in a parameter (No.6071 to No. 6079), the corresponding custom macro program (O9001 to O9009) can be called in the same way as with M98.
15. CUSTOM MACRO

• Correspondence between parameter numbers and program numbers

<table>
<thead>
<tr>
<th>Program number</th>
<th>Parameter number</th>
</tr>
</thead>
<tbody>
<tr>
<td>O9001</td>
<td>6071</td>
</tr>
<tr>
<td>O9002</td>
<td>6072</td>
</tr>
<tr>
<td>O9003</td>
<td>6073</td>
</tr>
<tr>
<td>O9004</td>
<td>6074</td>
</tr>
<tr>
<td>O9005</td>
<td>6075</td>
</tr>
<tr>
<td>O9006</td>
<td>6076</td>
</tr>
<tr>
<td>O9007</td>
<td>6077</td>
</tr>
<tr>
<td>O9008</td>
<td>6078</td>
</tr>
<tr>
<td>O9009</td>
<td>6079</td>
</tr>
</tbody>
</table>

• Repetition

As with a simple call, a number of repetitions from 1 to 9999 can be specified at address L.

• Argument specification

Argument specification is not allowed.

• M code

An M code in a macro program that has been called is treated as an ordinary M code.

Limitations

In a macro called with a G code or in a program called with an M or T code, no subprograms can be called using an M code. An M code in such a macro or program is treated as an ordinary M code.

15.6.6 Subprogram Calls Using a T Code

By enabling subprograms (macro program) to be called with a T code in a parameter, a macro program can be called each time the T code is specified in the machining program.

```
O0001 ;
    ...
T23 ;
    ...
M30 ;
    ...
```

Bit 5 of parameter 6001 = 1

Explanations

• Call

By setting bit 5 of parameter TCS No.6001 to 1, the macro program O9000 can be called when a T code is specified in the machining program. A T code specified in a machining program is assigned to common variable #149.

Limitations

In a macro called with a G code or in a program called with an M or T code, no subprograms can be called using a T code. A T code in such a macro or program is treated as an ordinary T code.
15.6.7 Sample Program

Conditions

By using the subprogram call function that uses M codes, the cumulative usage time of each tool is measured.

- The cumulative usage time of each of tools T01 to T05 is measured. No measurement is made for tools with numbers greater than T05.

- The following variables are used to store the tool numbers and measured times:

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>#501</td>
<td>Cumulative usage time of tool number 1</td>
</tr>
<tr>
<td>#502</td>
<td>Cumulative usage time of tool number 2</td>
</tr>
<tr>
<td>#503</td>
<td>Cumulative usage time of tool number 3</td>
</tr>
<tr>
<td>#504</td>
<td>Cumulative usage time of tool number 4</td>
</tr>
<tr>
<td>#505</td>
<td>Cumulative usage time of tool number 5</td>
</tr>
</tbody>
</table>

- Usage time starts being counted when the M03 command is specified and stops when M05 is specified. System variable #3002 is used to measure the time during which the cycle start lamp is on. The time during which the machine is stopped by feed hold and single block stop operation is not counted, but the time used to change tools and pallets is included.

Operation check

- **Parameter setting**
  
  Set 3 in parameter No.6071, and set 05 in parameter No.6072.

- **Variable value setting**
  
  Set 0 in variables #501 to #505.

- **Program that calls a macro program**

  O0001;
  T01 M06;
  M03;
  M05;  ................. Changes #501.
  T02 M06;
  M03;
  M05;  ................. Changes #502.
  T03 M06;
  M03;
  M05;  ................. Changes #503.
  T04 M06;
  M03;
  M05;  ................. Changes #504.
  T05 M06;
  M03;
  M05;  ................. Changes #505.
  M30;
Macro program (program called)

O9001(M03); ................. Macro to start counting
M01;
IF[#4120 EQ 0]GOTO 9; ........ No tool specified
IF[#4120 GT 5]GOTO 9; ........ Out-of-range tool number
#3002=0; ..................... Clears the timer.
N9 M03; ....................... Rotates the spindle in the forward direction.
M99;

O9002(M05); ................. Macro to end counting
M01;
IF[#4120 EQ 0]GOTO 9; ........ No tool specified
IF[#4120 GT 5]GOTO 9; ........ Out-of-range tool number
#(500+#4120)=#3002+#(500+#4120); Calculates cumulative time.
N9 M05; ....................... Stops the spindle.
M99;
For smooth machining, the CNC prereads the NC statement to be performed next. This operation is referred to as buffering. During AI contour control mode or AI nano contour control mode, the CNC prereads not only the next block but also the multiple blocks. And in the cutter compensation mode (G41, G42), the CNC prereads the NC statements two or three blocks ahead to find intersections even if the CNC is not in AI contour control mode nor AI nano contour control mode. Macro statements for arithmetic expressions and conditional branches are processed as soon as they are read into the buffer. Therefore, the timing of the macro statement execution is not always the specified order. At the blocks containing M00, M01, M02 or M30, blocks containing M-codes for which buffering is suppressed by setting parameter (No.3411–3432), and blocks containing prevention buffering G codes such as G53, the CNC stops to preread the NC statement after that. Then, the stop of the macro statement execution is guaranteed until such M codes or G codes complete its execution.

### 15.7.1 Details of NC Statements and Macro Statements Execution

- **When the next block is not buffered** (M codes that are not buffered, G53, G31, etc.)

![Diagram showing NC and Macro statement execution](image_url)

**NOTE**

In case that you need to execute the macro statement after completing the block just before the macro statement, specify M code or G code that are not buffered just before the macro statement. Specially, in case of reading / writing the system variables to control signals, coordinates, offset value, etc., it may different system variable data by the timing of the NC statement execution. To avoid this phenomenon, specify such M codes or G codes before the macro statement, if necessary.
• Buffering the next block in other than cutter compensation mode (G41, G42) (normally prereading one block)

When N1 is being executed, the next NC statement (N4) is read into the buffer. The macro statements (N2, N3) between N1 and N4 are processed during execution of N1.

• Buffering the next block in cutter compensation mode (G41, G42)

When N1 is being executed, the NC statements in the next two blocks (up to N5) are read into the buffer. The macro statements (N2, N4) between N1 and N5 are processed during execution of N1.
• When the next block involves no movement in cutter compensation C (G41, G42) mode

When the N1 is being executed, the NC statements in the next two blocks (up to N5) are read into the buffer. Since N5 is a block that involves no movement, an intersection cannot be calculated. In this case, the NC statements in the next three blocks (up to N7) are read. The macro statements (N2, N4, and N6) between N1 and N7 are processed during execution of N1.

15.7.2
Caution for Using System Variables

In case of using the following system variables in macro program and you need to execute the macro program after completing the block execution just before the macro program, M code which can prevent buffering (parameter No.3411–3432) or G53 command block is necessary just before the macro program.

<table>
<thead>
<tr>
<th>Meaning</th>
<th>Read</th>
<th>Write</th>
<th>Number of Variable</th>
<th>Note (In case not to command M code preventing buffering or G53 block.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interface signals</td>
<td>Read</td>
<td>Write</td>
<td>#1000 – #1015,</td>
<td>The data is read at buffering a macro program.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>#1032</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tool compensation values</td>
<td>Write</td>
<td></td>
<td>#10001 –</td>
<td>The data is written at buffering a macro program.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Macro alarms</td>
<td>Write</td>
<td></td>
<td>#3000</td>
<td>Macro alarm is generated at maximum 2 blocks before a macro program.</td>
</tr>
<tr>
<td>Program stop with message</td>
<td>Write</td>
<td></td>
<td>#3006</td>
<td>Program stops at maximum 2 blocks before a macro program.</td>
</tr>
<tr>
<td>Meaning</td>
<td>Read/Write</td>
<td>Number of Variable</td>
<td>Note (In case not to command M code preventing buffering or G53 block.)</td>
<td></td>
</tr>
<tr>
<td>----------------------------------------------</td>
<td>------------</td>
<td>-------------------------------------</td>
<td>------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Meanings</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time information</td>
<td>Read/Write</td>
<td>#3001,#3002</td>
<td>The data is read/written at buffering a macro program.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Read</td>
<td>#3011,#3012</td>
<td>The data is read at buffering a macro program.</td>
<td></td>
</tr>
<tr>
<td>Automatic operation control</td>
<td>Write</td>
<td>#3003,#3004</td>
<td>Setting data is available at maximum 2 blocks before a macro program.</td>
<td></td>
</tr>
<tr>
<td>Settings</td>
<td>Write</td>
<td>#3005</td>
<td>The data is written at buffering a macro program.</td>
<td></td>
</tr>
<tr>
<td>Mirror image</td>
<td>Read</td>
<td>#3007</td>
<td>The data is read at buffering a macro program.</td>
<td></td>
</tr>
<tr>
<td>Currently selected additional workpiece coordinate system</td>
<td>Read</td>
<td>#4130(P) #4014 (G54–G59)</td>
<td>The data is read at maximum 3 blocks before a macro program.</td>
<td></td>
</tr>
<tr>
<td>Current position (Machine coordinate system)</td>
<td>Read</td>
<td>#5021–#5028</td>
<td>The uncertain position in moving is read.</td>
<td></td>
</tr>
<tr>
<td>Current position (Workpiece coordinate system)</td>
<td>Read</td>
<td>#5041–#5048</td>
<td>The uncertain position in moving is read.</td>
<td></td>
</tr>
<tr>
<td>Tool length offset value</td>
<td>Read</td>
<td>#5081–#5088</td>
<td>The offset value of current execution block is read.</td>
<td></td>
</tr>
<tr>
<td>Deviated servo position</td>
<td>Read</td>
<td>#5101–#5108</td>
<td>The uncertain deviation in moving is read.</td>
<td></td>
</tr>
<tr>
<td>Workpiece zero point offset value</td>
<td>Write</td>
<td>#5201–#5328 #7001–#7948 #14001–#19988</td>
<td>The data is written at buffering a macro program.</td>
<td></td>
</tr>
</tbody>
</table>
Example)

```
O0001
N1 X10.Y10.;  (Mxx ;) Specify preventing buffering M code or G53
N2 M98P2000;  N100 #1=#5041;(Reading X axis current position)
N3 Y200.0;  N101 #2=#5042;(Reading Y axis current position)
            M99;
```

In above case, the buffering of N2 block is done and the macro program of O2000 is read and executed during N1 block of main program O1000 execution. Therefore, the current position readings are executed during axes movements at N1 block. So the unexpected position data can be read to #1 and #2 because of axes movements. In this case, please specify M code preventing buffering Mxx ; (or G53 ;) just before N100 block of O2000. By this, the position data at completing the execution of N1 block can be read to #1 and #2 because O2000 is executed after completing the execution of N1 block of O0001.

**NOTE**

G53 can not be specified during the canned cycle mode. (In this case, the alarm 44 is generated.) Therefore, in order to prevent buffering during the canned cycle mode, please specify preventing buffering M code.
15.8 REGISTERING CUSTOM MACRO PROGRAMS

Custom macro programs are similar to subprograms. They can be registered and edited in the same way as subprograms. The storage capacity is determined by the total length of tape used to store both custom macros and subprograms.
15.9 LIMITATIONS

- **MDI operation**
  The macro call command can be specified in MDI mode. During automatic operation, however, it is impossible to switch to the MDI mode for a macro program call.

- **Sequence number search**
  A custom macro program cannot be searched for a sequence number.

- **Single block**
  Even while a macro program is being executed, blocks can be stopped in the single block mode.
  A block containing a macro call command (G65, G66, or G67) does not stop even when the single block mode is on. Blocks containing arithmetic operation commands and control commands can be stopped in single block mode by setting SBM (bit 5 of parameter 6000) to 1.
  Single block stop operation is used for testing custom macro programs. Note that when a single block stop occurs at a macro statement in cutter compensation C mode, the statement is assumed to be a block that does not involve movement, and proper compensation cannot be performed in some cases. (Strictly speaking, the block is regarded as specifying a movement with a travel distance 0.)

- **Optional block skip**
  A / appearing in the middle of an <expression> (enclosed in brackets [ ] on the right-hand side of an arithmetic expression) is regarded as a division operator; it is not regarded as the specifier for an optional block skip code.

- **Operation in EDIT mode**
  By setting NE8 (bit 0 of parameter 3202) and NE9 (bit 4 of parameter 3202) to 1, deletion and editing are disabled for custom macro programs and subprograms with program numbers 8000 to 8999 and 9000 to 9999. This prevents registered custom macro programs and subprograms from being destroyed by accident. When the entire memory is cleared (by pressing the [RESET] and [DELETE] keys at the same time to turn on the power), the contents of memory such as custom macro programs are deleted.

- **Reset**
  With a reset operation, local variables and common variables #100 to #149 are cleared to null values. They can be prevented from clearing by setting, CLV and CCV (bits 7 and 6 of parameter 6001). System variables #1000 to #1133 are not cleared.
  A reset operation clears any called states of custom macro programs and subprograms, and any DO states, and returns control to the main program.

- **Display of the PROGRAM RESTART**
  As with M98, the M and T codes used for subprogram calls are not displayed.

- **Feed hold**
  When a feed hold is enabled during execution of a macro statement, the machine stops after execution of the macro statement. The machine also stops when a reset or alarm occurs.

- **Constant values that can be used in <expression>**
  +0.0000001 to +99999999
  –99999999 to –0.0000001
  The number of significant digits is 8 (decimal). If this range is exceeded, P/S alarm No. 003 occurs.
In addition to the standard custom macro commands, the following macro commands are available. They are referred to as external output commands.

- **BPRNT**
- **DPRNT**
- **POPEN**
- **PCLOS**

These commands are provided to output variable values and characters through the reader/punch interface.

**Explanations**

Specify these commands in the following order:

**Open command: POPEN**

Before specifying a sequence of data output commands, specify this command to establish a connection to an external input/output device.

**Data output command: BPRNT or DPRNT**

Specify necessary data output.

**Close command: PCLOS**

When all data output commands have completed, specify PCLOS to release a connection to an external input/output device.

**Open command POPEN**

**POPEN**

POPEN establishes a connection to an external input/output device. It must be specified before a sequence of data output commands. The CNC outputs a DC2 control code.

**Data output command BPRNT**

BPRNT [ a #b [ c ] ...]

Number of significant decimal places

Variable

Character

The BPRNT command outputs characters and variable values in binary.

(i) Specified characters are converted to the codes according to the setting data (ISO) that is output at that time. Specifiable characters are as follows:

- **Letters (A to Z)**
- **Numbers**
- **Special characters (*, /, +, −, etc.)**

An asterisk (*) is output by a space code.

(ii) All variables are stored with a decimal point. Specify a variable followed by the number of significant decimal places enclosed in brackets. A variable value is treated as 2–word (32–bit) data, including the decimal digits. It is output as binary data starting from the highest byte.

(iii) When specified data has been output, an EOB code is output according to the setting code (ISO).

(iv) Null variables are regarded as 0.
Example)

\[ \text{BPRNT } \{ \text{C}^* \text{ X}\#100 [3] Y\#101 [3] M\#10 [0] } \]

Variable value

\#100=0.40956
\#101=-1638.4
\#10=12.34

\[ \text{DPRNT } \{ a \#b \text{ [c d]} \ldots \}\]

Number of significant decimal places
Number of significant digits in the integer part
Variable
digit
Character

The DPRNT command outputs characters and each digit in the value of a variable according to the code set in the settings (ISO).

(i) For an explanation of the DPRNT command, see Items (i), (iii), and (iv) for the BPRNT command.

(ii) When outputting a variable, specify \# followed by the variable number, then specify the number of digits in the integer part and the number of decimal places enclosed in brackets.
One code is output for each of the specified number of digits, starting with the highest digit. For each digit, a code is output according to the settings (ISO). The decimal point is also output using a code set in the settings (ISO).
Each variable must be a numeric value consisting of up to eight digits. When high-order digits are zeros, these zeros are not output if PRT (bit 1 of parameter 6001) is 1. If parameter PRT is 0, a space code is output each time a zero is encountered.
When the number of decimal places is not zero, digits in the decimal part are always output. If the number of decimal places is zero, no decimal point is output.
When PRT (bit 1 of parameter 6001) is 0, a space code is output to indicate a positive number instead of +; if parameter PRT is 1, no code is output.
Example )


Variable value
#2=128.47398
#5=–91.2
#30=123.456

(1) Parameter PRT(No.6001#1)=0

(2) Parameter PRT(No.6001#1)=0

- Close command PCLOS
  PCLOS ;
  The PCLOS command releases a connection to an external input/output device. Specify this command when all data output commands have terminated. DC4 control code is output from the CNC.

- Required setting
  Specify the channel use for setting data (I/O channel). According to the specification of this data, set data items (such as the baud rate) for the reader/punch interface.
  I/O channel 0 : Parameters (No.101, No.102 and No.103)
  I/O channel 1 : Parameters (No.111, No.112 and No.113)
  I/O channel 2 : Parameters (No.112, No.122 and No.123)
  Never specify the output device FANUC Cassette or Floppy for punching. When specifying a DPRNT command to output data, specify whether leading zeros are output as spaces (by setting PRT (bit 1 of parameter 6001) to 1 or 0).
  To indicate the end of a line of data in ISO code, specify whether to use only an LF (CRO, of bit 4 of parameter 6001 is 0) or an LF and CR (CRO of bit 4 of parameter 6001 is 1).
NOTE
1 It is not necessary to always specify the open command (POpen), data output command (BPRNT, DPRNT), and close command (PCLOS) together. Once an open command is specified at the beginning of a program, it does not need to be specified again except after a close command was specified.
2 Be sure to specify open commands and close commands in pairs. Specify the close command at the end of the program. However, do not specify a close command if no open command has been specified.
3 When a reset operation is performed while commands are being output by a data output command, output is stopped and subsequent data is erased. Therefore, when a reset operation is performed by a code such as M30 at the end of a program that performs data output, specify a close command at the end of the program so that processing such as M30 is not performed until all data is output.
4 Abbreviated macro words enclosed in brackets [ ] remains unchanged. However, note that when the characters in brackets are divided and input several times, the second and subsequent abbreviations are converted and input.
5 O can be specified in brackets [ ]. Note that when the characters in brackets [ ] are divided and input several times, O is omitted in the second and subsequent inputs.
When a program is being executed, another program can be called by inputting an interrupt signal (UINT) from the machine. This function is referred to as an interruption type custom macro function. Program an interrupt command in the following format:

<table>
<thead>
<tr>
<th>M96 Pxxxx;</th>
<th>Enables custom macro interrupt</th>
</tr>
</thead>
<tbody>
<tr>
<td>M97</td>
<td>Disables custom macro interrupt</td>
</tr>
</tbody>
</table>

Use of the interruption type custom macro function allows the user to call a program during execution of an arbitrary block of another program. This allows programs to be operated to match situations which vary from time to time.

1. When a tool abnormality is detected, processing to handle the abnormality is started by an external signal.
2. A sequence of machining operations is interrupted by another machining operation without the cancellation of the current operation.
3. At regular intervals, information on current machining is read. Listed above are examples like adaptive control applications of the interruption type custom macro function.

When M96Pxxxx is specified in a program, subsequent program operation can be interrupted by an interrupt signal (UINT) input to execute the program specified by Pxxxx.


CAUTION
When the interrupt signal (UINT, marked by * in Fig. 15.11) is input after M97 is specified, it is ignored.
And, the interrupt signal must not be input during execution of the interrupt program.

15.11.1 Specification Method

Explanations
- **Interrupt conditions**
  
  A custom macro interrupt is available only during program execution. It is enabled under the following conditions:
  - When memory operation or MDI operation is selected
  - When STL (start lamp) is on
  - When a custom macro interrupt is not currently being processed
  
- **Specification**

  Generally, the custom macro interrupt function is used by specifying M96 to enable the interrupt signal (UINT) and M97 to disable the signal. Once M96 is specified, a custom macro interrupt can be initiated by the input of the interrupt signal (UINT) until M97 is specified or the NC is reset. After M97 is specified or the NC is reset, no custom macro interrupts are initiated even when the interrupt signal (UINT) is input. The interrupt signal (UINT) is ignored until another M96 command is specified.

The interrupt signal (UINT) becomes valid after M96 is specified. Even when the signal is input in M97 mode, it is ignored. When the signal input in M97 mode is kept on until M96 is specified, a custom macro interrupt is initiated as soon as M96 is specified (only when the status–triggered scheme is employed); when the edge–triggered scheme is employed, the custom macro interrupt is not initiated even when M96 is specified.

NOTE

For the status–triggered and edge–triggered schemes, see Item “Custom macro interrupt signal (UINT)” of II– 15.11.2.
15.11.2 Details of Functions

Explanations

- **Subprogram–type interrupt and macro–type interrupt**

  There are two types of custom macro interrupts: Subprogram–type interrupts and macro–type interrupts. The interrupt type used is selected by MSB (bit 5 of parameter 6003).

  (a) **Subprogram–type interrupt**

  An interrupt program is called as a subprogram. This means that the levels of local variables remain unchanged before and after the interrupt. This interrupt is not included in the nesting level of subprogram calls.

  (b) **Macro–type interrupt**

  An interrupt program is called as a custom macro. This means that the levels of local variables change before and after the interrupt. The interrupt is not included in the nesting level of custom macro calls. When a subprogram call or a custom macro call is performed within the interrupt program, this call is included in the nesting level of subprogram calls or custom macro calls. Arguments cannot be passed from the current program even when the custom macro interrupt is a macro–type interrupt.

- **M codes for custom macro interrupt control**

  In general, custom macro interrupts are controlled by M96 and M97. However, these M codes, may already being used for other purposes (such as an M function or macro M code call) by some machine tool builders. For this reason, MPR (bit 4 of parameter 6003) is provided to set M codes for custom macro interrupt control.

  When specifying this parameter to use the custom macro interrupt control M codes by parameters, set parameters 6033 and 6034 as follows:

  Set the M code to enable custom macro interrupts in parameter 6033, and set the M code to disable custom macro interrupts in parameter 6034.

  When specifying that parameter–set M codes are not used, M96 and M97 are used as the custom macro control M codes regardless of the settings of parameters 6033 and 6034.

  The M codes used for custom macro interrupt control are processed internally (they are not output to external units). However, in terms of program compatibility, it is undesirable to use M codes other than M96 and M97 to control custom macro interrupts.

- **Custom macro interrupts and NC statements**

  When performing a custom macro interrupt, the user may want to interrupt the NC statement being executed, or the user may not want to perform the interrupt until the execution of the current block is completed. MIN (bit 2 of parameter 6003) is used to select whether to perform interrupts even in the middle of a block or to wait until the end of the block.

  (i) When the interrupt signal (UINT) is input, any movement or dwell being performed is stopped immediately and the interrupt program is executed.

  (ii) If there are NC statements in the interrupt program, the command in the interrupted block is lost and the NC statement in the interrupt program is executed. When control is returned to the interrupted program, the program is restarted from the next block after the interrupted block.
(iii) If there are no NC statements in the interrupt program, control is returned to the interrupted program by M99, then the program is restarted from the command in the interrupted block.

(i) If the block being executed is not a block that consists of several cycle operations such as a drilling canned cycle and automatic reference position return (G28), an interrupt is performed as follows: When an interrupt signal (UINT) is input, macro statements in the interrupt program are executed immediately unless an NC statement is encountered in the interrupt program. NC statements are not executed until the current block is completed.

(ii) If the block being executed consists of several cycle operations, an interrupt is performed as follows: When the last movement in the cycle operations is started, macro statements in the interrupt program are executed unless an NC statement is encountered. NC statements are executed after all cycle operations are completed.
• Conditions for enabling and disabling the custom macro interrupt signal

The interrupt signal becomes valid after execution starts of a block that contains M96 for enabling custom macro interrupts. The signal becomes invalid when execution starts of a block that contains M97. While an interrupt program is being executed, the interrupt signal becomes invalid. The signal become valid when the execution of the block that immediately follows the interrupted block in the main program is started after control returns from the interrupt program. In type I, if the interrupt program consists of only macro statements, the interrupt signal becomes valid when execution of the interrupted block is started after control returns from the interrupt program.

• Custom macro interrupt during execution of a block that involves cycle operation

   For type I

Even when cycle operation is in progress, movement is interrupted, and the interrupt program is executed. If the interrupt program contains no NC statements, the cycle operation is restarted after control is returned to the interrupted program. If there are NC statements, the remaining operations in the interrupted cycle are discarded, and the next block is executed.

   For type II

When the last movement of the cycle operation is started, macro statements in the interrupt program are executed unless an NC statement is encountered. NC statements are executed after cycle operation is completed.
• Custom macro interrupt signal (UINT)

There are two schemes for custom macro interrupt signal (UINT) input: The status–triggered scheme and edge–triggered scheme. When the status–triggered scheme is used, the signal is valid when it is on. When the edge triggered scheme is used, the signal becomes valid on the rising edge when it switches from off to on status.

One of the two schemes is selected with TSE (bit 3 of parameter 6003). When the status–triggered scheme is selected by this parameter, a custom macro interrupt is generated if the interrupt signal (UINT) is on at the time the signal becomes valid. By keeping the interrupt signal (UINT) on, the interrupt program can be executed repeatedly.

When the edge–triggered scheme is selected, the interrupt signal (UINT) becomes valid only on its rising edge. Therefore, the interrupt program is executed only momentarily (in cases when the program consists of only macro statements). When the status–triggered scheme is inappropriate, or when a custom macro interrupt is to be performed just once for the entire program (in this case, the interrupt signal may be kept on), the edge–triggered scheme is useful.

Except for the specific applications mentioned above, use of either scheme results in the same effects. The time from signal input until a custom macro interrupt is executed does not vary between the two schemes.

In the above example, an interrupt is executed four times when the status triggered scheme is used; when the edge–triggered scheme is used, the interrupt is executed just once.
To return control from a custom macro interrupt to the interrupted program, specify M99. A sequence number in the interrupted program can also be specified using address P. If this is specified, the program is searched from the beginning for the specified sequence number. Control is returned to the first sequence number found.

When a custom macro interrupt program is being executed, no interrupts are generated. To enable another interrupt, execute M99. When M99 is specified alone, it is executed before the preceding commands terminate. Therefore, a custom macro interrupt is enabled for the last command of the interrupt program. If this is inconvenient, custom macro interrupts should be controlled by specifying M96 and M97 in the program.

When a custom macro interrupt is being executed, no other custom macro interrupts are generated; when an interrupt is generated, additional interrupts are inhibited automatically. Executing M99 makes it possible for another custom macro interrupt to occur. M99 specified alone in a block is executed before the previous block terminates. In the following example, an interrupt is enabled for the Gxx block of O1234. When the signal is input, O1234 is executed again. O5678 is controlled by M96 and M97. In this case, an interrupt is not enabled for O5678 (enabled after control is returned to O1000).
NOTE
When an M99 block consists only of address O, N, P, L, or M, this block is regarded as belonging to the previous block in the program. Therefore, a single-block stop does not occur for this block. In terms of programming, the following and are basically the same. (The difference is whether G00 is executed before M99 is recognized.)

\[
\begin{align*}
\text{1} & \quad G00 \ X000 \ ; \\
& \quad M99 \ ; \\
\text{2} & \quad G00 \ X000 \ M99 \ ;
\end{align*}
\]

- Custom macro interrupt and modal information

A custom macro interrupt is different from a normal program call. It is initiated by an interrupt signal (UINT) during program execution. In general, any modifications of modal information made by the interrupt program should not affect the interrupted program. For this reason, even when modal information is modified by the interrupt program, the modal information before the interrupt is restored when control is returned to the interrupted program by M99.

When control is returned from the interrupt program to the interrupted program by M99 Pxxx, modal information can again be controlled by the program. In this case, the new continuous information modified by the interrupt program is passed to the interrupted program. Restoration of the old modal information present before the interrupt is not desirable. This is because after control is returned, some programs may operate differently depending on the modal information present before the interrupt. In this case, the following measures are applicable:

1. The interrupt program provides modal information to be used after control is returned to the interrupted program.
(2) After control is returned to the interrupted program, modal information is specified again as necessary.

Modal information when control is returned by M99

The modal information present before the interrupt becomes valid. The new modal information modified by the interrupt program is made invalid.

The new modal information modified by the interrupt program remains valid even after control is returned. The old modal information which was valid in the interrupted block can be read using custom macro system variables #4001 to #4120.

Note that when modal information is modified by the interrupt program, system variables #4001 to #4120 are not changed.

- The coordinates of point A can be read using system variables #5001 and up until the first NC statement is encountered.
- The coordinates of point A’ can be read after an NC statement with no move specifications appears.
- The machine coordinates and workpiece coordinates of point B’ can be read using system variables #5021 and up and #5041 and up.
| Custom macro interrupt and custom macro modal call | When the interrupt signal (UINT) is input and an interrupt program is called, the custom macro modal call is canceled (G67). However, when G66 is specified in the interrupt program, the custom macro modal call becomes valid. When control is returned from the interrupt program by M99, the modal call is restored to the state it was in before the interrupt was generated. When control is returned by M99Pxxxx;, the modal call in the interrupt program remains valid. |
| Custom macro interrupt and program restart | When the interrupt signal (UINT) is input while a return operation is being performed in the dry run mode after the search operation for program restart, the interrupt program is called after restart operation terminates for all axes. This means that interrupt type II is used regardless of the parameter setting. |
| DNC operation and interruption type custom macro | “ Interruption type custom macro” cannot be done during DNC operation or executing a program with an external input–output device. |
This function enables users to perform programming simply by extracting numeric data (pattern data) from a drawing and specifying the numerical values from the MDI panel. This eliminates the need for programming using an existing NC language.

With the aid of this function, a machine tool builder can prepare the program of a hole machining cycle (such as a boring cycle or tapping cycle) using the custom macro function, and can store it into the program memory. This cycle is assigned pattern names, such as BOR1, TAP3, and DRL2.

An operator can select a pattern from the menu of pattern names displayed on the screen. Data (pattern data) which is to be specified by the operator should be created in advance with variables in a drilling cycle. The operator can identify these variables using names such as DEPTH, RETURN RELIEF, FEED, MATERIAL or other pattern data names. The operator assigns values (pattern data) to these names.
16.1  DISPLAYING THE PATTERN MENU

Pressing the OFFSET SETTING key and [MENU] is displayed on the following pattern menu screen.

![Pattern Menu Screen]

**HOLE PATTERN**: This is the menu title. An arbitrary character string consisting of up to 12 characters can be specified.

**BOLT HOLE**: This is the pattern name. An arbitrary character string consisting of up to 10 characters can be specified, including katakana.

The machine tool builder should specify the character strings for the menu title and pattern name using the custom macro, and load the character strings into program memory as a subprogram of program No. 9500.
16. PATTERN DATA INPUT

FUNCTION

PROGRAMMING

B-63534EN/02

• Macro commands specifying the menu title

Menu title: C1 C2 C3 C4 C5 C6 C7 C8 C9 C10 C11 C12
C1, C2, . . . C12: Characters in the menu title (12 characters)

Macro instruction

G65 H90 P Q R I J K:
H90: Specifies the menu title
p: Assume a1 and a2 to be the codes of characters C1 and C2. Then,

q: Assume a3 and a4 to be the codes of characters C3 and C4. Then,

r: Assume a5 and a6 to be the codes of characters C5 and C6. Then,

i: Assume a7 and a8 to be the codes of characters C7 and C8. Then,

j: Assume a9 and a10 to be the codes of characters C9 and C10. Then,

k: Assume a11 and a12 to be the codes of characters C11 and C12. Then,

Example) If the title of the menu is "HOLE PATTERN" then the macro instruction is as follows:

G65 H90 P072079 Q076069 R032080

HO LE P

I065084 J084069 K082078;

AT TE RN

For codes corresponding to these characters, refer to the table in II–16.3.
16. PATTERN DATA INPUT

FUNCTION

- **Macro instruction describing the pattern name**

  - **Pattern name**: C₁ C₂ C₃ C₄ C₅ C₆ C₇ C₈ C₉ C₁₀
  - C₁, C₂, C₁₀: Characters in the pattern name (10 characters)

  **Macro instruction**
  
  G65 H91 Pₙ Qᵣ Iᵢ Jⱼ Kₖ ;

  **H91**: Specifies the menu title
  - n: Specifies the menu No. of the pattern name
    - n = 1 to 10
  - q: Assume a₁ and a₂ to be the codes of characters C₁ and C₂. Then,
    - q = a₁ × 10³ + a₂
  - r: Assume a₃ and a₄ to be the codes of characters C₃ and C₄. Then,
    - r = a₃ × 10³ + a₄
  - i: Assume a₅ and a₆ to be the codes of characters C₅ and C₆. Then,
    - i = a₅ × 10³ + a₆
  - j: Assume a₇ and a₈ to be the codes of characters C₇ and C₈. Then,
    - j = a₇ × 10³ + a₈
  - k: Assume a₉ and a₁₀ to be the codes of characters C₉ and C₁₀. Then,
    - k = a₉ × 10³ + a₁₀

  **Example**
  - If the pattern name of menu No. 1 is "BOLT HOLE" then the macro instruction is as follows.
    
    G65 H91 P1 Q066079 R076084 I032072 J079076 K069032 ;
    
    BOLT HOLE

- **Pattern No. selection**

  To select a pattern from the pattern menu screen, enter the corresponding pattern No. The following is an example.

  ![Pattern No. selection](image)

  The selected pattern No. is assigned to system variable #5900. The custom macro of the selected pattern can be started by starting a fixed program (external program No. search) with an external signal then referring to the system variable #5900 in the program.

<table>
<thead>
<tr>
<th>NOTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>If each characters of P, Q, R, I, J, and K are not specified in a macro instruction, two spaces are assigned to each omitted character.</td>
</tr>
</tbody>
</table>
Custom macros for the menu title and hole pattern names.

```
MENU : HOLE PATTERN
1. TAPPING
2. DRILLING
3. BORING
4. POCKET
5. BOLT HOLE
6. LINE ANGLE
7. GRID
8. PECK
9. TEST PATRN
10. BACK
```

O9500;
N1G65 H90 P072 079 Q076 069 R032 080 I 065 084 J 084 069 K082 078 ; 1. HOLE PATTERN
N2G65 H91 P1 Q066 079 R076 084 I 032 072 J 079 076 K069 032 ; 2. BOLT HOLE
N3G65 H91 P2 Q071 082 R073 068 ; 3. GRID
N4G65 H91 P3 Q076 073 R078 069 I 032 065 J 078 071 K076 069 ; 4. LINE ANGLE
N5G65 H91 P4 Q084 065 R080 080 I 073 078 J 071 032 ; 5. TAPPING
N6G65 H91 P5 Q068 082 R073 076 I 076 073 J 078 071 ; 6. BORING
N7G65 H91 P6 Q066079 R082073 I078071 ; 7. POCKET
N8G65 H91 P7 Q080 079 R067 075 I 069 084 ; 8. PECK
N9G65 H91 P8 Q080069 R067075 ; 9. TEST PATRN
N10G65 H91 P9 Q084 069 R083 084 I032 080 J065 084 K082 078 ; 10. BACK
N11G65 H91 P10 Q066 065 R067 0750 ;
N12M99:
16.2 PATTERN DATA DISPLAY

When a pattern menu is selected, the necessary pattern data is displayed.

<table>
<thead>
<tr>
<th>NO.</th>
<th>NAME</th>
<th>DATA</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>TOOL</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>501</td>
<td>STANDARD X</td>
<td>0.000</td>
<td>*BOLT HOLE</td>
</tr>
<tr>
<td>502</td>
<td>STANDARD Y</td>
<td>0.000</td>
<td>CIRCLE*</td>
</tr>
<tr>
<td>503</td>
<td>RADIUS</td>
<td>0.000</td>
<td>SET PATTERN</td>
</tr>
<tr>
<td>504</td>
<td>S.ANGL</td>
<td>0.000</td>
<td>DATA TO VAR.</td>
</tr>
<tr>
<td>505</td>
<td>HOLES NO</td>
<td>0.000</td>
<td>NO.500-505.</td>
</tr>
<tr>
<td>506</td>
<td></td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>507</td>
<td></td>
<td>0.000</td>
<td></td>
</tr>
</tbody>
</table>

ACTUAL POSITION (RELATIVE)

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>Y</td>
<td>Z</td>
</tr>
<tr>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
</tbody>
</table>

VAR. : BOLT HOLE O0001 N00000

BOLT HOLE : This is the pattern data title. A character string consisting of up to 12 characters can be set.

TOOL : This is the variable name. A character string consisting of up to 10 characters can be set.

*BOLT HOLE CIRCLE* : This is a comment statement. A character string can be displayed consisting of up to 8 lines, 12 characters per line.

(It is permissible to use katakana in a character string or line.)

The machine tool builder should program the character strings of pattern data title, pattern name, and variable name using the custom macro, and load them into the program memory as a subprogram whose No. is 9500 plus the pattern No. (O9501 to O9510).
Macro instruction specifying the pattern data title
(the menu title)

Menu title : C1 C2 C3 C4 C5 C6 C7 C8 C9 C10 C11 C12
C1, C2, C12 : Characters in the menu title (12 characters)
Macro instruction
G65 H92 Pp Qq Rr Ii Jj Kk ;
H92 : Specifies the pattern name
p : Assume a1 and a2 to be the codes of characters C1 and C2. Then,
p = a1.10^3 + a2
See 16.3 for character codes.
q : Assume a3 and a4 to be the codes of characters C3 and C4. Then,
q = a3.10^3 + a4
r : Assume a5 and a6 to be the codes of characters C5 and C6. Then,
r = a5.10^3 + a6
i : Assume a7 and a8 to be the codes of characters C7 and C8. Then,
i = a7.10^3 + a8
j : Assume a9 and a10 to be the codes of characters C9 and C10. Then,
j = a9.10^3 + a10
k : Assume a11 and a12 to be the codes of characters C11 and C12. Then,
k = a11.10^3 + a12
Example) Assume that the pattern data title is "BOLT HOLE." The macro instruction is given as follows:

G65 H92 P066079 Q076084 R032072 I079076 J069032 ;

BO LT H OL E

Macro instruction specifying the variable name

Variable name : C1 C2 C3 C4 C5 C6 C7 C8 C9 C10
C1, C2, C10 : Characters in the variable name (10 characters)
Macro instruction
G65 H93 Pp Qq Rr Ii Jj Kk ;
H93 : Specifies the variable name
p : Specifies the menu No. of the variable name
p = 100 to 149 (199), 500 to 531 (999)
q : Assume a1 and a2 to be the codes of characters C1 and C2. Then,
q = a1.10^3 + a2
r : Assume a3 and a4 to be the codes of characters C3 and C4. Then,
r = a3.10^3 + a4
i : Assume a5 and a6 to be the codes of characters C5 and C6. Then,
i = a5.10^3 + a6
j : Assume a7 and a8 to be the codes of characters C7 and C8. Then,
j = a7.10^3 + a8
k : Assume a9 and a10 to be the codes of characters C9 and C10. Then,
k = a9.10^3 + a10
Example) Assume that the variable name of the variable No. 503 is "RADIUS." The macro instruction is given as follows:

G65 H93 P503 Q082065 R068073 I085083 ;
RA DI US
16. PATTERN DATA INPUT

FUNCTION

**Macro instruction to describe a comment**

One comment line: C1 C2 C3 C4 C5 C6 C7 C8 C9 C10 C11 C12
C1, C2, ..., C12: Character string in one comment line (12 characters)

Macro instruction

G65 H94 Pp Qq Rr Ii Jj Kk ;

H94: Specifies the comment

p: Assume a1 and a2 to be the codes of characters C1 and C2. Then,
   \[ p = a_1 \times 10^3 + a_2 \]
   See 17.7 for character codes.

q: Assume a3 and a4 to be the codes of characters C3 and C4. Then,
   \[ q = a_3 \times 10^3 + a_4 \]

r: Assume a5 and a6 to be the codes of characters C5 and C6. Then,
   \[ r = a_5 \times 10^3 + a_6 \]

i: Assume a7 and a8 to be the codes of characters C7 and C8. Then,
   \[ i = a_7 \times 10^3 + a_8 \]

j: Assume a9 and a10 to be the codes of characters C9 and C10. Then,
   \[ j = a_9 \times 10^3 + a_{10} \]

k: Assume a11 and a12 to be the codes of characters C11 and C12. Then,
   \[ k = a_{11} \times 10^3 + a_{12} \]

A comment can be displayed in up to eight lines. The comment consists of the first line to the eighth line in the programmed sequence of G65 H94 for each line.

Example) Assume that the comment is “BOLT HOLE.” The macro instruction is given as follows:

G65 H94 P042066 Q079076 R084032 I072079 J076069;

*B     OL    TL    HO    LE
### Examples

Macro instruction to describe a parameter title, the variable name, and a comment.

<table>
<thead>
<tr>
<th>NO.</th>
<th>NAME</th>
<th>DATA</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>TOOL</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>501</td>
<td>STANDARD X</td>
<td>0.000</td>
<td>*BOLT HOLE</td>
</tr>
<tr>
<td>502</td>
<td>STANDARD Y</td>
<td>0.000</td>
<td>CIRCLE*</td>
</tr>
<tr>
<td>503</td>
<td>RADIUS</td>
<td>0.000</td>
<td>SET PATTERN</td>
</tr>
<tr>
<td>504</td>
<td>S.ANGL</td>
<td>0.000</td>
<td>DATA TO VAR.</td>
</tr>
<tr>
<td>505</td>
<td>HOLES NO</td>
<td>0.000</td>
<td>NO.500–505.</td>
</tr>
</tbody>
</table>

### ACTUAL POSITION (RELATIVE)

<table>
<thead>
<tr>
<th>X</th>
<th>Y</th>
<th>Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
</tbody>
</table>

O9501 ;

```
N1 G65 H92 P066 079 Q076 084 R032 072 I 079 076 J069 032 ; VAR : BOLT HOLE
N2 G65 H93 P500 Q084 079 R079076 ; #500 TOOL
N3 G65 H93 P501 Q075 073 R074 085 I078 032 J088 032 ; #501 KIJUN X
N4 G65 H93 P502 Q075 073 R074 085 I 078 032 J089 032 ; #502 KIJUN Y
N5 G65 H93 P503 Q082 065 R068 073 I 085 083 ; #503 RADIUS
N6 G65 H93 P504 Q083 046 R032 065 I 078 071 J 076 032 ; #504 S.ANGL
N7 G65 H93 P505 Q072 079 R076 069 I 083 032 J078 079 K046 032 ; #505 HOLES NO
N8 G65 H94 ; Comment
N9 G65 H94 P042 066 Q079 076 R084 032 I072 079 J076 069 ; 'BOLT HOLE
N10 G65 H94 R032 067 I073 082 J067 076 K069 042 ; CIRCLE'
N11 G65 H94 P083 069 Q084 032 080 065 I084 084 J069 082 K078 032 ; SET PATTERN
N12 G65 H94 P068 065 Q084 065 R032 084 I079 032 J086 065 K082046 ; DATA NO VAR.
N13 G65 H94 P078 079 Q046 053 R048 048 I045 053 J048 053 K046 032 ; No.500–505
N14 M99 ;
```
### 16.3 Characters and Codes to Be Used for the Pattern Data Input Function

<table>
<thead>
<tr>
<th>Character</th>
<th>Code</th>
<th>Comment</th>
<th>Character</th>
<th>Code</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>065</td>
<td></td>
<td>6</td>
<td>054</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>066</td>
<td></td>
<td>7</td>
<td>055</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>067</td>
<td></td>
<td>8</td>
<td>056</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>068</td>
<td></td>
<td>9</td>
<td>057</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>069</td>
<td>032</td>
<td>Space</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>070</td>
<td>!</td>
<td>Exclamation mark</td>
<td>033</td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>071</td>
<td>&quot;</td>
<td>Quotation mark</td>
<td>034</td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>072</td>
<td>#</td>
<td>Hash sign</td>
<td>035</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>073</td>
<td>$</td>
<td>Dollar sign</td>
<td>036</td>
<td></td>
</tr>
<tr>
<td>J</td>
<td>074</td>
<td>%</td>
<td>Percent</td>
<td>037</td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>075</td>
<td>&amp;</td>
<td>Ampersand</td>
<td>038</td>
<td></td>
</tr>
<tr>
<td>L</td>
<td>076</td>
<td>'</td>
<td>Apostrophe</td>
<td>039</td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>077</td>
<td>(</td>
<td>Left parenthesis</td>
<td>040</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>078</td>
<td>)</td>
<td>Right parenthesis</td>
<td>041</td>
<td></td>
</tr>
<tr>
<td>O</td>
<td>079</td>
<td>*</td>
<td>Asterisk</td>
<td>042</td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>080</td>
<td>+</td>
<td>Plus sign</td>
<td>043</td>
<td></td>
</tr>
<tr>
<td>Q</td>
<td>081</td>
<td>.</td>
<td>Comma</td>
<td>044</td>
<td></td>
</tr>
<tr>
<td>R</td>
<td>082</td>
<td>-</td>
<td>Minus sign</td>
<td>045</td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>083</td>
<td>.</td>
<td>Period</td>
<td>046</td>
<td></td>
</tr>
<tr>
<td>T</td>
<td>084</td>
<td>/</td>
<td>Slash</td>
<td>047</td>
<td></td>
</tr>
<tr>
<td>U</td>
<td>085</td>
<td>:</td>
<td>Colon</td>
<td>058</td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>086</td>
<td>;</td>
<td>Semicolon</td>
<td>059</td>
<td></td>
</tr>
<tr>
<td>W</td>
<td>087</td>
<td>&lt;</td>
<td>Left angle bracket</td>
<td>060</td>
<td></td>
</tr>
<tr>
<td>X</td>
<td>088</td>
<td>=</td>
<td>Equal sign</td>
<td>061</td>
<td></td>
</tr>
<tr>
<td>Y</td>
<td>089</td>
<td>&gt;</td>
<td>Right angle bracket</td>
<td>062</td>
<td></td>
</tr>
<tr>
<td>Z</td>
<td>090</td>
<td>?</td>
<td>Question mark</td>
<td>083</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>048</td>
<td>@</td>
<td>HAT mark</td>
<td>064</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>049</td>
<td>[</td>
<td>Left square bracket</td>
<td>091</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>050</td>
<td>^</td>
<td>092</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>051</td>
<td>¥</td>
<td>Yen sign</td>
<td>093</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>052</td>
<td>]</td>
<td>Right square bracket</td>
<td>094</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>053</td>
<td>_</td>
<td>Underscore</td>
<td>095</td>
<td></td>
</tr>
</tbody>
</table>

**NOTE**

Right and left parentheses cannot be used.
### Table 16.3 (b) Numbers of subprograms employed in the pattern data input function

<table>
<thead>
<tr>
<th>Subprogram No.</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>O9500</td>
<td>Specifies character strings displayed on the pattern data menu.</td>
</tr>
<tr>
<td>O9501</td>
<td>Specifies a character string of the pattern data corresponding to pattern No.1</td>
</tr>
<tr>
<td>O9502</td>
<td>Specifies a character string of the pattern data corresponding to pattern No.2</td>
</tr>
<tr>
<td>O9503</td>
<td>Specifies a character string of the pattern data corresponding to pattern No.3</td>
</tr>
<tr>
<td>O9504</td>
<td>Specifies a character string of the pattern data corresponding to pattern No.4</td>
</tr>
<tr>
<td>O9505</td>
<td>Specifies a character string of the pattern data corresponding to pattern No.5</td>
</tr>
<tr>
<td>O9506</td>
<td>Specifies a character string of the pattern data corresponding to pattern No.6</td>
</tr>
<tr>
<td>O9507</td>
<td>Specifies a character string of the pattern data corresponding to pattern No.7</td>
</tr>
<tr>
<td>O9508</td>
<td>Specifies a character string of the pattern data corresponding to pattern No.8</td>
</tr>
<tr>
<td>O9509</td>
<td>Specifies a character string of the pattern data corresponding to pattern No.9</td>
</tr>
<tr>
<td>O9510</td>
<td>Specifies a character string of the pattern data corresponding to pattern No.10</td>
</tr>
</tbody>
</table>

### Table 16.3 (c) Macro instructions used in the pattern data input function

<table>
<thead>
<tr>
<th>G code</th>
<th>H code</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>G65</td>
<td>H90</td>
<td>Specifies the menu title.</td>
</tr>
<tr>
<td>G65</td>
<td>H91</td>
<td>Specifies the pattern name.</td>
</tr>
<tr>
<td>G65</td>
<td>H92</td>
<td>Specifies the pattern data title.</td>
</tr>
<tr>
<td>G65</td>
<td>G93</td>
<td>Specifies the variable name.</td>
</tr>
<tr>
<td>G65</td>
<td>H94</td>
<td>Specifies the comment.</td>
</tr>
</tbody>
</table>

### Table 16.3 (d) System variables employed in the pattern data input function

<table>
<thead>
<tr>
<th>System variable</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>#5900</td>
<td>Pattern No. selected by user.</td>
</tr>
</tbody>
</table>
17 PROGRAMMABLE PARAMETER ENTRY (G10)

General

The values of parameters can be entered in a program. This function is used for setting pitch error compensation data when attachments are changed or the maximum cutting feedrate or cutting time constants are changed to meet changing machining conditions.

Format

<table>
<thead>
<tr>
<th>Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>G10L50: Parameter entry mode setting</td>
</tr>
<tr>
<td>N_R_: For parameters other than the axis type</td>
</tr>
<tr>
<td>N_P_R_: For axis type parameters</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>G11: Parameter entry mode cancel</td>
</tr>
</tbody>
</table>

Meaning of command

| N_: Parameter No. (4digits) or compensation position No. for pitch errors compensation +10,000 (5digits) |
| R_: Parameter setting value (Leading zeros can be omitted.)                                   |
| P_: Axis No. 1 to 8 (Used for entering axis type parameters)                                  |

Explanations

- Parameter setting value (R_)
- Axis No.(P_)

Do not use a decimal point in a value set in a parameter (R_).

WARNING

1. Do not fail to perform reference point return manually after changing the pitch error compensation data or backlash compensation data. Without this, the machine position can deviate from the correct position.

2. The canned—cycle mode must be cancelled before entering of parameters. When not cancelled, the drilling motion may be activated.

NOTE

Other NC statements cannot be specified while in parameter input mode.
Examples

1. Set bit 2 (SBP) of bit type parameter No. 3404

```
G10L50 ;  Parameter entry mode
N3404 R 00000100 ;  SBP setting
G11 ;  cancel parameter entry mode
```

2. Change the values for the Z–axis (3rd axis) and A–axis (4th axis) in axis type parameter No. 1322 (the coordinates of stored stroke limit 2 in the positive direction for each axis).

```
G10L50 ;  Parameter entry mode
N1322P3R4500 ;  Modify Z axis
N1322P4R12000 ;  Modify A axis
G11 ;  cancel parameter entry mode
```
18 MEMORY OPERATION USING FS15 TAPE FORMAT

General
Memory operation of the program registered by FS15 tape format is possible with setting of the setting parameter (No. 0001#1).

Explanations
Data formats for cutter compensation, subprogram calling, and canned cycles are different between the Series 16/18 and Series 15. The Series 15 data formats can be processed for memory operation. Other data formats must comply with the Series 16/18. When a value out of the specified range for the Series 16/18 is registered, an alarm occurs. Functions not available in the Series 16/18 cannot be registered or used for memory operation.

- Address for the cutter compensation offset number
  Offset numbers are specified by address D in the Series 15. When an offset number is specified by address D, the modal value specified by address H is replaced with the offset number specified by address D.

- Subprogram call
  If a subprogram number of more than four digits is specified, the four low-order digits are regarded as the subprogram number. If no repeat count is specified, 1 is assumed.

  Table 18 (a) Subprogram call data format

<table>
<thead>
<tr>
<th>CNC</th>
<th>Data format</th>
</tr>
</thead>
<tbody>
<tr>
<td>Series 15</td>
<td>M98 P00000 L00000 ;</td>
</tr>
<tr>
<td></td>
<td>P : Subprogram number</td>
</tr>
<tr>
<td></td>
<td>L : Repetition count (1 to 9999)</td>
</tr>
<tr>
<td>Series 16/18</td>
<td>M98 P00000 00000 ;</td>
</tr>
<tr>
<td></td>
<td>Repetition count Subprogram number (1 to 9999)</td>
</tr>
</tbody>
</table>

- Address for the canned cycle repetition count
  The Series 15 and Series 16/18 use different addresses for the repeat count for canned cycles as listed in Table 18 (b).

  Table 18 (b) Address for times of repetition of canned cycle

<table>
<thead>
<tr>
<th>CNC</th>
<th>Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>Series 15</td>
<td>L</td>
</tr>
<tr>
<td>Series 16/18</td>
<td>K</td>
</tr>
</tbody>
</table>
19 HIGH SPEED CUTTING FUNCTIONS
19.1 HIGH–SPEED CYCLE CUTTING

General

This function can convert the machining profile to a data group that can be distributed as pulses at high-speed by the macro compiler and macro executor. The function can also call and execute the data group as a machining cycle using the CNC command (G05 command).

Format

```
G05 P10000 L0000;
```

- **P10000** is number of the machining cycle to be called first: P10001 to P10999
- **L0000** is repetition count of the machining cycle
  - (L1 applies when this parameter is omitted.)
  - L1 to L999

Call and execute the data for the high speed cutting cycle specified by the macro compiler and macro executor using the above command. Cycle data can be prepared for up to 999 cycles. Select the machining cycle by address `P`. More than one cycle can be called and executed in series using the cycle connection data in the header. Specify the repetition count of the called machining cycle by address `L`. The repetition count in the header can be specified for each cycle. The connection of cycles and their repetition count are explained below with an example.

Example) Assume the following:
- Cycle 1  Cycle connection data 2  Repetition count 1
- Cycle 2  Cycle connection data 3  Repetition count 3
- Cycle 3  Cycle connection data 0  Repetition count 1

```
G05 P10001 L2;
```

The following cycles are executed in sequence:
- Cycles 1, 2, 2, 2, 3, 1, 2, 2, and 3

**NOTE**

1. An alarm is issued if the function is executed in the G41/G42 mode.
2. Single block stop, dry run/feederate override, automatic acceleration/deceleration and handle interruption are disabled during high–speed cycle machining.
Alarms

<table>
<thead>
<tr>
<th>Alarm number</th>
<th>Descriptions</th>
</tr>
</thead>
</table>
| 115          | The contents of the header are invalid. This alarm is issued in the following cases.  
1. The header corresponding to the number of the specified call machining cycle was not found.  
2. A cycle connection data value is not in the valid range (0 to 999).  
3. The number of data items in the header is not in the valid range (1 to 32767).  
4. The first variable No. for storing data in the executable format is not in the valid range (#20000 to #85535).  
5. The last variable No. for storing data in the executable format exceeds the limit (#85535).  
6. The first variable No. for start data in the executable format overlaps with a variable No. used in the header. |
| 178          | High-speed cycle machining was specified in the G41/G42 mode. |
| 179          | The number of control axes specified in parameter 7510 exceeds the maximum number. |
19.2 FEEDRATE CLAMPING BY ARC RADIUS

When an arc is cut at a high speed in circular interpolation, a radial error exists between the actual tool path and the programmed arc. An approximation of this error can be obtained from the following expression:

\[ \Delta r = \frac{1}{2} \left( T_1^2 + T_2^2 \right) \frac{v^2}{r} \]

- \( \Delta r \): Maximum radial error (mm)
- \( v \): Feedrate (mm/s)
- \( r \): Arc radius (mm)
- \( T_1 \): Time constant (s) for exponential acceleration/deceleration of cutting feed
- \( T_2 \): Time constant of the servo motor (s)

When actual machining is performed, radius \( r \) of the arc to be machined and permissible error \( D_r \) are given. Then, maximum allowable feedrate \( v \) (mm/min) is determined from the above expression.

The function for clamping the feedrate by the arc radius automatically clamps the feedrate of arc cutting to the value set in a parameter. This function is effective when the specified feedrate may cause the radial error for an arc with a programmed radius to exceed the permissible degree of error.

For details, refer to the relevant manual published by the machine tool builder.
19.3 HIGH-SPEED REMOTE BUFFER

A remote buffer can continuously supply a large amount of data to the CNC at high speeds when connected to the host computer or input/output equipment via a serial interface.

```
CNC
Remote buffer
RS-232-C / RS-422
Host computer
Input/output equipment
```

When the remote buffer is connected online to the host computer, fast and reliable DNC operation is possible. The remote buffer function includes high-speed remote buffer A and high-speed remote buffer B for high-speed machining. High-speed remote buffer A uses binary data. High-speed remote buffer B uses NC language. For details on remote buffer specifications, refer to the “Remote Buffer Supplement” (B-61802E-1).

19.3.1 High-Speed Remote Buffer A (G05)

Specify G05 only in a block using normal NC command format. Then specify move data in the special format explained below. When zero is specified as the travel distance along all axes, normal NC command format can be used again for subsequent command specification.

```
CNC
Remote buffer
RS-232-C / RS-422
Host computer
```
### Format

| Binary input operation enabled: | G05; |
| Binary input operation disabled: | The travel distance along all axes are set to zero. |

#### Data format for binary input operation

<table>
<thead>
<tr>
<th>Data sequence</th>
<th>Byte</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High byte</td>
</tr>
<tr>
<td></td>
<td>Low byte</td>
</tr>
<tr>
<td></td>
<td>High byte</td>
</tr>
<tr>
<td></td>
<td>Low byte</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>High byte</td>
</tr>
<tr>
<td></td>
<td>Low byte</td>
</tr>
<tr>
<td></td>
<td>Check byte</td>
</tr>
</tbody>
</table>

In the data format for binary input operation, the travel distance along each axis (2 bytes) per unit time is specified. The travel distances along all axes are placed sequentially from the first axis, then a check byte is added. (The data length for one block is \([2 \times N + 1]\) bytes). All data must be specified in binary.

### Explanations

- **Selecting the unit time**

  The unit time (in ms) can be selected by setting bits 4, 5, and 6 of parameter IT0, IT1, IT2 No. 7501.

- **Travel distance data**

  The following unit is used for specifying the travel distance along each axis. (A negative travel distance is indicated in 2's complement.)

<table>
<thead>
<tr>
<th>Increment system</th>
<th>IS–B</th>
<th>IS–C</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Millimeter machine</td>
<td>0.001</td>
<td>0.0001</td>
<td>mm</td>
</tr>
<tr>
<td>Inch machine</td>
<td>0.0001</td>
<td>0.00001</td>
<td>inch</td>
</tr>
</tbody>
</table>

The data format of the travel distance is as follows. The bits marked * are used to specify a travel distance per unit time.
Example: When the travel distance is 700 µm per unit time (millimeter machine with increment system IS-B)

<table>
<thead>
<tr>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>0</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>0</td>
</tr>
</tbody>
</table>

All bytes of the block except for the check byte ([2*N] bytes) are summed up, and any bits above 8th bit are discarded.

The CNC reads (2 x N + 1)–byte data (where N is the number of axes) for every unit time that is set in the parameter. To allow the CNC to continue machining without interruption, the following minimum baud rate is required for data transfer between the host and remote buffer:

\[(2\times N + 1) \times \frac{11}{T} \times 1000 \text{ baud (T: Unit time)}\]

If G05 is specified in cutter compensation mode, the P/S 178 alarm is issued.

Feed hold and interlock are effective.

The mirror image function (programmable mirror image and setting mirror image) cannot be turned on or off in the G05 mode.

In binary input operation mode, when tool movement starts and stops in cutting feed mode, exponential acceleration/deceleration is performed (the acceleration/deceleration time constant set in parameter No. 1622 is used).

In binary input operation mode, only linear interpolation as specified in the defined data format is executed (equivalent to the incremental command for linear interpolation).

The single block, feedrate override, and maximum cutting feedrate clamp functions have no effect. The program restart, block restart, and high-speed machining functions cannot be used. In addition, miscellaneous functions cannot be executed in binary operation.

No data can be stored in memory.
19.3.2
High-Speed Remote Buffer B (G05)

High-speed remote buffer A uses binary data. On the other hand, high-speed remote buffer B can directly use NC language coded with equipment such as an automatic programming unit to perform high-speed machining.

Format

G05P01 ; Start high-speed machining
G05P00 ; End high-speed machining

Example:
O1234 ;
G05P01 ; ← Start high-speed machining
X_ Y_ Z_ ;
G05P00 ; ← End high-speed machining
M02 ;

Explanations

- Specified data

The following data can be specified during high-speed machining:

<table>
<thead>
<tr>
<th>Address</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>Travel distance along the X-axis</td>
</tr>
<tr>
<td>Y</td>
<td>Travel distance along the Y-axis</td>
</tr>
<tr>
<td>Z</td>
<td>Travel distance along the Z-axis</td>
</tr>
<tr>
<td>F</td>
<td>Cutting feedrate</td>
</tr>
</tbody>
</table>

Data other than the above cannot be specified.

- Number of controlled axes

Be sure to set 3 in parameter No. 7510 as the number of controlled axes.

Limitations

- Incremental command

Move commands can be specified only in incremental mode.

- Functions that cannot be specified

Cutter compensation B and C cannot be specified. The feedrate cannot be overridden.

- Feedrate clamp

The maximum cutting feedrate clamp function is disabled.

- Binary data format

The format of high-speed remote buffer A can also be used for high-speed remote buffer B. This format, however, cannot be used together with NC language within the same program.
19.4 DISTRIBUTION PROCESSING TERMINATION MONITORING FUNCTION FOR THE HIGH–SPEED MACHINING COMMAND (G05)

Explanations

- High–speed machining command
  - During high–speed machining, the distribution processing status is monitored. When distribution processing terminates, P/S alarm No. 000 and P/S alarm No. 179 are issued upon completion of the high–speed machining command (according to the setting of ITPDL (bit 7 of parameter No. 7501)).
  - These P/S alarms can be canceled only by turning off the CNC power.

- Distribution processing termination
  - Failure to perform normal distribution processing because distribution processing required for high–speed machining exceeded the CNC processing capacity, or because distribution data sent from the host was delayed for some reason while the high–speed remote buffer A or G function was being used

Alarm

<table>
<thead>
<tr>
<th>Alarm No.</th>
<th>Message</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>000</td>
<td>PLEASE TURN OFF POWER</td>
<td>During high–speed machining, distribution processing was terminated.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Related parameters:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Remote buffer transfer baud rate (parameter No. 133)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Number of controlled axes in high–speed machining (parameter No. 7150)</td>
</tr>
<tr>
<td>179</td>
<td>PARAM. (PRM No. 7510) SETTING ERROR</td>
<td>High–speed axis selection during high–speed machining (bit 0 of parameter No. 7510)</td>
</tr>
</tbody>
</table>
19.5 HIGH–SPEED LINEAR INTERPOLATION (G05)

Format

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>G05 P2</td>
<td>Start high–speed linear interpolation</td>
</tr>
<tr>
<td>G05 P0</td>
<td>End high–speed linear interpolation</td>
</tr>
</tbody>
</table>

A block for specifying G05 must not contain any other command.

Explanations

- **High–speed linear interpolation mode**

  The high–speed linear interpolation start command G05 P2; places the system in high–speed linear interpolation mode, in which high–speed linear interpolation is executed. The high–speed linear interpolation end command G05 P0; places the system in the standard NC program operation mode.

  At power–up or in the NC reset state, the system enters the standard NC program operation mode.

- **Commands in high–speed linear interpolation mode**

  The commands that can be programmed in high–speed linear interpolation mode are:

  X/Y/Z/C–axis incremental travel distance command, cutting feedrate command, and high–speed linear interpolation end command.

  In high–speed linear interpolation mode, an address other than those listed in the following table is ignored.

<table>
<thead>
<tr>
<th>Address</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>X—— ——</td>
<td>X–axis incremental travel distance</td>
</tr>
<tr>
<td>Y—— ——</td>
<td>Y–axis incremental travel distance</td>
</tr>
<tr>
<td>Z—— ——</td>
<td>Z–axis incremental travel distance</td>
</tr>
<tr>
<td>C— ——</td>
<td>C–axis incremental travel distance</td>
</tr>
<tr>
<td>G05 P0</td>
<td>High–speed linear interpolation end command</td>
</tr>
</tbody>
</table>

- **X/Y/Z/C–axis incremental traveling distance**

  A travel distance specified in high–speed linear interpolation mode is regarded as being an incremental travel distance, regardless of the G90/G91 mode setting.

- **Cutting feedrate**

  Specify a cutting feedrate in high–speed linear interpolation mode. If no cutting feedrate is specified, the modal F value is assumed.

<table>
<thead>
<tr>
<th>Maximum feedrate</th>
<th>Interpolation period: 8 msec</th>
<th>Interpolation period: 4 msec</th>
</tr>
</thead>
<tbody>
<tr>
<td>(IS–B, metric input)</td>
<td>122,848 mm/min</td>
<td>245,696 mm/min</td>
</tr>
<tr>
<td>(IS–B, inch input)</td>
<td>12,284.8 inch/min</td>
<td>24,569.6 inch/min</td>
</tr>
<tr>
<td>(IS–C, metric input)</td>
<td>12,284 mm/min</td>
<td>24,569 mm/min</td>
</tr>
<tr>
<td>(IS–C, inch input)</td>
<td>1,228.48 inch/min</td>
<td>2,456.96 inch/min</td>
</tr>
</tbody>
</table>
(Maximum feedrate) = 
\[
122,848 \times \frac{8}{\text{(interpolation period)}} \quad \text{(IS–B, metric input)}
\]

Minimum feedrate: 
- IS–B, metric input: 4 mm/min
- IS–B, inch input: 0.38 inch/min
- IS–C, metric input: 4 mm/min
- IS–C, inch input: 0.38 inch/min

Interpolation period: 
- 8 msec
- 4 msec

(Interpolation period) = 4 \times \frac{8}{\text{(interpolation period)}} \quad \text{(IS–B, metric input)}

- Interpolation period

In high–speed linear interpolation mode, the NC interpolation period can be changed. As the interpolation period decreases, the machining speed and precision increase.

IT2, IT1, and IT0 bits (bits 6, 5, and 4 of parameter 7501)

<table>
<thead>
<tr>
<th>IT2</th>
<th>IT1</th>
<th>IT0</th>
<th>Interpolation period</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>8 msec in high–speed linear interpolation mode</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>4 msec in high–speed linear interpolation mode</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2 msec in high–speed linear interpolation mode</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1 msec in high–speed linear interpolation mode</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.5 msec in high–speed linear interpolation mode</td>
</tr>
</tbody>
</table>

- Limitations

- Controlled axes

Up to four axes can be controlled. The names of the controlled axes are X, Y, Z, and C. Any other axis name is ignored. Set X, Y, Z, then C in axis name setting parameter 1020.

- Enabled interpolation

Only the linear interpolation function can be executed. Circular interpolation and other interpolation functions cannot be executed.

- Absolute command

Movement cannot be specified by absolute values. A specified travel distance is always considered as an incremental travel distance, regardless of the G90/G91 mode setting.

- Feed per rotation

The feed per rotation command cannot be specified. Feed per minute is always assumed, regardless of the G94/G95 mode setting.

- Cutter compensation

High–speed linear interpolation commands cannot be specified in cutter compensation mode (G41/G42). If the high–speed linear interpolation start command is specified in cutter compensation mode, P/S alarm No. 178 is issued.

- Modes related to the coordinate system

The high–speed interpolation commands cannot be specified in polar coordinate interpolation mode (G12.1), scaling mode (G51), or coordinate system rotation mode.
- **Single-block operation**
  
  Single-block operation is disabled in high-speed linear interpolation mode.

  ```
  G05 P2 ;
  X10 Z20 F1000 ;
  
  Y30 ;
  G05 P0 ;
  ```

  Handled as a single block

- **Feed hold**

  Feed hold is disabled in high-speed linear interpolation mode.

- **Cutting feed override**

  The cutting feed override function is enabled. Because of the intermediate buffer between high-speed linear interpolation processing and axis move command processing, the override is applied only after the elapse of a slight delay after the override signal is switched.

- **Maximum cutting feedrate for each axis**

  The maximum cutting feedrate for each axis (parameter 1430) is invalid in high-speed linear interpolation mode. The maximum cutting feedrate for all axes (parameter 1422) becomes valid.

- **Custom macro/optimal block skip**

  No macro variables or macro statements can be used in high-speed linear interpolation mode. If their use is attempted, P/S alarm No. 009 is issued. When an optional block skip symbol / is specified, P/S alarm No. 009 is issued as well.

- **Comment**

  No comment can be specified.

- **G codes**

  If a G code other than G05 P0 is specified in high-speed linear interpolation mode, P/S alarm No. 010 is issued.

**Example**

```
NC program
O0001 ;
G00 X0 Y0 Z0 ;
:
:
:
G05 P2 ;
X10 Y20 F1000 ;
X5 Y6 Z7 ;
:
:
:
G05 P0 ;
G00 DDD ;
:
:
:
M02 ;
%```
This function is designed for high-speed precise machining. With this function, the delay due to acceleration/deceleration and the delay in the servo system which increase as the feedrate becomes higher can be suppressed. The tool can then follow specified values accurately and errors in the machining profile can be reduced. This function becomes effective when advanced preview control mode is entered. For details, refer to the relevant manual published by the machine tool builder.

**Format**

```
G08 P_
P1 : Turn on advanced preview control mode.
P0 : Turn off advanced preview control mode.
```

**Explanations**

- **Available functions**
  In advanced preview control mode, the following functions are available:
  (1) Linear acceleration/deceleration before interpolation
  (2) Automatic corner deceleration function
  For details on the above functions, see the descriptions of the functions. Each function, specific parameters are provided.

- **Reset**
  Advanced preview control mode is canceled by reset.

**Limitations**

- **G08 command**
  Specify G08 code only in a block.

- **Functions that can be specified**
  In the advanced preview control mode, the optional functions listed below can be specified.

**NOTE**

To use a function other than the following optional functions, turn the advanced preview control mode off, specify the desired function, then turn the mode on again.
· Inverse time feed
· High-precision contour control
· Axis control by the PMC
  (Bits 4 (G8R) and 3 (G8C) of parameter No. 8004 can be set to also use this function in the look-ahead control mode.)
· Single direction positioning
· Polar coordinate command
· Helical interpolation
· Rigid tapping
  (Bit 5 (G8S) of parameter No. 1602 can be set to also use this function in the look-ahead control mode. The serial spindle parameters must also be set.)
· Program restart
· External deceleration
· Simple synchronous control
· Sequence number comparison and stop
· Position switch
  (Bit 3 (PSF) of parameter No. 6901 can be set to also use this function in the look-ahead control mode.)
· Cs contour control
  (Bit 5 (G8S) of parameter No. 1602 can be set to also use this function in the look-ahead control mode. The serial spindle parameters must also be set.)
· Constant surface speed control
· Spindle speed fluctuation detection
· Spindle synchronous control
· Simple spindle synchronization
· Custom macro B
· Optional-angle chamfering/corner rounding
· Inch/metric conversion
· Programmable mirror image
· Canned cycle
· Automatic corner override
  (Only the internal circular cutting feedrate change is valid.)
· Scaling
· Coordinate system rotation
· Three-dimensional coordinate conversion
· Workpiece coordinate system
· Figure copy
· Workpiece coordinate system preset
· Cutter compensation B
· Cutter compensation C
· Corner circular interpolation
· Tool offset
· Tool life management
· Tool length measurement
· Graphic display
· Dynamic graphic display
· Feed per revolution
19.7
AI CONTOUR CONTROL FUNCTION/AI NANO CONTOUR CONTROL FUNCTION

Overview

The AI contour control/AI nano contour control function is provided for high-speed, high-precision machining. This function enables suppression of acceleration/deceleration delays and servo delays that become larger with increases in the feedrate and reduction of machining profile errors.

Look-ahead acceleration/deceleration before interpolation is enabled for up to 40 blocks in AI contour control or for up to 180 blocks in AI nano contour control. This enables execution of smooth acceleration/deceleration extending over multiple blocks and higher machining.

The AI nano contour control function calculates a position command to be output to the digital servo in nanometers (nm) with nano-interpolation, so the machine can be moved smoothly and the surface precision is improved.

Explanation

This function is enabled by setting the AI contour control or AI nano contour control mode.

• Format

```
G05.1 Q_ ;
Q1 : AI contour control/AI nano contour control mode on
Q0 : AI contour control/AI nano contour control mode off
```

NOTE

1. Always specify G05.1 in an independent block.
2. The AI contour control/AI nano contour control mode is also canceled by a reset.
3. When the AI nano contour control option is installed, bit 0 (NAN) of parameter No. 7053 is set to 1 to set the AI contour control mode.
The functions listed below are valid in the AI contour control/AI nano contour control mode:

- Nano–interpolation (only in the AI nano contour control mode)
- Look–ahead linear acceleration/deceleration before interpolation
- Look–ahead bell–shaped acceleration/deceleration before interpolation
  (The option of look–ahead bell–shaped acceleration/deceleration before interpolation is required.)
- Automatic corner deceleration
- Feedrate clamping by acceleration
- Feedrate clamping by arc radius
- Block overlap (up to five blocks)
- Advanced preview feed forward

Nano–interpolation calculates a position command to be output to the digital servo in nanometers (nm) for a conventional program (IS–B or IS–C command). Using the calculation results, a smooth position command is output to the servo, so the machine can be moved smoothly and the surface precision is improved.

For a cutting feed command in the feed per minute mode, linear acceleration/deceleration can be applied before interpolation, that is, for the specified feedrate by reading up to 40 blocks (in the AI contour control mode) or 180 blocks (in the AI nano contour control mode) in advance. With acceleration/deceleration after interpolation, the interpolated data is changed because acceleration/deceleration is applied to the data. With acceleration/deceleration before interpolation, the interpolated data cannot be changed by acceleration/deceleration because acceleration/deceleration is applied to the feedrate data before interpolation. For this reason, the interpolated data can always be applied to the specified straight line or curve to eliminate machining profile errors caused by acceleration/deceleration delays.

NOTE
The positioning precision depends on the detection unit.
(Example of deceleration)

Deceleration is started in a prior block so that the feedrate specified for the target block is reached at the execution.

To decelerate from feedrate F3 to F2, deceleration must start with point 1. To decelerate from feedrate F2 to F1, deceleration must start with point 2. Multiple blocks can be read in advance to perform deceleration extending over several blocks.

(Example of acceleration)

Acceleration is performed so that the feedrate specified for the target block is reached at the execution.
Look-ahead bell–shaped acceleration/deceleration before interpolation

Linear acceleration/deceleration before interpolation for cutting feed in the AI contour control/AI nano contour control mode can be changed to bell–shaped acceleration/deceleration before interpolation. With bell–shaped acceleration/deceleration before interpolation, smooth acceleration/deceleration can be applied to the cutting feedrate to reduce the shock on the machine by fluctuations in acceleration that are involved in changes in the cutting feedrate.

To use this function, the option of look–ahead bell–shaped acceleration/deceleration before interpolation is required.

\[
\begin{align*}
\text{Feedrate} & \quad \text{Time} \\
\hline \\
\text{ta} & \quad \text{Depends on the linear acceleration.} \\
\text{tb} & \quad \text{Time constant for bell–shaped acceleration/deceleration} \\
\text{tc} & \quad \text{Bell–shaped acceleration/deceleration time} \\
\text{tc} &= \text{ta} + \text{tb} \\
\text{ta} & \quad \text{is not constant and depends on the specified feedrate.} \\
\text{Specified feedrate} & \quad \text{Linear acceleration} \\
\text{tb} & \quad \text{is constant.} \\
\end{align*}
\]

\[
\begin{align*}
\text{Acceleration} & \quad \text{Time} \\
\hline \\
\text{ta} & \quad \text{Depends on the linear acceleration.} \\
\text{tb} & \quad \text{Time constant for bell–shaped acceleration/deceleration} \\
\text{tc} & \quad \text{Bell–shaped acceleration/deceleration time} \\
\text{tc} &= \text{ta} + \text{tb} \\
\end{align*}
\]
When the feedrate is changed, deceleration and acceleration are performed as follows:

For deceleration: Bell–shaped deceleration is started in the preceding block so that deceleration terminates by the beginning of the block in which the feedrate is changed.

For acceleration: Bell–shaped acceleration is started after the beginning of the block in which the feedrate is changed.

### Automatic corner deceleration

Between contiguous two blocks, the feedrate difference for an axis may exceed the setting (parameter No. 1783). In this case, the feedrate at the corner is calculated as follows based on the axis for which the ratio of the actual feedrate difference to the allowable feedrate difference is the largest. Deceleration is performed so that the feedrate is reached at the interface of the blocks.

The change in the feedrate for each axis (Vx, Vy, ...) during movement at the specified feedrate F is compared with the setting of parameter No. 1783 (Vprm–x, Vprm–y, ...). If the change in the feedrate for any axis exceeds the setting of the parameter, the following expression is used:

$$ R_{\text{max}} = \max \left[ \frac{V_x}{V_{\text{prm}} - x}, \frac{V_y}{V_{\text{prm}} - y}, \ldots \right] $$

The required feedrate (Fc) is obtained as follows and deceleration is performed at the corner:

$$ F_c = F \times \frac{1}{R_{\text{max}}} $$

For example, assume that the tool move direction changes by 90 degrees from movement along the X–axis to that along the Y–axis. Also assume that the specified feedrate is 1000 mm/min and the allowable feedrate difference (parameter No. 1783) is 500 mm/min. Deceleration is performed as shown in the figure below:
Feedrate along the X-axis

Tool path when deceleration is not performed at the corner

Tool path when deceleration is performed at the corner

N1 G01 G91 X100. F1000 ;
N2 Y100. ;

Feedrate

When deceleration is not performed at the corner

When deceleration is performed at the corner

Feedrate along the Y-axis

Feedrate along the X-axis

Feedrate along the Y-axis

Tangential feedrate
When continuous minute straight lines form curves as shown in the example in the figure below, the feedrate difference for each axis at each corner is not so large. For this reason, deceleration according to the feedrate difference is not effective. Continuous small feedrate differences make a large acceleration for each axis as a whole, however.

In this case, deceleration is performed to suppress the shock on the machine and machining errors caused by too large acceleration. The feedrate is decreased so that the acceleration for each axis that is obtained using the expression below does not exceed the allowable acceleration setting for all axes.

The allowable acceleration is set based on the maximum cutting feedrate (parameter No. 1432) and time required to reach the feedrate (parameter No. 1785).

\[
\text{Acceleration for each axis} = \frac{\text{Feedrate difference for each axis at each corner}}{\max\left(\frac{\text{Travel distance in preceding block}}{F}, \frac{\text{Travel distance in following block}}{F}\right)}
\]

The decreased feedrate is obtained for each corner. The decreased feedrate obtained at the start or end point of the block, whichever is lower, is used as the actual feedrate.

(Example) In the example below, deceleration is performed because the acceleration (gradient of each dotted line in the feedrate graphs) from N2 to N4 and from N6 to N8 is too large.
The maximum allowable feedrate $v$ for an arc of radius $r$ specified in a program is calculated using the arc radius $R$ and maximum allowable feedrate $V$ (setting of a parameter) for the radius as follows so that the acceleration in an arc block does not exceed the allowable value. If the specified feedrate exceeds the feedrate $v$, the feedrate is automatically clamped to the feedrate $v$.

Maximum allowable feedrate $= \frac{V^2}{R}$

$R$ : Arc radius $V$ : Feedrate for arc radius $R$

then, the maximum allowable feedrate $v$ for an arc of radius $r$ can be obtained using the following expression:

$$v = \sqrt{\frac{r}{R}} \times V$$

**NOTE**

As the specified arc radius becomes smaller, the maximum allowable feedrate $v$ becomes lower. If the maximum allowable feedrate $v$ is lower than the setting of parameter No. 1732 (lower feedrate limit for feedrate clamping by arc radius), it can be assumed to be the setting of the parameter to prevent the maximum allowable feedrate from becoming too low.
- **Rapid traverse**

By setting the corresponding parameter, the linear or non-linear interpolation type can be selected. (In the AI nano contour control mode, the non-linear interpolation type cannot be selected.)

When the linear interpolation type is selected, acceleration/deceleration is performed before interpolation and linear interpolation type positioning is used for movement. For acceleration/deceleration, linear or bell-shaped acceleration/deceleration can be selected by setting the corresponding parameter. (To select bell-shaped acceleration/deceleration, the option of bell-shaped acceleration/deceleration for rapid traverse is required.)

The feedrate during movement and acceleration for acceleration/deceleration before interpolation are obtained as follows:

1. **Feedrate during movement**

   The minimum value obtained using the following expression for each axis along which movement is done is used as the feedrate during movement:

   \[
   \text{Rapid traverse rate for each axis (parameter No. 1420)} = \frac{\text{Amount of travel in block}}{\text{Amount of travel for each axis}}
   \]

2. **Acceleration for acceleration/deceleration before interpolation**

   - **For linear acceleration/deceleration**

     The minimum value obtained using the following expression for each axis along which movement is done is used as the acceleration for linear acceleration/deceleration before interpolation during movement:

     \[
     \frac{\text{Rapid traverse rate for each axis (parameter No. 1420)}}{\text{Time constant for each axis (parameter No. 1620)}} \times \frac{\text{Amount of travel in block}}{\text{Amount of travel for each axis}}
     \]

   - **For bell-shaped acceleration/deceleration**

     The time constant set in parameter No. 1621 (time constant for bell-shaped acceleration/deceleration for rapid traverse for each axis) for the axis for which the minimum value is obtained using the above expression is applied to the feedrate obtained using the above acceleration.
Feedrate

<table>
<thead>
<tr>
<th>Linear acceleration/deceleration</th>
<th>Bell-shaped acceleration/deceleration</th>
</tr>
</thead>
<tbody>
<tr>
<td>tta</td>
<td>Depends on the linear acceleration.</td>
</tr>
<tr>
<td>tbb</td>
<td>Time constant for bell-shaped</td>
</tr>
<tr>
<td>tcc</td>
<td>acceleration/deceleration</td>
</tr>
<tr>
<td>tca</td>
<td>tta + tbb</td>
</tr>
<tr>
<td>tbc</td>
<td>tc</td>
</tr>
</tbody>
</table>

\[
\text{tc} = \text{ta} + \text{tb}
\]
If the feedrate during movement is $F$, the acceleration for linear acceleration/deceleration is $A$, the time constant for bell–shaped acceleration/deceleration is $T$, the time required for acceleration/deceleration can be obtained as follows:

Time required for acceleration/deceleration

\[
\text{Time required for linear acceleration/deceleration} = \frac{F}{A} \\
\text{Time required for bell–shaped acceleration/deceleration} = \frac{F}{A} + T
\]

When the non–linear interpolation type is selected, movement is performed at the feedrate set in parameter No. 1420 with acceleration/deceleration set in parameter No. 1620. The corresponding value can be set in parameter No. 1621 to select bell–shaped acceleration/deceleration. (To select bell–shaped acceleration/deceleration, the option of bell–shaped acceleration/deceleration for rapid traverse is required.)

**NOTE**
Rapid traverse block overlap is disabled.
To use bell–shaped acceleration/deceleration, the option of bell–shaped acceleration/deceleration for rapid traverse is required.
In the AI nano contour control mode, the non–linear interpolation type cannot be selected.
During involute interpolation, the following overrides are applied to the specified cutting feedrate. By this function, a good cutting surface with higher machining precision can be obtained.

1. Override for inward offset in cutter compensation
2. Override near the base circle

(1) Override for inward offset in cutter compensation

When cutter compensation C is applied to involute interpolation, control is exercised in ordinary involute interpolation so that the tangential feedrate on the tool–center path always keeps the specified feedrate. Under the control, the actual cutting feedrate (feedrate around the perimeter of the tool (cutting point) on the path specified in the program) changes because the curvature of the involute curve changes every moment. If the tool is offset in the inward direction of the involute curve in particular, the actual cutting feedrate becomes higher than the specified feedrate as the tool gets nearer to the base circle.

For smooth machining, it is desirable to control the actual cutting feedrate so that the feedrate keeps the specified feedrate. This function calculates the override commensurate with the curvature of the involute curve which changes every moment in involute interpolation, in particular, with inward offset. The function also controls the actual cutting feedrate (tangential feedrate at the cutting point) so that it always keeps the specified feedrate.

The override is calculated as follows:

\[ OVRa = \frac{Rcp}{Rcp + Rofs} \times 100 \]

- \( Rcp \) : Radius of curvature at the center of the tool of the involute curve passing through the center of the tool
- \( Rofs \) : Radius of the cutter
(2) Override near the base circle

In a part near the base circle where the change in the curvature of the involute curve is relatively significant, cutting at the feedrate as specified in the program may put a heavy load on the cutter, resulting in a rough cutting surface. This function automatically decelerates the movement of the tool in a part near the base circle where the change in the curvature of the involute curve is significant according to the settings of parameters to decrease the load on the cutter for a fine cutting surface.

If the radius of curvature at the cutting point reaches a value within the range specified in parameter (Rlmt1) to (Rlmt5), the corresponding override listed below is applied:

When Rlmt1 > Rcp ± Rofs ≥ Rlmt2:

\[
OVRb = \frac{100 - OVR2}{Rlmt1 - Rlmt2} \times (Rcp + Rofs - Rlmt2) + OVR2
\]

When Rlmt2 > Rcp ± Rofs ≥ Rlmt3:

\[
OVRb = \frac{OVR2 - OVR3}{Rlmt2 - Rlmt3} \times (Rcp + Rofs - Rlmt3) + OVR3
\]

When Rlmt3 > Rcp ± Rofs ≥ Rlmt4:

\[
OVRb = \frac{OVR3 - OVR4}{Rlmt3 - Rlmt4} \times (Rcp + Rofs - Rlmt4) + OVR4
\]

When Rlmt4 > Rcp ± Rofs ≥ Rlmt5:

\[
OVRb = \frac{OVR4 - OVR5}{Rlmt4 - Rlmt5} \times (Rcp + Rofs - Rlmt5) + OVR5
\]

Set Rlmt1 to Rlmt5 and OVR2 to OVR5 in parameter Nos. 5611 to 5615 and 5616 to 5619, respectively. Rcp ( Rofs means Rcp + Rofs for inward offset or Rcp – Rofs for outward offset.

If the calculated override is lower than the lower limit set in the corresponding parameter, it is clamped to the lower override limit.
NOTE
1 When the override near the base circle is enabled, the override for inward offset in cutter compensation is disabled. These overrides cannot be enabled simultaneously.
2 When the distance from the center of the base circle to the start point is the same as that from the center of the base circle to the end point, that is, for a circle, circular interpolation is used. For this reason, no automatic override is applied.
3 If there is an end point error, the feedrate is not guaranteed.
4 If there is an end point error, the remaining distance required for acceleration/deceleration before interpolation may not be obtained exactly. In this case, alarm 242 occurs.
5 For other restrictions, refer to the operator’s manual.
6 In the AI nano contour control mode, involute interpolation cannot be specified.

In the following tables, AI control means the AI contour control/AI nano contour control mode.

(1) Parameters related to linear acceleration/deceleration before interpolation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Parameter number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acceleration/deceleration type (A or B)</td>
<td>FWB/1602#0</td>
</tr>
<tr>
<td>Parameter 1 for setting the acceleration</td>
<td>1630</td>
</tr>
<tr>
<td>Parameter 2 for setting the acceleration</td>
<td>1631</td>
</tr>
<tr>
<td>Feedrate at which an overtravel alarm occurs</td>
<td>1784</td>
</tr>
</tbody>
</table>

(2) Parameters related to automatic corner deceleration

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Parameter number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method for determining whether to perform automatic corner deceleration</td>
<td>CSD/1602#4</td>
</tr>
<tr>
<td>(angle/feederate difference)</td>
<td>None</td>
</tr>
<tr>
<td>Lower feedrate limit (control according to the angle)</td>
<td>1778</td>
</tr>
<tr>
<td>Angle at which automatic corner deceleration is performed (control according to the angle)</td>
<td>1740</td>
</tr>
<tr>
<td>Allowable feedrate difference for all axes (control according to the feederate difference)</td>
<td>1780</td>
</tr>
<tr>
<td>Allowable feedrate difference for each axis (control according to the feederate difference)</td>
<td>1783</td>
</tr>
<tr>
<td>Acceleration/deceleration type (Type A/Type B)</td>
<td>FWB/1602#0</td>
</tr>
<tr>
<td>Corresponding parameter numbers in the normal mode, advanced preview control mode, and AI contour control/AI nano contour control mode</td>
<td></td>
</tr>
</tbody>
</table>
(3) Parameter related to feedrate clamping by acceleration

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Parameter number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>Advanced preview control</td>
</tr>
<tr>
<td>Parameter for determining the allowable acceleration</td>
<td>None</td>
</tr>
</tbody>
</table>

(4) Parameters related to feedrate clamping by arc radius

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Parameter number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>Advanced preview control</td>
</tr>
<tr>
<td>Arc radius corresponding to the upper feedrate limit</td>
<td>1731</td>
</tr>
<tr>
<td>Upper feedrate limit at arc radius R</td>
<td>1730</td>
</tr>
<tr>
<td>Lower clamped feedrate limit</td>
<td>1732</td>
</tr>
</tbody>
</table>

(5) Parameters related to involute interpolation (only in the AI contour control mode)(*1)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Parameter number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>Advanced preview control</td>
</tr>
<tr>
<td>Initial angle error limit</td>
<td>5610</td>
</tr>
<tr>
<td>Override near the base circle: Radius of curvature</td>
<td>None</td>
</tr>
<tr>
<td>Override near the base circle: Override</td>
<td>None</td>
</tr>
<tr>
<td>Lower override limit</td>
<td>None</td>
</tr>
</tbody>
</table>

(6) Other parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Parameter number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>Advanced preview control</td>
</tr>
<tr>
<td>Precision of radius errors in circular interpolation</td>
<td>PCIR1/3403#0</td>
</tr>
<tr>
<td>Maximum cutting feedrate (common to all axes)</td>
<td>1422</td>
</tr>
<tr>
<td>Maximum cutting feedrate (for each axis)</td>
<td>1430</td>
</tr>
<tr>
<td>Rapid traverse movement type*</td>
<td>LRP/1401#1</td>
</tr>
<tr>
<td>Time constant for bell–shaped acceleration/deceleration for rapid traverse</td>
<td>1621</td>
</tr>
<tr>
<td>Parameter</td>
<td>Parameter number</td>
</tr>
<tr>
<td>-----------</td>
<td>------------------</td>
</tr>
<tr>
<td>Normal</td>
<td>Advanced preview control</td>
</tr>
<tr>
<td>Arc radius corresponding to the upper feedrate limit</td>
<td>1731</td>
</tr>
</tbody>
</table>

* For AI nano—contour control, the rapid traverse movement type is not set with a parameter, but is always linear interpolation positioning.

### Alarms

<table>
<thead>
<tr>
<th>Number</th>
<th>Message</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>5110</td>
<td>IMPROPER G CODE (G05.1 Q1 MODE)</td>
<td>An unspecifiable G code was specified in the AI contour control/AI nano contour control mode.</td>
</tr>
<tr>
<td>5111</td>
<td>IMPROPER MODAL G CODE (G05.1 Q1)</td>
<td>An unavailable modal G code was found when the AI contour control/AI nano contour control mode was specified.</td>
</tr>
<tr>
<td>5112</td>
<td>G08 CAN NOT BE COMMANDED (G05.1 Q1)</td>
<td>The look-ahead control command (G08) was specified in the AI contour control/AI nano contour control mode.</td>
</tr>
<tr>
<td>5114</td>
<td>CAN NOT ERROR IN MDI MODE (G05.1 Q1)</td>
<td>Intervention by manual operation was performed during execution of the G28, G30, G30.1, or G53 command (linear interpolation type) in the AI contour control mode. After that, automatic operation was restarted at a position other than the stop position.</td>
</tr>
<tr>
<td>5156</td>
<td>ILLEGAL AXIS OPERATION (AICC)</td>
<td>In the AI contour control/AI nano contour control mode, the controlled axis selection signal (PMC axis control) changed.</td>
</tr>
<tr>
<td>5157</td>
<td>PARAMETER 0 (AICC)</td>
<td>The setting of the parameter for specifying the maximum cutting feedrate (No. 1422, 1432, or 1420) is 0. The setting of the parameter for specifying acceleration/deceleration before interpolation (No. 1770 or 1771) is 0.</td>
</tr>
</tbody>
</table>

### Notes

1) This function requires the AI contour control function or AI nano contour control function option.

When the AI contour control function option is installed, the look–ahead control function (G08P1) can also be specified. When the AI nano contour control function option is installed, the AI contour control function and look–ahead control function (G08P1) can also be specified.
2) When the total distance of blocks read in advance reaches the distance for decelerating from the current feedrate, deceleration is started. When look-ahead operation proceeds and the total distance of blocks increases by termination of deceleration, acceleration is started again. If a series of blocks with a small amount of travel are specified, the deceleration and acceleration may be alternated, which prevents the feedrate from being constant. In this case, specify a lower feedrate.

3) When the dry run signal is inverted from "0" to "1" or from "1" to "0" during movement along an axis, acceleration/deceleration is performed to the specified feedrate without deceleration to feedrate 0.

4) If a non-movement block or one-shot G code command such as G04 is found in the AI contour control/AI nano contour control mode, the movement is decelerated and temporarily stopped in the preceding block.

5) For acceleration/deceleration after interpolation, use linear or bell-shaped acceleration/deceleration. Exponential acceleration/deceleration cannot be used.

### Specifications

<table>
<thead>
<tr>
<th>Name</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of controlled axes</td>
<td>3 to 8</td>
</tr>
<tr>
<td></td>
<td>To use four to eight axes, another option is required.</td>
</tr>
<tr>
<td>Number of simultaneously controlled axes</td>
<td>Up to 6</td>
</tr>
<tr>
<td></td>
<td>To use three or more simultaneously controlled axes, another option is required.</td>
</tr>
<tr>
<td>Axis name</td>
<td>The basic three axes are fixed to X, Y, and Z. Other axes are any of U, V, W, A, B, and C.</td>
</tr>
<tr>
<td>Least input increment</td>
<td>0.001 mm, 0.001 deg, 0.0001 inch</td>
</tr>
<tr>
<td>One-tenth input increment</td>
<td>0.0001 mm, 0.0001 deg, 0.00001 inch</td>
</tr>
<tr>
<td></td>
<td>One-tenth input increment for each axis cannot be used.</td>
</tr>
<tr>
<td>Simple synchronous control</td>
<td>○</td>
</tr>
<tr>
<td></td>
<td>If the AI contour control/AI nano contour control option is installed, however, switching between synchronous and normal operation cannot be performed during automatic operation (when the automatic operation signal (OP) is set to 1) regardless of whether the AI contour control/AI nano contour control mode is set. In this case, switching causes a PS213 alarm.</td>
</tr>
<tr>
<td>Twin table</td>
<td>×</td>
</tr>
<tr>
<td>Angular axis/Arbitrary angular axis control</td>
<td>×</td>
</tr>
<tr>
<td>Tandem control</td>
<td>○</td>
</tr>
<tr>
<td></td>
<td>Full preloading cannot be performed, however.</td>
</tr>
<tr>
<td>Chopping</td>
<td>×</td>
</tr>
<tr>
<td>Hobbing machine function</td>
<td>×</td>
</tr>
<tr>
<td>Simple electric gear box</td>
<td>×</td>
</tr>
<tr>
<td>Learning control</td>
<td>×</td>
</tr>
<tr>
<td>Foreseeing repetition control</td>
<td>×</td>
</tr>
<tr>
<td>Inch/metric conversion (G20, G21)</td>
<td>○</td>
</tr>
<tr>
<td>(&quot;1&quot;)</td>
<td></td>
</tr>
<tr>
<td>Interlock</td>
<td>○</td>
</tr>
<tr>
<td>Interlock for each axis</td>
<td>○</td>
</tr>
<tr>
<td></td>
<td>Movement along all axes stops. To stop movement only along the interlock axis in non-linear interpolation type positioning in the AI contour control mode, set bit 5 (AIL) of parameter No. 7054 to 1 and bit 4 (XIK) of parameter No. 1002 to 0.</td>
</tr>
</tbody>
</table>
### High Speed Cutting Functions

<table>
<thead>
<tr>
<th>Name</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machine lock</td>
<td>○ When the machine lock signal for each axis (MLK1 to MLK8) is turned on or off, acceleration/deceleration is not applied to the axis for which machine lock is performed.</td>
</tr>
<tr>
<td>Stroke check before movement</td>
<td>×</td>
</tr>
<tr>
<td>Mirror image</td>
<td>○</td>
</tr>
<tr>
<td>Stored pitch error compensation</td>
<td>○</td>
</tr>
<tr>
<td>Gradient compensation</td>
<td>○</td>
</tr>
<tr>
<td>Straightness compensation</td>
<td>○</td>
</tr>
<tr>
<td>Position switch</td>
<td>○ Set bit 3 (PSF) of parameter No. 6901 to 1. When this parameter is set to 1, the signal output timing changes.</td>
</tr>
<tr>
<td>Abnormal load detection</td>
<td>○</td>
</tr>
<tr>
<td>Manual handle interruption</td>
<td>○ (AI contour control) Manual handle interruption is disabled during switching to the AI contour control mode.</td>
</tr>
<tr>
<td></td>
<td>× (AI nano contour control)</td>
</tr>
<tr>
<td>External pulse synchronization</td>
<td>×</td>
</tr>
<tr>
<td>Flexible synchronization</td>
<td>×</td>
</tr>
</tbody>
</table>

**Interpolation functions**

○ : Can be specified.  × : Cannot be specified.

<table>
<thead>
<tr>
<th>Name</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positioning (G00)</td>
<td>○ To perform single direction positioning in the AI contour control/AI nano contour control mode, set bit 4 (ADP) of parameter No. 7055 to 1.</td>
</tr>
<tr>
<td>Single direction positioning (G60)</td>
<td>○</td>
</tr>
<tr>
<td>Exact stop (G09)</td>
<td>○</td>
</tr>
<tr>
<td>Exact stop mode (G61)</td>
<td>○</td>
</tr>
<tr>
<td>Tapping mode (G63)</td>
<td>○</td>
</tr>
<tr>
<td>Linear interpolation (G01)</td>
<td>○</td>
</tr>
<tr>
<td>Circular interpolation (G02, G03)</td>
<td>○ (Circular interpolation for multiple quadrants is enabled.)</td>
</tr>
<tr>
<td>Exponential interpolation (G02.3, G03.3)</td>
<td>×</td>
</tr>
<tr>
<td>Dwell (G04)</td>
<td>○ (Dwell with the time in seconds or speed specified) For dwell with the speed specified, another option is required.</td>
</tr>
<tr>
<td>Polarcordinate interpolation (G12.1, G13.1)</td>
<td>×</td>
</tr>
<tr>
<td>Cylindrical interpolation (G07.1)</td>
<td>×</td>
</tr>
<tr>
<td>Helical interpolation (G02, G03)</td>
<td>○ (Circular interpolation + linear interpolation for up to four axes) When the helical interpolation option is installed, linear interpolation for up to two axes is performed. When the helical interpolation B option is installed, linear interpolation for up to four axes is performed. Specify the feedrate including the helical axis in the feedrate command.</td>
</tr>
<tr>
<td>Involute interpolation (G02.2, G03.2)</td>
<td>○</td>
</tr>
<tr>
<td>Hypothetical axis interpolation (G07)</td>
<td>×</td>
</tr>
<tr>
<td>Spiral interpolation and conical interpo-</td>
<td>○ (AI contour control)</td>
</tr>
<tr>
<td>lation (G02, G03)</td>
<td>× (AI nano contour control)</td>
</tr>
<tr>
<td>Smooth interpolation (G05.1)</td>
<td>×</td>
</tr>
<tr>
<td>Threading and synchronous feed (G33)</td>
<td>×</td>
</tr>
</tbody>
</table>
### 19. HIGH SPEED CUTTING FUNCTIONS

#### PROGRAMMING

<table>
<thead>
<tr>
<th>Name</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skip function (G31)</td>
<td>○</td>
</tr>
<tr>
<td>High-speed skip function (G31)</td>
<td>○</td>
</tr>
<tr>
<td>Continuous high-speed skip (G31)</td>
<td>×</td>
</tr>
<tr>
<td>Multistage skip function (G31 Px)</td>
<td>○</td>
</tr>
<tr>
<td>Reference position return (G28)</td>
<td>○</td>
</tr>
<tr>
<td>Reference position return check (G27)</td>
<td>○</td>
</tr>
<tr>
<td>2nd, 3rd, and 4th reference position return (G30)</td>
<td>○</td>
</tr>
<tr>
<td>Floating reference position return (G30.1)</td>
<td>○</td>
</tr>
<tr>
<td>Normal direction control (G41.1, G42.1)</td>
<td>○</td>
</tr>
<tr>
<td>Gentle curve normal direction control</td>
<td>×</td>
</tr>
<tr>
<td>Continuous dressing</td>
<td>×</td>
</tr>
<tr>
<td>In–feed control (G161)</td>
<td>×</td>
</tr>
<tr>
<td>Index table indexing</td>
<td>○</td>
</tr>
<tr>
<td>High–speed cycle cutting (G05)</td>
<td>×</td>
</tr>
<tr>
<td>High–speed linear interpolation (G05P2)</td>
<td>×</td>
</tr>
</tbody>
</table>

#### Feed functions

- ○: Can be specified.
- ×: Cannot be specified.

<table>
<thead>
<tr>
<th>Name</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rapid traverse rate</td>
<td>Up to 240 m/min (0.001 mm)</td>
</tr>
<tr>
<td>Rapid traverse rate override</td>
<td></td>
</tr>
<tr>
<td>Rapid traverse rate override in increments of 1%</td>
<td>0 to 100 %</td>
</tr>
<tr>
<td>Feed per minute (G94)</td>
<td>○</td>
</tr>
<tr>
<td>Feed per revolution (G95)</td>
<td>×</td>
</tr>
<tr>
<td>Cutting feedrate clamp</td>
<td>○</td>
</tr>
<tr>
<td>Bell–shaped acceleration/deceleration for rapid traverse</td>
<td>○</td>
</tr>
<tr>
<td>Positioning according to the optimum acceleration</td>
<td>×</td>
</tr>
<tr>
<td>Linear acceleration/deceleration after cutting feed interpolation</td>
<td>○</td>
</tr>
<tr>
<td>Bell–shaped acceleration/deceleration after cutting feed interpolation</td>
<td>○</td>
</tr>
<tr>
<td>Linear acceleration/deceleration before cutting feed interpolation</td>
<td>○</td>
</tr>
<tr>
<td>Feedrate override</td>
<td>0 to 254 %</td>
</tr>
<tr>
<td>Second feedrate override</td>
<td>×</td>
</tr>
<tr>
<td>Single–digit F code feed</td>
<td>○</td>
</tr>
</tbody>
</table>

To enable feedrate change using a manual handle, set bit 1 (AF1) of parameter No. 7055 to 1.
### 19. HIGH SPEED CUTTING FUNCTIONS

#### Inverse time feed (G93)
- ○
  - Override cancel
  - External deceleration
  - Look-ahead bell-shaped acceleration/deceleration before interpolation
  - High-precision contour control (G05P10000)
  - NURBS interpolation (G06.2)

#### Program input
- ○: Can be specified.
- ×: Cannot be specified.

<table>
<thead>
<tr>
<th>Name</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control in/control out command ()</td>
<td>○</td>
</tr>
<tr>
<td>Optional block skip command (/n: n is a number.)</td>
<td>○</td>
</tr>
<tr>
<td>Absolute command (G90)/incremental command (G91)</td>
<td>○</td>
</tr>
<tr>
<td>Decimal point programming/pocket calculator type decimal point programming</td>
<td>○</td>
</tr>
<tr>
<td>10-fold input unit</td>
<td>○</td>
</tr>
<tr>
<td>Plane selection (G17, G18, G19)</td>
<td>○</td>
</tr>
<tr>
<td>Rotation axis specification</td>
<td>○</td>
</tr>
<tr>
<td>Rotation axis roll over</td>
<td>○</td>
</tr>
<tr>
<td>Polar coordinate command (G16)</td>
<td>×</td>
</tr>
<tr>
<td>Local coordinate system (G52)</td>
<td>○</td>
</tr>
<tr>
<td>Machine coordinate system (G53)</td>
<td>○</td>
</tr>
<tr>
<td>Workpiece coordinate system (G54 to G59)</td>
<td>○</td>
</tr>
<tr>
<td>Workpiece coordinate system (G54.1Pxx)</td>
<td>○</td>
</tr>
<tr>
<td>Workpiece coordinate system (G92)</td>
<td>○</td>
</tr>
<tr>
<td>Workpiece coordinate system preset (G92.1)</td>
<td>○ ×</td>
</tr>
<tr>
<td>Arbitrary angle chamfering/corner rounding</td>
<td>×</td>
</tr>
<tr>
<td>Programmable data input (G10)</td>
<td>○ (1)</td>
</tr>
<tr>
<td>Custom macro B</td>
<td>○</td>
</tr>
<tr>
<td>Addition of custom macro common variables</td>
<td>○</td>
</tr>
<tr>
<td>Pattern data input</td>
<td>×</td>
</tr>
<tr>
<td>Interruption type custom macro</td>
<td>×</td>
</tr>
<tr>
<td>Canned cycle (G73 to G89)</td>
<td>○ (1)</td>
</tr>
<tr>
<td>Initial level return (G98)/point R level return (G99)</td>
<td>○ (1)</td>
</tr>
<tr>
<td>Small hole peck drilling cycle (G83)</td>
<td>×</td>
</tr>
<tr>
<td>Arc radius R programming</td>
<td>○</td>
</tr>
<tr>
<td>Automatic corner override (G62)</td>
<td>○</td>
</tr>
<tr>
<td>Automatic corner deceleration</td>
<td>○</td>
</tr>
<tr>
<td>Feedrate clamping by arc radius</td>
<td>○</td>
</tr>
<tr>
<td>Scaling (G51)</td>
<td>○</td>
</tr>
<tr>
<td>Coordinate system rotation (G68)</td>
<td>○</td>
</tr>
</tbody>
</table>
### 19. HIGH SPEED CUTTING FUNCTIONS

**PROGRAMMING**

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<table>
<thead>
<tr>
<th>Name</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three-dimensional coordinate conversion (G68)</td>
<td>×</td>
</tr>
<tr>
<td>Programmable mirror image (G51.1)</td>
<td>○</td>
</tr>
<tr>
<td>Figure copy (G72.1, G72.2)</td>
<td>×</td>
</tr>
<tr>
<td>Retrace</td>
<td>×</td>
</tr>
<tr>
<td>F15 tape format</td>
<td>○</td>
</tr>
</tbody>
</table>

**Auxiliary functions/spindle–speed functions**

○ : Can be specified.  × : Cannot be specified.

<table>
<thead>
<tr>
<th>Name</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miscellaneous function (Mxxxx)</td>
<td>○</td>
</tr>
<tr>
<td>The function code and function strobe signals are output only.</td>
<td></td>
</tr>
<tr>
<td>Second auxiliary function (Bxxxx)</td>
<td>○</td>
</tr>
<tr>
<td>The function code and function strobe signals are output only.</td>
<td></td>
</tr>
<tr>
<td>High–speed M/S/T/B interface</td>
<td>○</td>
</tr>
<tr>
<td>Multiple miscellaneous function specification</td>
<td>○</td>
</tr>
<tr>
<td>M code group check</td>
<td>○</td>
</tr>
<tr>
<td>Spindle–speed function (Sxxxx)</td>
<td>○</td>
</tr>
<tr>
<td>Spindle synchronous control</td>
<td>○</td>
</tr>
<tr>
<td>Simple spindle synchronous control</td>
<td>○</td>
</tr>
<tr>
<td>Rigid tapping</td>
<td>○</td>
</tr>
<tr>
<td>(*1) Set bit 5 (G8S) of parameter No. 1602 or bit 3 (ACR) of parameter No. 7051 to 1. (AI contour control)</td>
<td></td>
</tr>
<tr>
<td>Three–dimensional rigid tapping</td>
<td>×</td>
</tr>
</tbody>
</table>

**Tool compensation functions**

○ : Can be specified.  × : Cannot be specified.

<table>
<thead>
<tr>
<th>Name</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tool function (Txxxx)</td>
<td>○</td>
</tr>
<tr>
<td>The function code and function strobe signals are output only.</td>
<td></td>
</tr>
<tr>
<td>Tool offset memory B</td>
<td>○</td>
</tr>
<tr>
<td>Tool offset memory C</td>
<td>○</td>
</tr>
<tr>
<td>Tool length compensation (G43, G44, G49)</td>
<td>○</td>
</tr>
<tr>
<td>Tool offset (G45 to G48)</td>
<td>×</td>
</tr>
<tr>
<td>Cutter compensation B (G39 to G42)</td>
<td>×</td>
</tr>
<tr>
<td>Cutter compensation C (G40, G41, G42)</td>
<td>○</td>
</tr>
<tr>
<td>Three–dimensional tool compensation</td>
<td>×</td>
</tr>
<tr>
<td>Tool life management</td>
<td>×</td>
</tr>
<tr>
<td>Automatic tool length measurement</td>
<td>×</td>
</tr>
<tr>
<td>Tool length/workpiece origin measurement B</td>
<td>×</td>
</tr>
<tr>
<td>Grinding–wheel wear compensation</td>
<td>×</td>
</tr>
</tbody>
</table>
Other functions  ○ : Can be specified.  × : Cannot be specified.

<table>
<thead>
<tr>
<th>Name</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cycle start/feed hold</td>
<td>○</td>
</tr>
<tr>
<td>Dry run</td>
<td>○</td>
</tr>
<tr>
<td>Single block</td>
<td>○</td>
</tr>
<tr>
<td>Sequence number comparison and stop</td>
<td>○</td>
</tr>
<tr>
<td>Program restart</td>
<td>○</td>
</tr>
<tr>
<td>Tool retract and recover</td>
<td>×</td>
</tr>
<tr>
<td>Rigid tapping return</td>
<td>×</td>
</tr>
<tr>
<td>Macro executor (execution macro)</td>
<td>×</td>
</tr>
<tr>
<td>MDI operation</td>
<td>○</td>
</tr>
<tr>
<td>Manual intervention</td>
<td>○</td>
</tr>
</tbody>
</table>

**NOTE**
The above tables include a function that another option is required for specifying.
1 Multiple blocks are not read in advance.

- **Conditions for setting the Al contour control/Al nano contour control mode**

When G05.1 Q1 is specified, the modal G codes must be set as listed below. If one of these conditions is satisfied, a PS5111 alarm occurs.

<table>
<thead>
<tr>
<th>G code(s)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>G00</td>
<td>Positioning</td>
</tr>
<tr>
<td>G01</td>
<td>Linear interpolation</td>
</tr>
<tr>
<td>G02</td>
<td>Circular interpolation (CW)</td>
</tr>
<tr>
<td>G03</td>
<td>Circular interpolation (CCW)</td>
</tr>
<tr>
<td>G13.1</td>
<td>Polar coordinate interpolation cancel mode</td>
</tr>
<tr>
<td>G15</td>
<td>Polar coordinate command cancel</td>
</tr>
<tr>
<td>G25</td>
<td>Spindle speed fluctuation detection off</td>
</tr>
<tr>
<td>G40</td>
<td>Cutter compensation cancel</td>
</tr>
<tr>
<td>G40.1</td>
<td>Normal direction control cancel mode</td>
</tr>
<tr>
<td>G49</td>
<td>Tool length compensation cancel</td>
</tr>
<tr>
<td>G50</td>
<td>Scaling cancel</td>
</tr>
<tr>
<td>G50.1</td>
<td>Programmable mirror image cancel</td>
</tr>
<tr>
<td>G64</td>
<td>Cutting mode</td>
</tr>
<tr>
<td>G67</td>
<td>Macro modal call cancel</td>
</tr>
<tr>
<td>G69</td>
<td>Coordinate system rotation cancel</td>
</tr>
<tr>
<td>G80</td>
<td>Canned cycle cancel</td>
</tr>
<tr>
<td>G94</td>
<td>Feed per minute</td>
</tr>
<tr>
<td>G97</td>
<td>Constant surface speed control cancel</td>
</tr>
<tr>
<td>G160</td>
<td>In–feed control function cancel</td>
</tr>
</tbody>
</table>
Some machining errors are due to the CNC. Such errors include machining errors caused by acceleration/deceleration after interpolation. To eliminate these errors, the following functions are performed at high speed by an RISC processor. These functions are called high-precision contour control functions.

(1) Function for multiple-block look-ahead acceleration/deceleration before interpolation. This function eliminates machining errors due to acceleration/deceleration.

(2) Automatic speed control function which enables smooth acceleration/deceleration by considering changes in the figure and speed and allowable acceleration for the machine. This is performed by reading multiple blocks in advance.

For details on high-precision contour control using RISC, refer to the relevant manual published by the machine tool builder.

**Format**

```
G05P10000 ; Start HPCC mode
G05P0 ; End HPCC mode
```

**Explanations**

- **HPCC mode**
  
  The mode used to perform high-precision contour control using RISC is called HPCC mode. To start the HPCC mode in a certain block, specify G05P10000 before that block. To end the HPCC mode, specify G05P0 at the point at which to end the mode.

- **Data that can be specified**
  
  The following data can be specified in HPCC mode:
  
  - **G00**: Positioning (Note)
  - **G01**: Linear interpolation
  - **G02**: Circular interpolation or helical interpolation (CW)
  - **G02.2**: Involute interpolation (CW)
  - **G03**: Circular interpolation or helical interpolation (CCW)
  - **G03.2**: Involute interpolation (CCW)
  - **G17**: Plane selection (XpYp plane)
    where, Xp is the X-axis or a parallel axis;
  - **G18**: Plane selection (ZpXp plane)
    where, Yp is the Y-axis or a parallel axis;
  - **G19**: Plane selection (YpZp plane)
    where, Zp is the Z-axis or a parallel axis.
  - **G38**: Cutter compensation C with vector held
  - **G40**: Cutter compensation cancel
  - **G41**: Cutter compensation, left
  - **G42**: Cutter compensation, right
  - **G50**: Scaling cancel
  - **G51**: Start scaling
  - **G68**: Start coordinate system rotation
  - **G69**: Coordinate system rotation cancel
G73, G74, G76, G81 to G89
  : Canned cycle, rigid tapping
G80  : Canned cycle cancel
G90  : Absolute command
G91  : Incremental command
Dxxxx : Specifying a D code
Fxxxxx : Specifying an F code
Nxxxxx : Specifying a sequence number
G05P10000 : Setting the HPCC mode
G05P0 : Canceling the HPCC mode
Data for movement along axis : Data for moving the tool along the
  axis set in parameter No. 1020 (any
  axis selected from X, Y, Z, U, V, W, A,
  B, and C)
( ) : Control--in and control--out commands
     (comment specification)
/n  : Optional block skip command (n is a number.)
Mxxxx : Auxiliary function (Note)
Sxxxx : Auxiliary function (Note)
Txxxx : Auxiliary function (Note)
Bxxxx : Auxiliary function (Note)
M98, M198, etc. : Subprogram call

NOTE
1  G00, auxiliary functions, subprogram call (M98, M198), and macro
call M and T codes can be specified in the HPCC mode only when
bit 1 of parameter MSU No. 8403 is 1. If these codes are specified
when MSU is not 1, an alarm is issued.
   (Alarm No.5012 for G00 and alarm No.9 for auxiliary functions and
subprogram calls)
2  To specify the following functions in HPCC mode, the following
parameters are required. Specifying any of the following functions
without setting the corresponding parameter causes an alarm.
  Helical interpolation      : Parameter G02 (No.8485*)
    (Alarm to be issued: No.28)
  Involute interpolation    : Parameter INV (No. 8485)
    (Alarm to be issued: No.10)
  Scaling, coordinate rotation : Parameter G51 (No. 8485)
    (Alarm to be issued: No.10)
  Canned cycle, rigid tapping : Parameter G81 (No.8485)
    (Alarm to be issued: No.5000)
• When unspecifiable data is specified

In the HPCC mode, specifying unspecifiable data causes an alarm No. 5000. To specify a program containing unspecifiable data, specify G05P0 to exit from the HPCC mode before specifying the program.

< Sample program >

Main program
O0001 ;
G05P10000 ; HPCC–ON
G00X100.Y200. ;
G91G01X100Y200Z300F2000 ;
X200Y300Z400 ;
X300Y400Z500 ;
X400Y500Z600 ;
X300Y400Z500 ;
M98P0002 ; SUB PROGRAM
X10. ;
G05P0 ; HPCC–OFF
G90G51X0Y0Z0 ;
X500Y400Z300 ;
X600Y500Z400 ;
G50 ;
G05 P10000 ; HPCC–ON
X100Y200 ;
X200Y400 ;
G05P0 ; HPCC–OFF
G04X3. ;
M30 ;

Subprogram
O0002 ;
G00X50.Y50. ;
M11 ;
G02I20.F3000 ;
G01X100. ;
G03I80. ;
G01X–50. ;
G02I100.F5000 ;

Note) When bit 1 of parameter MSU No. 8403 is 1

• Cutter compensation C

When the cutter compensation C option is provided, cutter compensation C is enabled even in HPCC mode. Operation in the offset mode is the same as when HPCC mode is not set, except in the following cases:

• When the end point for an arc does not lie on the arc

In the HPCC mode, when the end point for an arc does not lie on the arc, the start point and end point are connected with a smooth curve; no arc leading line is created. In this case, the system assumes an imaginary circle to perform cutter compensation C. The center of the imaginary circle is the same as the center of the arc, but the imaginary circle passes through the end point. Under the assumption that cutter compensation has been performed with respect to the imaginary circle, the system creates a vector and performs compensation.
• When the offset mode is canceled temporarily

In the HPCC mode, automatic reference position return (G28) and automatic return from the reference position (G29) cannot be specified. Therefore, commands that must cancel the offset mode temporarily cannot be specified.

When using cutter compensation C in the HPCC mode, note the following points:

(1) When G05 P10000 and G05 P0, and G41/G42 and G40 are to be specified together, G41/G42 to G40 must be nested between G05 P10000 and G05 P0. This means that HPCC mode cannot be started or canceled in cutter compensation (G41/G42) mode. If such a specification is made, the P/S alarm No.0178 or P/S alarm No.5013 P/S alarm is issued.

(Example of a correct program)

G05 P10000;
G41 X__ Y__ D01;
G40 X__ Y__;
G42 X__ Y__ D02;
G40 X__ Y__;
G05 P0;

(Example of an incorrect program (1))

G41 X__ Y__ D01;
G05 P10000;       When the start of HPCC mode is specified in cutter compensation mode, the P/S alarm No.0178 is issued.

(Example of an incorrect program (2))

G05 P10000;
G41 X__ Y__ D01;
G05 P0;            When cancellation of HPCC mode is specified in cutter compensation mode, the P/S alarm No.5013 alarm is issued.
(2) When a block containing no movement operation is specified together with the cutter compensation cancel code (G40), a vector with a length equal to the offset value is created in a direction perpendicular to the movement direction of the previous block. Cutter compensation mode is canceled while this vector still remains. This vector is canceled when the next move command is executed.

If cutter compensation mode is canceled while a vector still remains and HPCC mode is canceled before a move command is specified, the P/S alarm No. 5013 is issued.

(3) When an offset value is changed during cutter compensation C in HPCC mode, the new offset value is not used until a block specifying a D code appears.
When bit 1 of parameter MSU No. 8403 is set to 1, G00, M, S, T, and B codes can be specified even in HPCC mode. When specifying these codes in HPCC mode, note the following:

1. When a G00, M, S, T, or B code is specified in cutter compensation mode, the offset vector created in the previous block is maintained.

Example 1) When the following program is executed for machining with offset value D1 set to 10 mm, the start point of N6 is determined by the vector created between N3 and N4:

```
O0001 ;
G92 G90 X-10. Y20. ;
G05 P10000 ;
N1 G01 G42 X0 D1 F1000 ;
N2 X20. ;
N3 X40. Y0 ;
N4 X60. Y20 ;
N5 M01 ;
N6 X80. ;
N7 X90. Y-20. ;
N8 G40 Y-50. ;
G05 P0 ;
M30
```

This vector is used as the vector between N4 and N6.

Programmed path

Tool path

An incorrect offset value is used in this range.

Example 2) When the following program is executed for machining with offset value D1 set to 10 mm, the start point of N5 is determined by the vector created between N3 and N4. If the simplified G00 execution function is enabled (by setting bit 7 of parameter SG0 No. 8403 to 1), a correct vector can be obtained at the intersection of N4 and N5.

```
O0001 ;
G92 G90 X-10. Y20. ;
G05 P10000 ;
N1 G01 G42 X0 D1 F1000 ;
N2 X20. ;
N3 X40. Y0 ;
N4 X60. Y20 ;
N5 G00 X80. ;
N6 G01 X90. Y-20. ;
N7 G40. Y-50. ;
G05 P0 ;
M30
```

This vector is used as the vector between N4 and N5, and N5 and N6.

Programmed path

Tool path

An incorrect offset value is used in this range.
(2) When G00 is specified with bit 7 of parameter SG0 No. 8403 set to 1, the following points should be noted:

- Since the G00 command is replaced by the G01 command, the tool moves at the feedrate set in parameter No. 8481 even when data is specified for two axes.

Example) If the following is specified when parameter No. 8481 is set to 1000 mm/min, F1000 is used instead of F1414

```
G00 X100. Y100. ;
```

- Since the G00 command is replaced by the G01 command, rapid traverse override is disabled and cutting feed override is enabled.

- For acceleration/deceleration after interpolation, the time constant used for cutting feed acceleration/deceleration after interpolation is selected.

- Linear and bell–shaped acceleration/deceleration before interpolation in HPCC mode is enabled.

- No position check is performed.

- Linear interpolation type positioning is performed.

- **Status display**

When G05P10000 is specified, “HPCC” starts blinking at the right–bottom of the screen. While “HPCC” is blinking, the system performs automatic operation in HPCC mode.

Display example for when the system is in HPCC mode

<table>
<thead>
<tr>
<th>Program screen</th>
<th></th>
<th>PROGRAM(MEMORY)</th>
<th>O1234 N00010</th>
</tr>
</thead>
<tbody>
<tr>
<td>N70 (FANUC Series 16) ;</td>
<td></td>
<td>N80 X10. Y10. Z10. ;</td>
<td></td>
</tr>
<tr>
<td>G05 P0 ;</td>
<td></td>
<td>MEM STRT MTN * * *</td>
<td></td>
</tr>
<tr>
<td>MEM STRT MTN * * *</td>
<td>01 : 23 : 45</td>
<td>HPCC</td>
<td></td>
</tr>
</tbody>
</table>
Limitations

- **Modes that can be specified**

Before G05P10000 can be specified, the following modal values must be set. If they are not set, the P/S alarm No. 5012 is issued.

<table>
<thead>
<tr>
<th>G code</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>G13.1</td>
<td>Cancels polar coordinate interpolation.</td>
</tr>
<tr>
<td>G15</td>
<td>Cancels a polar coordinate command.</td>
</tr>
<tr>
<td>G40</td>
<td>Cancels cutter compensation (M series).</td>
</tr>
<tr>
<td>G40.1</td>
<td>Cancels normal direction control (for the M series only).</td>
</tr>
<tr>
<td>G50</td>
<td>Cancels scaling.</td>
</tr>
<tr>
<td>G50.1</td>
<td>Cancels the programmable mirror image function.</td>
</tr>
<tr>
<td>G64</td>
<td>Cutting mode</td>
</tr>
<tr>
<td>G69</td>
<td>Cancels coordinate conversion.</td>
</tr>
<tr>
<td>G80</td>
<td>Cancels canned cycles.</td>
</tr>
<tr>
<td>G94</td>
<td>Feed per minute</td>
</tr>
<tr>
<td>G97</td>
<td>Cancels constant surface speed control.</td>
</tr>
<tr>
<td>M97</td>
<td>Cancels interrupt type macros.</td>
</tr>
</tbody>
</table>

- **Single block**

The G05P10000 block cannot be executed in the single block mode.

- **Second feedrate override and optional block skip**

The second feedrate override and optional block skip functions cannot be used in HPCC mode unless these options are provided.

- **Invalid command**

Externally-requested deceleration, feed at address F with one digit, and automatic corner override commands are ignored.

- **MDI operation**

Switching to the MDI mode cannot be performed in HPCC mode. In addition, MDI operation is not possible.

- **Interlock**

Interlock (for each axis and in each direction) is disabled in HPCC mode.

- **Mirror image and machine lock**

In HPCC mode, never change the external mirror image signal (DI signal), parameter–set mirror image, and each–axis machine lock.

- **Calculator–type input**

In HPCC mode, calculator type input (when bit 0 of parameter DPI No. 3401 is 1) is ignored.

- **Program reset**

A program containing G05P10000; cannot be restarted.

- **Custom macro**

No custom macros can be specified in HPCC mode.

- **Scaling**

In scaling for each axis, a negative magnification cannot be used to create a mirror image.
In Look–ahead bell–shaped acceleration/deceleration before interpolation, the speed during acceleration/deceleration is as shown in the figure below.

![Diagram showing specified speed, linear acceleration/deceleration, and non-linear acceleration/deceleration](image)

- **T1**: Time determined from the specified speed and the specified acceleration
  - Specified acceleration:
    - In case of AI contour control (AICC) and AI nano contour control (AI nanoCC): Parameter No.1770/Parameter No.1771
    - In case of AI High precision contour control (AI–HPCC) and AI nano High precision contour control (AI–nanoHPCC): Parameter No.8400/Parameter No.8401 (or No.19510)
- **T2**: Acceleration change time
  - In case of AICC and AI nanoCC: Parameter No.1772
  - In case of AI–HPCC and AI–nanoHPCC: Parameter No.8416

The time T1, shown above, varies with the specified speed. If the specified speed is low, the speed will be as shown below, causing linear acceleration/deceleration not reaching the specified acceleration.
Linear acceleration/deceleration not reaching specified acceleration/deceleration

![Diagram](image)

**Fig.19.9 (b)**

If linear acceleration/deceleration not reaching the specified acceleration occurs in AI contour control (AICC) mode or AI Nano contour control (AI-nanoCC) mode or AI High Precision Contour control (AI–HPCC) mode or AI Nano High Precision Contour control (AI–nanoHPCC) mode as shown above, this function shortens the acceleration/deceleration time by changing the internal acceleration for acceleration/deceleration before interpolation and the bell–shaped time constant in order to generate an acceleration/deceleration pattern as close as possible to that permits optimum bell–shaped acceleration/deceleration before interpolation for the specified speed.

Optimum bell–shaped acceleration/deceleration before interpolation, as mentioned here, refers to bell–shaped acceleration/deceleration before interpolation in which if \( T_2 > T_1 \), \( T_1 \) and \( T_2 \) are changed to \( T'_1 \) and \( T'_2 \) as shown in the figure below so that linear acceleration/deceleration not reaching the specified acceleration/deceleration does not occur.

This function becomes effective for the Acceleration/deceleration before look–ahead interpolation in AI contour control mode or AI Nano contour control mode or AI High Precision Contour control mode or AI Nano Contour control mode.
Description

- **Methods of specifying the acceleration/deceleration reference speed**

  The acceleration/deceleration reference speed is the feedrate used as the reference for calculating optimum acceleration. In Fig.19.9 (c), it is equivalent to the specified speed used to determine $T_1'$ and $T_2'$. There are three methods for specifying the acceleration/deceleration reference speed.

  1. Specifying the speed using an $F$ in a G05.1 Q1 (AICC or AI nanoCC) block or G05 P10000 (AI–HPCC or AI–nanoHPCC) block

  2. Setting the speed on Parameter

  3. Setting the speed specified with the $F$ command issued at the start of cutting as the reference speed

**NOTE**

This function is effective if BCG (No. 7055 bit 3) is 1 in AI contour control mode or AI Nano contour control mode, or if BCG (No.19501#6) is 1 in AI High Precision Contour control mode or AI Nano High Precision Contour control mode.
If an F command is used in a G05.1 Q1 (AICC or AI nanoCC) block or G05 P10000 (AI–HPCC or AI–nanoHPCC) block, the speed specified with the F command is assumed the acceleration/deceleration reference speed. This acceleration/deceleration reference speed is cleared upon a reset. After the acceleration/deceleration reference speed is cleared upon a reset or after the power is turned off and then on again, the acceleration/deceleration reference speed specified for parameter No. 7066 (AICC or AI nanoCC) or No.19520 (AI–HPCC or AI–nanoHPCC) will be used. (Method (2), described later)

If the acceleration/deceleration reference speed specified for the parameter is 0, the feedrate assumed at the start of cutting will be assumed the acceleration/deceleration reference speed. (Method (3), described later)

(1) Specifying the speed in a G05.1 Q1 block or G05 P10000 block

(2) Setting the speed on the Parameter

(Program example)

G05.1 Q1 F5000 ; ... Sets the reference speed to 5000 mm/min.
The F command used in a G05.1 block is used to specify the acceleration/deceleration reference speed, and is also used as a normal F command.

Even if the feedrate is changed during the execution of the machining program, the acceleration/deceleration reference speed specified with the above command remains in effect. If this occurs, the machining time may become longer because machining is performed at the feedrate different from the acceleration/deceleration reference speed.

For this reason, the acceleration/deceleration reference speed to be specified with the above command should be as close as possible to the actual machining speed.

NOTE
The G05.1Q1Fxxxx, G05P10000Fxxxx command must be issued in feed per minute (G94) mode. If this command is issued in another mode, the speed specified with this command will be generated the alarm (PS5111).

the acceleration/deceleration reference speed is set in parameter No. 7066 (AICC or AI nanoCC) or No.19520 (AI–HPCC or AI–nanoHPCC). Because these parameters must be set in input unit, when the input unit is changed, these parameters must be changed.

This method is used if the G05.1Q1 block or G05 P10000 block does not have an F command.
3) Using the speed specified with the F command issued at the start of cutting as the reference speed

The speed specified with the F command issued when a cutting block group (such as G01 and G02) starts is assumed the acceleration/deceleration reference speed. This method is used if the G05.1Q1 block or G05 P10000 block does not have an F command and the parameter of the acceleration/deceleration reference speed is set to 0.

```
(G00)
G01 X-- Y-- Z-- F*** ;
X-- Y-- Z--
X-- Y-- Z--
X-- Y-- Z--
G00 ;
```

Cutting block group

Even if an F command is issued before a cutting block group and the F command is effective to the cutting block group modally, the speed specified with the modal F effective at the start of cutting will be assumed the acceleration/deceleration reference speed.

Optimum bell-shaped acceleration/deceleration before interpolation, as mentioned here, refers to bell-shaped acceleration/deceleration before interpolation in which linear acceleration/deceleration not reaching the specified acceleration/deceleration does not occur if T2 > T1. Calculation is performed as described below.

1) If the bell-shaped acceleration/deceleration before interpolation time constant T2' is calculated under the condition that the bell-shaped acceleration/deceleration before interpolation must not have a linear portion,

\[
T2' = \sqrt{\frac{T2 \times F}{A}}
\]

T2: Acceleration change time specified for bell-shaped acceleration/deceleration before interpolation
F: Acceleration/deceleration reference speed
A: Acceleration for the acceleration/deceleration before interpolation
(2) A proper acceleration is determined under the condition that the acceleration change must be about the same as the setting so that parameter changes do not cause considerable shock to the machine, that is:

\[
\frac{\text{Acceleration after change}}{\text{Acceleration change time after change}} = \frac{\text{Acceleration before change}}{\text{Acceleration change time before change}}
\]

The acceleration change time is regarded to be the sum of the acceleration change time of bell-shaped acceleration/deceleration and the time constant of acceleration/deceleration after interpolation, and the acceleration A’ for the acceleration/deceleration before interpolation is determined as follows:

\[
A' = A \cdot \frac{T2' + Tc}{T2 + Tc}
\]

A: Acceleration for the acceleration/deceleration before interpolation
Tc: Time constant of acceleration/deceleration after interpolation

Acceleration/deceleration is performed using T2’ and A’, determined as described above.
19.10
OPTIMUM TORQUE ACCELERATION/DECeleration

General

This function enables acceleration/deceleration in accordance with the torque characteristics of the motor and the characteristics of the machines due to its friction and gravity and performs linear type positioning with optimum acceleration/deceleration during AI high precision contour control mode or AI nano high precision contour control mode.

Usually, because of the friction of the machine, gravity, the torque characteristics of the motor, and other factors, the acceleration/deceleration performance (torque for acceleration/deceleration) is different with direction of movement, acceleration or deceleration. In this function, acceleration pattern of rapid traverse for the following situations, plus movement and acceleration, plus movement and deceleration, minus movement and acceleration, minus movement and deceleration can be set into parameters according to the torque for acceleration/deceleration of each situation. Acceleration/deceleration can be performed according to these parameter setting, so that the most of the capability of the motor can be used and positioning time can be reduced.

![Optimum Torque Acceleration/Deceleration Diagram]

*Fig. 19.10 (a) Conventional acceleration/deceleration*
### Description

Optimum torque acceleration/deceleration selects the acceleration pattern set with parameters on the basis of the axial movement direction and the acceleration/deceleration state, determines the acceleration for each axis from the current speed, and controls the tangential acceleration/deceleration for rapid traverse in AI high precision contour control and AI nano high precision contour control mode.

#### Calculation of the reference acceleration

The reference acceleration is the standard acceleration to set the acceleration pattern, usually this is the same as the acceleration for rapid traverse at the selecting a motor.

\[
\text{Reference acceleration [mm/sec}^2] = \frac{\text{No.1420} \times 1000 \times \text{(Rapid traverse rate)}}{\text{No.1773} \times 60 \times \text{(Acc/Dec Time Constant of rapid traverse)}}
\]

#### Setting optimum torque acceleration/deceleration

By setting both FAP, bit 0 of parameter No. 19540, and FRP, bit 5 of parameter No. 19501, to 1 and setting parameter to determine the reference acceleration (No. 1420 and No.1773 ) as below, the acceleration/deceleration for rapid traverse in AI high precision contour control and AI nano high precision contour control mode will be optimum torque acceleration/deceleration. When Optimum torque acceleration/deceleration is enabled, linear type positioning for rapid traverse is selected automatically in AI high precision contour control and AI nano high precision contour control mode even if the parameter LRP, bit 1 of parameter No. 1401, is set to 0 (nonlinear type is selected). If rapid traverse is subject to optimum torque acceleration/deceleration, after-interpolation acceleration/deceleration does not apply to rapid traverse.
Table. 19.10 (a) Optimum torque acceleration/deceleration

<table>
<thead>
<tr>
<th>FAP 19540#0</th>
<th>FRP 19501#5</th>
<th>Reference acceleration</th>
<th>Bell-shaped acceleration change time</th>
<th>Acceleration pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>Before-interpolation acc/dec for rapid traverse</td>
<td>No.1420 &amp; No.1773</td>
<td>No.1774</td>
</tr>
</tbody>
</table>

To enable bell–shaped acceleration/deceleration in addition to optimum torque acceleration/deceleration, set HRB, bit 0 of parameter No. 19504 to 1 and the bell–shaped acceleration change time with parameter No.1774.

- **Cases in which optimum torque acceleration/deceleration is disabled**

In case that optimum torque acceleration/deceleration is disabled, acceleration/deceleration for rapid traverse will be after–interpolation acceleration/deceleration or before interpolation acceleration/deceleration. When the command having the following restriction is commanded, optimum torque acceleration/deceleration is disabled.

(Restriction)

Optimum torque acceleration/deceleration is disabled at the command with the restriction "AI high precision contour control mode or the AI nano high precision contour control mode is automatically canceled once and the buffering is inhibited” which is mentioned in the specification manual for AI high precision contour control mode or the AI NANO high precision contour control.

For example, during the following commands which includes the M,S,T,B code, optimum torque acceleration/deceleration is disabled:

1. G00 ×100.M13; (G00 with M code)
2. G00 ×100.S1000; (G00 with S code)
3. G00 ×100.T01; (G00 with T code)
4. G00 ×100.B20; (G00 with B code)

- **Setting acceleration pattern data**

![Acceleration Pattern Diagram](image-url)

**Fig.19.10 (c) Setting acceleration pattern**
Set the speed and the acceleration at each of the acceleration setting points P0 to P5 for each condition, plus movement and acceleration, plus movement and deceleration, minus movement and acceleration, minus movement and deceleration, and for each axis. The line joining the acceleration setting points is regarded a acceleration pattern.

For example, while the speed is between Fa and Fb in the previous figure, the acceleration is calculated with Aa and Ab. Tangential acceleration is controlled not to exceed the calculated acceleration for each axis.

<table>
<thead>
<tr>
<th>Acceleration setting point</th>
<th>Speed parameter</th>
<th>Acceleration parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>During acceleration</td>
<td>During deceleration</td>
</tr>
<tr>
<td></td>
<td>During movement in plus direction</td>
<td>During movement in minus direction</td>
</tr>
<tr>
<td></td>
<td>During movement in plus direction</td>
<td>During movement in minus direction</td>
</tr>
<tr>
<td>P0 (Speed 0)</td>
<td>No.19545</td>
<td>No.19551</td>
</tr>
<tr>
<td>P1 No.19541</td>
<td>No.19546</td>
<td>No.19552</td>
</tr>
<tr>
<td>P2 No.19542</td>
<td>No.19547</td>
<td>No.19553</td>
</tr>
<tr>
<td>P3 No.19543</td>
<td>No.19548</td>
<td>No.19554</td>
</tr>
<tr>
<td>P4 No.19544</td>
<td>No.19549</td>
<td>No.19555</td>
</tr>
<tr>
<td>P5 No.1420</td>
<td>No.19550</td>
<td>No.19556</td>
</tr>
</tbody>
</table>

The speed at P0 is 0, and the speed at P5 is the rapid traverse rate specified with parameter (No. 1420). The speeds at P1 to P4 are to be set into speed parameters Nos. 19541 to 19544 as ratio to the rapid traverse speed (parameter No. 1420).

Any acceleration setting point for which the speed parameter (one of Nos. 19541 to 19544) is set to 0 will be skipped, and the next point whose speed parameter is set to a non-zero value will be joined together as acceleration pattern.

The accelerations at P0 to P5 are to be set into acceleration parameters Nos. 19545 to 19568 as ratio to the reference acceleration. If any of the acceleration parameters Nos. 19545 to 19568 is set to 0, the acceleration is assumed 100% (Reference acceleration). Acceleration parameters should be set to 0 at the acceleration setting point whose speed parameter is set to 0.

If this function is enabled and both parameter No.1773 and No. 1620 for an axis are set to 0, the following values are assumed as the reference acceleration for that axis:

1000.0 mm/sec/sec, 100.0 inch/sec/sec, 100.0 degrees/sec/sec
In this example, the machine is equipped with the aM30/4000i. Motor speed at rapid traverse is 3000 (min\(^{-1}\)).

**Specifications of the motor model α30/4000i**

- Rotor inertia: 0.0099 (Kgm\(^2\))
- Maximum torque: 100 (Nm) Speed: 0 to 2000 (min\(^{-1}\))
- Torque at rapid traverse: 79 (Nm) Speed: 3000 (min\(^{-1}\))
- Minimum torque: 58 (Nm) Speed: 4000 (min\(^{-1}\))

It assumes that 10 (Nm) is needed for the friction torque, so that the torque for acceleration/deceleration is shown as the following figure. Because the friction torque is different on each machine, it is necessary to observe the actual torque output on the machine.

- Maximum torque: 90 (=100–10) (Nm) Speed: 0 to 2000 (min\(^{-1}\))
- Torque at rapid traverse: 69 (=79–10) (Nm) Speed: 3000 (min\(^{-1}\))
- Minimum torque: 48 (=58–10) (Nm) Speed: 4000 (min\(^{-1}\))
Let the torque be \( x \) (Nm), the inertia be \( y \)(Kgm²), and the ball screw pitch \( p \)(mm), then the acceleration \( A \) is calculated as follows:

\[
A = \frac{x[N \cdot m]}{y[kg \cdot m^2]} \times \frac{p}{2\pi}[mm] = \frac{x[(kg \cdot m/\text{sec}^2) [m]]}{y[kg \cdot m^2]} \times \frac{p}{2\pi}[mm]
\]

\[
A = \frac{x \times p}{2\pi \times y}[mm/\text{sec}^2]
\]

Machine specification is assumed as follows,

Ball screw pitch : 16 (mm)

Inertia : The machine inertia is to be 2.0 times higher than that of the rotor.

(Rotor inertia: 0.0099 (Kgm²))

The acceleration at maximum torque is,

\[
\frac{90 \times 16}{2\pi \times 3.0 \times 0.0099} = 7717[\text{mm}/\text{sec}^2]
\]

The acceleration at rapid traverse is,

\[
\frac{69 \times 16}{2\pi \times 3.0 \times 0.0099} = 5916[\text{mm}/\text{sec}^2]
\]

From the above data, the parameters related to acceleration pattern is given in the table below.

The example assumes that the acceleration is the same regardless of whether acceleration or deceleration is in progress or whether the movement is in the plus or minus direction.

**Table. 19.10 (c) Example of setting parameters related to acceleration pattern (1/2)**

<table>
<thead>
<tr>
<th>Parameter No.</th>
<th>Setting</th>
<th>Unit</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rapid traverse rate</td>
<td>1420</td>
<td>48000.</td>
<td>mm/ min The ball screw pitch is assumed 16 mm, so that the rapid traverse rate is 48000 mm/min at the maximum speed 3000 (min⁻¹).</td>
</tr>
<tr>
<td>Reference acceleration</td>
<td>1773</td>
<td>194</td>
<td>msec Reference acceleration is ( \frac{48000}{194/1000} = 4124 ) (mm/sec²)</td>
</tr>
<tr>
<td>Speed at P1</td>
<td>19541</td>
<td>6666</td>
<td>0.01% 66.66% is set at P1 because the torque 90(Nm) is constant up to 2000 (min⁻¹) (32000mm/min). 0.6666 = 32000/48000</td>
</tr>
<tr>
<td>Speeds at P2 to P4</td>
<td>19542 to 19544</td>
<td>0</td>
<td>0.01% P2 to P4 are skipped because the torque drops almost linearly from the speed 2000 (min⁻¹) to 3000 (min⁻¹).</td>
</tr>
<tr>
<td>Acceleration at P0</td>
<td>19545,19551 19557,19563</td>
<td>18712</td>
<td>0.01% At P0, 90(Nm) can be used for the acceleration/deceleration, so set the ratio 7717 (mm/sec²) to 4124 (mm/sec²). 1.8712 = 7717/4124</td>
</tr>
</tbody>
</table>

---

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Table. 19.10 (c) Example of setting parameters related to acceleration pattern (2/2)

<table>
<thead>
<tr>
<th>Parameter No.</th>
<th>Setting</th>
<th>Unit</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acceleration at P1</td>
<td>19546, 19552, 19558, 19564</td>
<td>18712</td>
<td>0.01%</td>
</tr>
<tr>
<td>Acceleration at P2 to P4</td>
<td>19547–19549, 19553–19555, 19559–19561, 19565–19567</td>
<td>0</td>
<td>0.01%</td>
</tr>
<tr>
<td>Acceleration at P5</td>
<td>19550, 19556, 19562, 19568</td>
<td>14345</td>
<td>0.01%</td>
</tr>
</tbody>
</table>

With the above parameter settings, the acceleration pattern will be shown as the following figure. The acceleration is 7716 (mm/sec²) in case speed is up to 32000 (mm/min) and acceleration is calculated according to the following figure in case speed is from 32000 (mm/min) up to 48000 (mm/min).

Fig.19.10 (f) Acceleration pattern with consideration of friction

NOTE
The values in the model α30/4000i speed–torque characteristic diagram are just typical ones. The values will change depending on the digital servo software, parameters, input voltage, and other factors. The optimum acceleration will, therefore, change due to the characteristics of the machine.
From the effect of gravity and friction, torque for acceleration/deceleration is different on each condition, such as acceleration, deceleration or plus move (up), minus move (down).

The following example is for the vertical axis and gravity and friction torque are assumed as follows.

Torque of gravity : 20 (Nm)
Torque of friction : 10 (Nm)

Because these value are different on each machine, it is necessary to observe the output torque on the actual machine for deciding acceleration pattern.

The conditions are the same as the previous example.

Motor speed at rapid traverse : 3000 (min⁻¹)
Ball screw pitch : 16 (mm)
Inertia : The machine inertia is to be 2.0 times higher than that of the rotor.
Rotor inertia : 0.0099 (Kgm²)
Maximum torque : 100 (Nm) Speed: 0 to 2000 (min⁻¹)
Torque at rapid traverse : 79 (Nm) Speed: 3000 (min⁻¹)
Minimum torque : 58 (Nm) Speed: 4000 (min⁻¹)

(1) In case of plus move (up) and acceleration

Because torque of Gravity and friction work against the output torque of motor, the torque for acceleration/deceleration is as follows.

Maximum torque : 70(=100–20–10) (Nm) Speed: 0 to 2000 (min⁻¹)
Torque at rapid traverse : 49(=79–20–10) (Nm) Speed: 3000 (min⁻¹)
Minimum torque : 28(=58–20–10) (Nm) Speed: 4000 (min⁻¹)

![Fig.19.10(g) Torque for Acc/Dec in case of + move and acceleration](image-url)
Parameter setting is as follows,

<table>
<thead>
<tr>
<th>Parameter No.</th>
<th>Setting</th>
<th>Unit</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acceleration at P0</td>
<td>19545</td>
<td>14554</td>
<td>0.01%</td>
</tr>
<tr>
<td>Acceleration at P1</td>
<td>19546</td>
<td>14554</td>
<td>0.01%</td>
</tr>
<tr>
<td>Acceleration at P2 – P4</td>
<td>19547–19549</td>
<td>0</td>
<td>0.01%</td>
</tr>
<tr>
<td>Acceleration at P5</td>
<td>19550</td>
<td>10187</td>
<td>0.01%</td>
</tr>
</tbody>
</table>

Fig.19.10(h) Acceleration pattern in case of + move and acceleration

(2) In case of plus move (up) and deceleration

Because torque of Gravity and friction work forward to the output torque of motor, the torque for acceleration/deceleration is as follows.

- Maximum torque: 130(=100+20+10) (Nm)
  Speed: 0 to 2000 (min⁻¹)
- Torque at rapid traverse: 109(=79+20+10) (Nm)
  Speed: 3000 (min⁻¹)
- Minimum torque: 88(=58+20+10) (Nm)
  Speed: 4000 (min⁻¹)
Parameter setting is as follows,

<table>
<thead>
<tr>
<th>Parameter No.</th>
<th>Setting</th>
<th>Unit</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acceleration at P0</td>
<td>19557</td>
<td>27027</td>
<td>0.01 %</td>
</tr>
<tr>
<td>Acceleration at P1</td>
<td>19558</td>
<td>27027</td>
<td>0.01 %</td>
</tr>
<tr>
<td>Acceleration at P2 –P4</td>
<td>19559–19561</td>
<td>0</td>
<td>0.01 %</td>
</tr>
<tr>
<td>Acceleration at P5</td>
<td>19562</td>
<td>22662</td>
<td>0.01 %</td>
</tr>
</tbody>
</table>
(3) In case of minus move (down) and acceleration

Because torque of Gravity works forward to the output torque of motor and torque of friction works against the output torque of motor, torque for acceleration/deceleration is as follows.

- **Maximum torque**: 110(=100+20–10) (Nm)
  Speed: 0 to 2000 (min⁻¹)
- **Torque at rapid traverse**: 89(=79+20–10) (Nm)
  Speed: 3000 (min⁻¹)
- **Minimum torque**: 68(=58+20–10) (Nm)
  Speed: 4000 (min⁻¹)

**Figure 19.10(k) Torque for Acc/Dec in case of – move and acceleration**

Parameter setting is as follows,

<table>
<thead>
<tr>
<th>Parameter No.</th>
<th>Setting</th>
<th>Unit</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acceleration at P0</td>
<td>19551</td>
<td>22869</td>
<td>0.01 %</td>
</tr>
<tr>
<td>Acceleration at P1</td>
<td>19552</td>
<td>22869</td>
<td>0.01 %</td>
</tr>
<tr>
<td>Acceleration at P2 – P4</td>
<td>19553–19555</td>
<td>0</td>
<td>0.01 %</td>
</tr>
<tr>
<td>Acceleration at P5</td>
<td>19556</td>
<td>18504</td>
<td>0.01 %</td>
</tr>
</tbody>
</table>

**Figure 19.10(l) Acceleration pattern in case of – move and acceleration**
(4) In case of minus move (down) and deceleration

Because torque of Gravity works against the output torque of motor and torque of friction works forward to the output torque of motor, torque for acceleration/deceleration is as follows.

- **Maximum torque**: 90 (=100−20+10) (Nm)
  - Speed: 0 to 2000 (min⁻¹)
- **Torque at rapid traverse**: 69 (=79−20+10) (Nm)
  - Speed: 3000 (min⁻¹)
- **Minimum torque**: 48 (=58−20+10) (Nm)
  - Speed: 4000 (min⁻¹)

![Fig.19.10(m) Torque for Acc/Dec in case of – move and deceleration](image_url)

Parameter setting is as follows,

<table>
<thead>
<tr>
<th>Parameter No.</th>
<th>Setting</th>
<th>Unit</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acceleration at P0</td>
<td>19563</td>
<td>18712</td>
<td>0.01%</td>
</tr>
<tr>
<td>Acceleration at P1</td>
<td>19564</td>
<td>18712</td>
<td>0.01%</td>
</tr>
<tr>
<td>Acceleration at P2−P4</td>
<td>19565−19567</td>
<td>0</td>
<td>0.01%</td>
</tr>
<tr>
<td>Acceleration at P5</td>
<td>19568</td>
<td>14345</td>
<td>0.01%</td>
</tr>
</tbody>
</table>
Optimum torque acceleration/deceleration is enabled when AI high precision contour control or AI nano high precision contour control mode is active and the conditions under which AI high precision contour control and AI nano high precision contour control are satisfied.

Optimum torque acceleration/deceleration can be performed on axes which are selected by parameter No.7510.

In the same direction move, it is necessary that the acceleration during deceleration is set 1/3 of one during acceleration at least. Also, the acceleration pattern data must be set so that the time required for the deceleration from the rapid traverse rate to a speed of 0 does not exceed 4000 (msec). This does not include the acceleration change time of bell–shaped acceleration/deceleration.

If the deceleration acceleration ratio or the time required for the deceleration to a speed of 0 exceeds the above range, P/S alarm (P/S5455) will be issued at the time rapid traverse is executed. A slight error will occur between the specified acceleration and the actual acceleration.

Optimum torque acceleration/deceleration is disabled in tool center point control mode (except startup and cancellation). If this occurs, the acceleration/deceleration for rapid traverse follows the reference acceleration.
20 AXIS CONTROL FUNCTIONS
20.1 SIMPLE SYNCHRONOUS CONTROL

It is possible to change the operating mode for two or more specified axes to either synchronous operation or normal operation by an input signal from the machine.

Synchronous control can be performed for up to four pairs of axes with the Series 16i/160i/160is, or up to three pairs with the Series 18i/180i/180is, according to the parameter setting (parameter No. 8311). The following operating modes are applicable to machines having two tables driven independently by separate control axes. The following example is of a machine with two tables driven independently by the Y axis and V axis. If the axis names and axis sets that are actually being used differ from those in the example, substitute the actual names for those below.

Explanations

- Synchronous operation

This mode is used for, for example, machining large workpieces that extend over two tables.

While operating one axis with a move command, it is possible to synchronously move the other axis. In the synchronous mode, the axis to which the move command applies is called the master axis, and the axis that moves synchronously with the master axis is called the slave axis. In this example, it is assumed that Y axis is the master axis and V axis is the slave axis. Here, the Y axis and the V axis move synchronously in accordance with program command Yyyyy issued to the Y axis (master axis).

Synchronous operation is possible during automatic operation, jog feed, manual handle feed using the manual pulse generator, and incremental feed, but is not possible during manual reference position return.
This operating mode is used for machining different workpieces on each table. The operation is the same as in ordinary CNC control, where the movement of the master axis and slave axis is controlled by the independent axis address (Y and V). It is possible to issue the move commands to both the master axis and slave axis in the same block.

(1) The Y axis moves normally according to program command Yyyyy issued to the master axis.

(2) The V axis moves normally according to program command Vvvvv issued to the slave axis.

(3) The Y axis and the V axis move simultaneously according to program command YyyyyVvvvv.

Both automatic and manual operations are the same as in ordinary CNC control.

For how to switch between the synchronous operation and normal operation modes, refer to the relevant manual published by the machine tool builder.

When the automatic reference position return command (G28) and the 2nd/3rd/4th reference position return command (G30) are issued during synchronous operation, the V axis follows the same movement as the Y axis returns to the reference position. After the return movement is complete, the reference position return complete signal of the V axis goes on when that of the Y axis goes on. As a rule, commands G28 and G30 must be issued in the normal operating mode.

When the automatic reference position return check command (G27) is issued during synchronous operation, the V axis and Y axis move in tandem. If both the Y axis and the V axis have reached their respective reference positions after the movement is complete, the reference position return complete signals go on. If either axis is not at the reference position, an alarm is issued. As a rule, command G27 must be issued in the normal operating mode.

When a move command is issued to the slave axis during synchronous operation, a P/S alarm (No. 213) is issued.

The axis to be used as the master axis is set in parameter No. 8311. The slave axis is selected by an external signal.

Setting bit 7 (SMF) of parameter No. 3105 to 1 suppresses display of the actual speed of the slave axes.
In synchronous axis control, commands that require no axis motion, such as the workpiece coordinate system setup command (G92) and the local coordinate system setup command (G52), are set to the Y axis by program command Yyyyy issued to the master axis.

For signals such as external deceleration, interlock, and machine lock, only the signals issued to the master axis are valid in the synchronous operating mode. Signals issued to other axes are ignored.

Both the pitch error and backlash are compensated independently for the master axis and the slave axis.

Turn on the manual absolute switch during synchronous operation. If it is off, the slave axis may not move correctly.

The difference between the master axis and slave axis in servo positional deviation is always monitored. If the difference exceeds the parameter-set limit, an P/S alarm (No. 213) is issued.

The difference between the master axis and slave axis in machine coordinates is always monitored. If the difference exceeds the parameter-set limit, an servo alarm (No. 407) is issued.

When the power is turned on, compensation pulses are output for the slave axis to match the machine position of the master axis with the machine position of the slave axis. (This is enabled only when the absolute position detection function is used.)

Compensation for out–of–synchronism (where the difference between the master and slave axes in servo positional deviation is always monitored and the servo motor for the slave axis is compensated to reduce the difference) is not performed.

When the machine is manually returned to the reference position during synchronous operation, both the master axis and the slave axis move synchronously until the acceleration movement is complete. However, grid detection thereafter is carried out independently.
20.2
ROTARY AXIS
ROLL–OVER

20.2.1
Rotary Axis Roll–over

The roll–over function prevents coordinates for the rotation axis from overflowing. The roll–over function is enabled by setting bit 0 of parameter ROAx 1008 to 1.

Explanations

For an incremental command, the tool moves the angle specified in the command. For an absolute command, the coordinates after the tool has moved are values set in parameter No. 1260, and rounded by the angle corresponding to one rotation. The tool moves in the direction in which the final coordinates are closest when bit 1 of parameter RABx No. 1008 is set to 0. Displayed values for relative coordinates are also rounded by the angle corresponding to one rotation when bit 2 of parameter RRLx No. 1008 is set to 1.

Examples

Assume that axis A is the rotating axis and that the amount of movement per rotation is 360.000 (parameter No. 1260 = 360000). When the following program is executed using the roll–over function of the rotating axis, the axis moves as shown below.

<table>
<thead>
<tr>
<th>G90 A0 ;</th>
<th>Sequence number</th>
<th>Actual movement value</th>
<th>Absolute coordinate value after movement end</th>
</tr>
</thead>
<tbody>
<tr>
<td>N1 G90 A–150.0 ;</td>
<td>N1</td>
<td>–150</td>
<td>210</td>
</tr>
<tr>
<td>N2 G90 A540.0 ;</td>
<td>N2</td>
<td>–30</td>
<td>180</td>
</tr>
<tr>
<td>N3 G90 A–620.0 ;</td>
<td>N3</td>
<td>–80</td>
<td>100</td>
</tr>
<tr>
<td>N4 G91 A380.0 ;</td>
<td>N4</td>
<td>+380</td>
<td>120</td>
</tr>
<tr>
<td>N5 G91 A–840.0 ;</td>
<td>N5</td>
<td>–840</td>
<td>0</td>
</tr>
</tbody>
</table>

Relative coordinate value

-720° –360° –0° 360°

Absolute coordinate value

-0° –0° –0° –0°

<table>
<thead>
<tr>
<th>N1</th>
<th>N2</th>
<th>N3</th>
<th>N4</th>
<th>N5</th>
</tr>
</thead>
<tbody>
<tr>
<td>210°(Absolute)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NOTE

This function cannot be used together with the indexing function of the index table.
This function controls a rotary axis as specified by an absolute command. With this function, the sign of the value specified in the command is interpreted as the direction of rotation, and the absolute value of the specified value is interpreted as the coordinates of the target end position.

Explanations

This function is valid when rotary axis roll–over is enabled (ROAx bit (bit 0 of parameter 1008) is set to 1).

If the RAAx bit (bit 3 of parameter 1008) is set to 1, an absolute command specified for the roll–over rotary axis is interpreted as follows: The sign and absolute value of the value specified in the command represent the direction of rotation and the end position of movement respectively.

If the RAAx bit (bit 3 of parameter 1008) is set to 0, the setting by the RABx bit (bit 1 of parameter 1008) becomes significant.

Notes

**NOTE**

1. This function can be used only when the corresponding option is provided.
2. This function is valid for a roll–over rotary axis.
3. If the RAAx bit (bit 3 of parameter 1008) is set to 1, the RABx bit (bit 1 of parameter 1008) is ignored. To select a rotary motion of a shorter travel distance, set both RAAx and RABx to 0.
4. This function is not supported when the machine coordinate system of the PMC axis control function is selected.
To replace the tool damaged during machining or to check the status of machining, the tool can be withdrawn from a workpiece. The tool can then be advanced again to restart machining efficiently.

The tool withdrawal and return operation consists of the following four steps:

- **Retract**
  The tool is retracted to a predefined position using the TOOL WITHDRAW switch.

- **Withdrawal**
  The tool is moved to the tool–change position manually.

- **Return**
  The tool returns to the retract position.

- **Repositioning**
  The tool returns to the interrupted position.

For the tool withdrawal and return operations, see III–4.10.

---

**Format**

Specify a retraction axis and distance in the following format:

```
G10.6 P_ ;
```

- **P_**: In incremental mode, retraction distance from the position where the retract signal is turned on.
- **P_**: In the absolute mode, retraction distance to an absolute position.
  The specified amount of retraction is effective until G10.6 is next executed. To cancel the retraction, specify the following:

```
G10.6 ; (as a single block containing no other commands)
```
Explanations

- **Retraction**

  When the TOOL WITHDRAW switch on the machine operator’s panel is turned on during automatic operation or in the automatic operation stop or hold state, the tool is retracted the length of the programmed retraction distance. This operation is called retraction. The position at which retraction is completed is called the retraction position. Upon completion of retraction, the RETRACT POSITION LED on the machine operator’s panel goes on.

  When the TOOL WITHDRAW switch is turned on during execution of a block in automatic operation, execution of the block is interrupted immediately and the tool is retracted. After retraction is completed, the system enters the automatic operation hold state.

  If the retraction distance and direction are not programmed, retraction is not performed. In this state, the tool can be withdrawn and returned.

  When the TOOL WITHDRAW switch is turned on in the automatic operation stop or hold state, the tool is retracted, then the automatic operation stop or hold state is entered again.

  When the TOOL WITHDRAW switch is turned on, the tool withdraw mode is set. When the tool withdraw mode is set, the TOOL BEING WITHDRAWN LED on the machine operator’s panel goes on.

- **Withdrawal**

  When the manual mode is set, the tool can be moved manually (Manual continuous feed or manual handle feed) to replace the tool or measure a machined workpiece. This operation is called a withdrawal. The tool withdrawal path is automatically memorized by the CNC.

- **Return**

  When the mode is returned to automatic operation mode and the TOOL RETURN switch on the machine operator’s panel is turned off, the CNC automatically moves the tool to the retraction position by tracing the manually–moved tool path backwards. This operation is called a return. Upon completion of a return to the retraction position, the RETRACTIONS POSITION LED comes on.

- **Repositioning**

  When the cycle start button is pressed while the tool is in the retraction position, the tool moves to the position where the TOOL WITHDRAW switch was turned on. This operation is called repositioning. Upon completion of repositioning, the TOOL BEING WITHDRAWN LED is turned off, indicating that the tool withdrawal mode has terminated.

  Operation after completion of repositioning depends on the automatic operation state when the tool withdrawal mode is set.

  1. When the tool withdrawal mode is set during automatic operation, operation is resumed after completion of repositioning.

  2. When the tool withdrawal mode is set when automatic operation is held or stopped, the original automatic operation hold or stop state is set after completion of repositioning. When the cycle start button is pressed again, automatic operation is resumed.
Limitations

- offset

If the origin, presetting, or workpiece origin offset value (or External workpiece origin offset value) is changed after retraction is specified with G10.6 in absolute mode, the change is not reflected in the retraction position. After such changes are made, the retraction position must be respecified with G10.6.

When the tool is damaged, automatic operation can be interrupted with a tool withdrawal and return operation in order to replace the tool. Note that if the tool offset value is changed after tool replacement, the change is ignored when automatic operation is resumed from the start point or other point in the interrupted block.

- Machine lock, mirror image, and scaling

When withdrawing the tool manually in the tool withdrawal mode, never use the machine lock, mirror-image, or scaling function.

- Thread cutting

Tool withdrawal and return operation cannot be performed during thread cutting.

- Drilling canned cycle

Tool withdrawal and return operation cannot be performed during a drilling canned cycle.

- Reset

Upon reset, the retraction data specified in G10.6 is cleared. Retraction data needs to be specified again.

- Retraction command

The tool withdrawal and return function is enabled even when the retraction command is not specified. In this case, retraction and repositioning are not performed.

**WARNING**

The retraction axis and retraction distance specified in G10.6 need to be changed in an appropriate block according to the figure being machined. Be very careful when specifying the retraction distance; an incorrect retraction distance may damage the workpiece, machine, or tool.
20.4 TANDEM CONTROL

When enough torque for driving a large table cannot be produced by only one motor, two motors can be used for movement along a single axis. Positioning is performed by the main motor only. The submotor is used only to produce torque. With this tandem control function, the torque produced can be doubled.

![Fig. 20.4 (a) Example of operation]

In general, the NC regards tandem control as being performed for one axis. However, for servo parameter management and servo alarm monitoring, tandem control is regarded as being performed for two axes. For details, refer to the relevant manual published by the machine tool builder.
When the angular axis makes an angle other than 90° with the perpendicular axis, the angular axis control function controls the distance traveled along each axis according to the inclination angle. For the ordinary angular axis control function, the angular axis is always the Y-axis and the perpendicular axis is always the Z-axis. For angular axis control B, however, arbitrary axes can be specified as the angular and perpendicular axes, using parameters. A program, when created, assumes that the angular axis and perpendicular axis intersect at right angles. However, the actual distance traveled is controlled according to an inclination angle.

![Diagram showing angular and perpendicular axes](image-url)

θ : Inclination angle

When the angular axis is the Y-axis and the perpendicular axis is the Z-axis, the amount of travel along each axis is controlled according to the formulas shown below.

The distance traveled along the Y-axis is determined by the following formula:

\[ Ya = \frac{Yp}{\cos \theta} \]

The distance traveled along the Z-axis is corrected by the inclination of the Y-axis, and is determined by the following formula:

\[ Za = Zp - Yp \cdot \tan \theta \]

The speed component along the Y-axis is determined by the following formula:

\[ Fa = \frac{Fp}{\cos \theta} \]

\( Ya, Za, Fa \) : Actual distance and speed

\( Yp, Zp, Fp \) : Programmed distance and speed

**Method of use**

The angular and perpendicular axes for which angular axis control is to be applied must be specified beforehand, using parameters (No. 8211 and 8212).

Parameter AAC (No. 8200#0) enables or disables the inclined axis control function. If the function is enabled, the distance traveled along each axis is controlled according to an inclination angle parameter (No. 8210).

Parameter AZR (No. 8200#2) enables angular axis manual reference point return only with a distance along the angular axis.

**Invalidity of normal axis**

By setting the normal axis/angular axis control invalid signal NOZAGC to 1, slanted axis control only for the angular axis can be available. In this time the angular axis are converted to those along the slanted coordinate system without affecting commands to normal axis.
• **Absolute and relative position display**

An absolute and a relative position are indicated in the programmed Cartesian coordinate system.

• **Machine position display**

A machine position indication is provided in the machine coordinate system where an actual movement is taking place according to an inclination angle. However, when inch/metric conversion is performed, a position is indicated which incorporates inch/metric conversion applied to the results of inclination angle operation.

---

**WARNING**

1. After angular axis control parameter setting, be sure to perform manual reference position return operation.
2. If once manual reference position return has been performed along the angular axis, also perform manual reference position return along the perpendicular axis. P/S alarm No.090 is issued when an attempt is made to manually return to the reference position along the perpendicular axis although the angular axis is not on the reference point.
3. Once the tool has been moved along the angular axis when perpendicular/angular axis control disable signal NOZAGC has been set to 1, manual reference position return must be performed.
4. Before attempting to manually move the tool along the angular and perpendicular axes simultaneously, set perpendicular/angular axis control disable signal NOZAGC to 1.

---

**NOTE**

1. For arbitrary angular axis control B, if the same axis number has been specified in both parameters No.8211 and 8212, or if a value outside the valid data range has been specified for either parameter, the angular and perpendicular axes become the following:
   - Angular axis: Second axis
   - Perpendicular axis: Third axis
2. If an inclination angle close to 0° or ±90° is set, an error can occur. (A range from ±20° to ±60° should be used.)
3. Before a perpendicular axis reference position return check (G27) can be made, angular axis reference position return operation must be completed.
20.6
CHOPPING FUNCTION
(G80, G81.1)

When contour grinding is performed, the chopping function can be used to grind the side face of a workpiece. By means of this function, while the grinding axis (the axis with the grinding wheel) is being moved vertically, a contour program can be executed to instigate movement along other axes.

In addition, a servo delay compensation function is supported for chopping operations. When the grinding axis is moved vertically at high speed, a servo delay and acceleration/deceleration delay occur. These delays prevent the tool from actually reaching the specified position. The servo delay compensation function compensates for any displacement by increasing the feedrate. Thus, grinding can be performed almost up to the specified position.

There are two types of chopping functions: that specified by programming, and that activated by signal input. For details of the chopping function activated by signal input, refer to the manual provided by the machine tool builder.

Format

G81.1 Z__ Q__ R__ F__ ;

Z : Upper dead point
(For an axis other than the Z–axis, specify the axis address.)
Q : Distance between the upper dead point and lower dead point
(Specify the distance as an incremental value, relative to the upper dead point.)
R : Distance from the upper dead point to point R
(Specify the distance as an incremental value, relative to the upper dead point.)
F : Feedrate during chopping

G80; Cancels chopping

Explanations

• Chopping activated by signal input

Before chopping can be started, the chopping axis, reference position, upper dead point, lower dead point, and chopping feedrate must be set using the parameter screen (or the chopping screen).

For details, refer to the manual provided by the machine tool builder.

• Chopping feedrate (feedrate of movement to point R)

From the start of chopping to point R, the tool moves at the rapid traverse rate (specified by parameter No. 1420).

The override function can be used for either the normal rapid traverse rate or chopping feedrate, one of which can be selected by setting CPRPD (bit 0 of parameter No. 8360).

When the chopping feedrate is overridden, settings between 110% and 150% are clamped to 100%.

• Chopping feedrate (feedrate of movement from point R)

Between point R, reached after the start of chopping, and the point where the chopping is canceled, the tool moves at the chopping feedrate (specified by parameter No. 8374).
The chopping feedrate is clamped to the maximum chopping feedrate (set with parameter No. 8375) if the specified feedrate is greater than the maximum chopping feedrate.

The feedrate can be overridden by 0% to 150% by applying the chopping feedrate override signal.

**Setting chopping data**

Set the following chopping data:

- Chopping axis: Parameter No. 8370
- Reference point (point R): Parameter No. 8371
- Upper dead point: Parameter No. 8372
- Lower dead point: Parameter No. 8373
- Chopping feedrate: Parameter No. 8374
- Maximum chopping feedrate: Parameter No. 8375

All data items other than the chopping axis and maximum chopping feedrate can be set on the chopping screen.

For details of how to set chopping data on the chopping screen, refer to III 11.4.13 Displaying and Setting Chopping Data.

When the upper dead point or lower dead point is changed while chopping is being performed, the tool moves to the position specified by the old data. Then, chopping is continued using the new data.

While chopping is being performed, data can be changed only on the chopping screen. Changing the data on the parameter screen has no effect on the current chopping operation.

When movement according to the new data starts, the servo delay compensation function stops the servo delay compensation for the old data, and starts the servo delay compensation for the new data.

The following describes the operations performed after the data has been changed.

1. When the upper dead point is changed during movement from the upper dead point to the lower dead point

   ![Diagram](image)

   The tool first moves to the lower dead point, then to the new upper dead point.

   Once movement to the lower dead point has been completed, the previous servo delay compensation is set to 0, and servo delay compensation is performed based on the new data.
(2) When the lower dead point is changed during movement from the upper dead point to the lower dead point

The tool first moves to the previous lower dead point, then to the upper dead point, and finally to the new lower dead point. Once movement to the upper dead point has been completed, the previous servo delay compensation is set to 0, and servo delay compensation is performed based on the new data.

(3) When the upper dead point is changed during movement from the lower dead point to the upper dead point

The tool first moves to the previous upper dead point, then to the lower dead point, and finally to the new upper dead point. Once movement to the lower dead point has been completed, the previous servo delay compensation is set to 0, and servo delay compensation is performed based on the new data.

(4) When the lower dead point is changed during movement from the lower dead point to the upper dead point

The tool first moves to the upper dead point, then to the new lower dead point. Once movement to the upper dead point has been completed, the previous servo delay compensation is set to 0, and servo delay compensation is performed based on the new data.
When high-speed chopping is performed with the grinding axis, a servo delay and acceleration/deceleration delay occur. These delays prevent the tool from actually reaching the specified position. The control unit measures the difference between the specified position and the actual tool position, and automatically compensates for the displacement of the tool. To compensate for this displacement, an amount of travel equal to the distance between the upper and lower dead points, plus an appropriate compensation amount, is specified. When a chopping command is specified, the feedrate is determined so that the chopping count per unit time equals the specified count. When the difference between the displacement of the tool from the upper dead point and the displacement of the tool from the lower dead point becomes smaller than the setting of parameter No. 8377, after the start of chopping, the control unit performs compensation.

When compensation is applied, the chopping axis moves beyond the specified upper dead point and lower dead point, and the chopping feedrate increases gradually.

When the difference between the actual machine position and the specified position becomes smaller than the effective area setting (parameter No. 1826), the control unit no longer applies compensation, allowing the tool to continue moving at its current feedrate.

A coefficient for the compensation amount for the displacement generated by the servo delay incurred by chopping and the delay incurred during acceleration/deceleration can be specified in parameter No. 8376.

Displacement between the tool and the upper dead point: L2, L4, L6
Displacement between the tool and the lower dead point: L1, L3, L5

Compensation starts when:

| L3 - L2 | < (parameter No. 8377)

When the following condition is satisfied, compensation is no longer applied, and the tool continues to move at its current feedrate:

| L6 | < effective area setting (parameter No. 1826)
• Mode switching during chopping  
  If the mode is changed during chopping, chopping does not stop. In manual mode, the chopping axis cannot be moved manually. It can, however, be moved manually by means of the manual interrupt.

• Reset during chopping  
  When a reset is performed during chopping, the tool immediately moves to point R, after which chopping mode is canceled.

  If an emergency stop or servo alarm occurs during chopping, mode is canceled, and the tool stops immediately.

• Stopping chopping  
  The following table lists the operations and commands that can be used to stop chopping, the positions at which chopping stops, and the operation performed after chopping stops:

<table>
<thead>
<tr>
<th>Operation/command</th>
<th>Stop position</th>
<th>Operation after chopping stops</th>
</tr>
</thead>
<tbody>
<tr>
<td>G80</td>
<td>Point R</td>
<td>Canceled</td>
</tr>
<tr>
<td>CHPST: “0”</td>
<td>The tool moves to the lower dead point, then to point R.</td>
<td>Canceled</td>
</tr>
<tr>
<td>“CHLD: “0”</td>
<td>Point R</td>
<td>Restart after “CHLD goes “1”</td>
</tr>
<tr>
<td>Reset</td>
<td>Point R</td>
<td>Canceled</td>
</tr>
<tr>
<td>Emergency stop</td>
<td>The tool stops immediately.</td>
<td>Canceled</td>
</tr>
<tr>
<td>Servo alarm</td>
<td>The tool stops immediately.</td>
<td>Canceled</td>
</tr>
<tr>
<td>P/S alarm</td>
<td>The tool moves to the lower dead point, then to point R.</td>
<td>Canceled</td>
</tr>
<tr>
<td>OT alarm</td>
<td>The tool moves from the upper or lower point to point R.</td>
<td>Canceled</td>
</tr>
</tbody>
</table>

• Background editing  
  When an alarm or battery alarm is issued during background editing, the tool does not stop at point R.

• Single block signal  
  Even when single block signal SBK is input during chopping, chopping continues.

Limitations

• Workpiece coordinate system  
  While chopping is being performed, do not change the workpiece coordinate system for the chopping axis.

• PMC axis  
  When the chopping axis is selected as the PMC axis, chopping is not started.

• Mirror image  
  While chopping is being performed, never attempt to apply the mirror image function about the chopping axis.

• Move command during chopping  
  If a move command is specified for the chopping axis while chopping is being performed, a P/S 5050 alarm is issued.

• Advanced preview control  
  This function does not support the advanced preview control function.
• **Program restart**

When a program contains G codes for starting chopping (G81.1) and stopping chopping (G80), an attempt to restart that program results in a P/S 5050 alarm being output.

When a program that does not include the chopping axis is restarted during chopping, the coordinates and amount of travel set for the chopping axis are not affected after the restart of the program.

**Examples**

G90 G81.1 Z100. Q–25. R10. F3000 ;

- Perform rapid traverse to position the tool to Z110. (point R).
- Then, perform reciprocating movement along the Z–axis between Z100. (upper dead point) and Z75. (lower dead point) at 3000 mm/min. Chopping override is enabled.

To cancel chopping, specify the following command:

G80 ;

- The tool stops at point R.
20.7 HOBBING MACHINE FUNCTION (G80, G81)

Gears can be cut by turning the workpiece (C-axis) in sync with the rotation of the spindle (hob axis) connected to a hob. Also, a helical gear can be cut by turning the workpiece (C-axis) in sync with the motion of the Z-axis (axial feed axis).

Format

```
G81 T_ L_ Q_ P_ ;
```

- **T**: Number of teeth (Specifiable range: 1 to 5000)
- **L**: Number of hob threads (Specifiable range: 1 to 20 with a sign)
  - The sign of L specifies the direction of rotation of the C-axis.
  - If L is positive, the C-axis rotates in the positive direction (+).
  - If L is negative, the C-axis rotates in the negative direction (-).
- **Q**: Module or diametral pitch
  - For metric input, specify a module.
    (Unit: 0.00001 mm, Specifiable range: 0.01 to 25.0 mm)
  - For inch input, specify a diametral pitch.
    (Unit: 0.00001 inch⁻¹, Specifiable range: 0.01 to 250.0 inch⁻¹)
- **P**: Gear helix angle
  (Unit: 0.0001 deg, Specifiable range: -90.0 to +90.0 deg)

**G80;** Cancels synchronization between the hob axis and C-axis.

Explanations

- **Setting the C-axis**
  - The C-axis (workpiece) is usually the fourth axis. However, any axis can be set as the C-axis by setting the corresponding parameter appropriately (parameter No. 7710).

- **Maintaining the synchronization status**
  - The synchronization status is maintained provided:
    - The interlock signal for the C-axis is turned on.
    - The feed hold state exists.
Synchronization between the hob axis and C–axis can also be canceled when:

- The power is turned off.
- An emergency stop or servo alarm occurs.
- A reset (external reset signal, reset & rewind signal, or reset key on the MDI panel) is issued.

By setting bit 0 (HBR) of parameter No. 7700, the release of the synchronization status by a reset can be suppressed.

When a helical gear is to be cut, compensation for the C–axis is needed according to the amount of travel along the Z–axis (third axis) (axial feed) and gear helix angle.

Helical gear compensation is performed by adding compensation pulses, calculated using the formula below, to the C–axis which is synchronized with the hob axis:

\[
\text{Compensation angle} = \frac{Z \times \sin (P)}{\pi \times T \times Q} \times 360 \quad \text{(For metric input)}
\]

or

\[
\text{Compensation angle} = \frac{Z \times Q \times \sin (P)}{\pi \times T} \times 360 \quad \text{(For inch input)}
\]

where

\[
\begin{align*}
\text{Compensation angle} & : \text{Signed absolute value (deg)} \\
Z & : \text{Amount of travel along the Z–axis after the specification of G81 (mm or inches)} \\
& \quad \text{Total amount of travel along the Z–axis in both automatic and manual modes} \\
P & : \text{Signed gear helix angle (deg)} \\
T & : \text{Number of teeth} \\
Q & : \text{Module (mm) or diametral pitch (inch}^{-1})
\end{align*}
\]

The values of P, T, and Q must be programmed.
### Direction of helical gear compensation

1. When bit 2 (HDR) of parameter No. 7700 = 1

<table>
<thead>
<tr>
<th>Diagram</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Diagram A" /></td>
<td>When bit 2 (HDR) of parameter No. 7700 = 1</td>
</tr>
<tr>
<td><img src="image" alt="Diagram B" /></td>
<td>Compensation direction: +</td>
</tr>
<tr>
<td><img src="image" alt="Diagram C" /></td>
<td>Compensation direction: -</td>
</tr>
<tr>
<td><img src="image" alt="Diagram D" /></td>
<td>Compensation direction: +</td>
</tr>
</tbody>
</table>

2. When bit 2 (HDR) of parameter No. 7700 = 0 (Items (a) to (d) are the same as for 1.)

<table>
<thead>
<tr>
<th>Diagram</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Diagram E" /></td>
<td>Compensation direction: -</td>
</tr>
<tr>
<td><img src="image" alt="Diagram F" /></td>
<td>Compensation direction: +</td>
</tr>
<tr>
<td><img src="image" alt="Diagram G" /></td>
<td>Compensation direction: +</td>
</tr>
<tr>
<td><img src="image" alt="Diagram H" /></td>
<td>Compensation direction: -</td>
</tr>
</tbody>
</table>
The Z-axis (axial feed axis) is usually the third axis. However, any axis can be set as the Z-axis by setting the corresponding parameter appropriately (parameter No. 7709).

The servo delay is proportional to the speed of the hob axis. Therefore, in a cycle where rough machining and finish machining are performed at different hob axis speeds, compensation for the servo delay is required. The servo delay is calculated as follows:

\[
E = \left( \frac{F_c}{60} \right) \times \left( \frac{1}{K_s} + C \times M + L \right) + Sup \times N
\]

where

- \( E \): C-axis servo delay compensation \( \text{(deg)} \)
- \( F_c \): C-axis speed when G83 is specified \( \text{(deg/min)} \)
- \( K_s \): Servo loop gain (LPGIN of parameter No. 1825) \( \text{(sec}^{-1}\text{)} \)
- \( C \): Delay incurred in the CNC \( \text{(sec)} \)
- \( M \): Delay compensation magnification 1 in the CNC (SVCMP1 of parameter No. 7715)
- \( L \): Delay incurred by smoothing, as specified by parameter No. 7701 \( \text{(sec)} \)
- \( Sup \): Remaining pulse error caused by acceleration/deceleration \( \text{(deg)} \)
- \( N \): C-axis servo delay compensation magnification 2 (SVCMP2 of parameter No. 7714)

When the hob axis speed is changed, C-axis servo delay compensation is performed using the following two methods:

- Compensation is specified both before and after the speed is changed. Each time G83 is specified, compensation for the delay at that time is applied.
- Before the speed is changed, the servo delay is recorded. After the speed is changed, compensation for the difference between the recorded delay and that observed when the command is specified is performed.

The latter method, in which the compensation before speed change is recorded, can be used by setting bit 5 (DLY) of parameter No. 7701 to 1. This method, in comparison with that where the amount of compensation is not recorded, offers the advantage of processing being possible at higher speeds.
Method in which compensation for the delay when a command is specified is performed (G82, G83)

G82: Cancels C-axis servo delay compensation.
G83: Executes C-axis servo delay compensation.

(Example)
G81 T__ L__ ; · · · Starts synchronization.
M03 S100 ; · · · Rotates the hob axis.
G04 P2000 ; · · · Dwell to assure constant hob axis rotation.
G01 G83 F__ ; · · · Performs C-axis delay compensation.
G01 X__ F__ ; · · ·

G82 ; · · · Cancels C-axis servo delay.
S200 ; · · · Changes the speed.
G04 P2000 ; · · · Dwell to assure constant hob axis rotation.
G01 G83 F__ ; · · · Performs C-axis delay compensation.

Method in which the delay before change is recorded (G82, G83, G84)

G82: Cancels C-axis servo delay compensation.
G83: Performs compensation for the difference between the C-axis servo delay, observed when G83 is specified, and the delay recorded by G84.
G84: Records the C-axis servo delay observed when G84 is specified.
(The recorded value remains as is until G81 is specified or another G84 is specified.)

(Example)
G81 T__ L__ ; · · · Starts synchronization.
M03 S100 ; · · · Rotates the hob axis.
G04 P2000 ; · · · Dwell to assure constant hob axis rotation.
G84 ; · · · Records the C-axis servo delay at the current speed.
G01 X__ F__ ; · · ·

S200 ; · · · Changes the speed.
G04 P2000 ; · · · Dwell to assure constant hob axis rotation
G01 G83 F__; · · · Performs C-axis servo delay compensation.

Notes

- Specify the G83 block in G01 mode. Also, specify a feedrate using the F code.
- Once G83 has been specified, another G83 command cannot be specified until compensation is canceled by specifying G82, or C-axis synchronization is canceled.
- Specify G83 once a constant hob axis rotation speed has been achieved.
In C-axis servo delay compensation (G83), compensation is not applied to the integer part of the gear pitch. The compensation direction is opposite to that of the C-axis rotation.

- **C-axis synchronous shift**

  During synchronization between the hob axis and C-axis, manual handle interrupt can be performed for the C-axis. The C-axis is shifted by the amount of the handle interrupt.

  For details of handle interrupts, refer to the relevant manual supplied by the machine tool builder.

- **Synchronous shift by programming**

  During synchronization between the hob axis and C-axis, the C-axis can be interrupted using G01. In this case, be careful not to exceed the maximum cutting speed.

  Example: Hob shifting during synchronization

  G01 Y__ C__ F__ ;

- **Manual setting of one-rotation signal**

  When the rotation of the position coder is stopped, the position of the one-rotation signal is shifted in the CNC as if the one-rotation signal had been output with the position coder at the current position.

  For details, refer to the relevant manual supplied by the machine tool builder.

- **Retract function**

  In both automatic and manual operation mode, retract movement can be made over the distance specified by parameter No. 7741, along the axis set by bit 0 (RTRx) of parameter No. 7730.

  For details, refer to the relevant manual supplied by the machine tool builder.

**Limitations**

- **Setting a rotation axis**

  Set a rotation axis as the C-axis (workpiece axis). (Bit 0 (RoTx) of parameter No. 1006 = 1)

- **Gear ratio of the spindle (bob axis) and Position coder**

  Set parameter No.7700#5 to 0 and also set the gear ratio of the spindle (bob axis) to the position coder in parameter No.7711.
In the same way as with the hobbing machine function, to machine (grind/cut) a gear, the rotation of the workpiece axis connected to a servo motor is synchronized with the rotation of the tool axis (grinding wheel/hob) connected to the spindle motor. To synchronize the tool axis with the workpiece axis, an electric gear box (EGB) function is used for direct control using a digital servo system. With the EGB function, the workpiece axis can trace tool axis speed variations without causing an error, thus machining gears with great precision.

Some conditions must be satisfied for setting the workpiece axis and tool axis. For details, refer to the relevant manual provided by the machine tool builder.

### 20.8.1 Simple Electric Gear Box (G80, G81)

#### Format

```
G81 T_ L_ Q_ P_ ;    Starts synchronization. 
S_ M03 (or M04) ;    Starts tool axis rotation. 
M05 ;                Stops tool axis rotation. 
G80 ;                Cancels synchronization. 
```

- **T**: Number of teeth (Specifiable range: 1 to 1000)
- **L**: Number of hob threads
  - (Specifiable range: -21 to +21 with 0 excluded)
- **Q**: Module or diametral pitch
  - Specify a module in the case of metric input.
    - (Unit: 0.00001 mm, Specifiable range: 0.01 to 25.0 mm)
  - Specify a diametral pitch in the case of inch input.
    - (Unit: 0.00001 inch⁻¹, Specifiable range: 0.01 to 25.0 inch⁻¹)
- **P**: Gear helix angle
  - (Unit: 0.0001 deg, Specifiable range: -90.0 to 90.0 deg.)
- * When specifying Q and P, the user can use a decimal point.
Explanations

• Synchronization control

1 Start of synchronization
When synchronization mode is set with G81, the synchronization switch of the EGB function is closed, and synchronization between the tool axis and workpiece axis starts. At this time, synchronization mode signal SYNMOD is turned on. During synchronization, the rotation of the tool axis and workpiece axis is controlled so that the relationship between T (number of teeth) and L (number of hob threads) can be maintained. Moreover, the synchronous relationship is maintained regardless of whether the operation is automatic or manual during synchronization.

G81 cannot be specified again during synchronization. Moreover, the specification of T, L, Q, and P cannot be modified during synchronization.

2 Start of tool axis rotation
When the rotation of the tool axis starts, the rotation of the workpiece starts so that the synchronous relationship specified in the G81 block can be maintained.

The rotation direction of the workpiece axis depends on the rotation direction of the tool axis. That is, when the rotation direction of the tool axis is positive, the rotation direction of the workpiece axis is also positive; when the rotation direction of the tool axis is negative, the rotation direction of the workpiece axis is also negative. However, by specifying a negative value for L, the rotation direction of the workpiece axis can be made opposite to the rotation direction of the tool axis.

During synchronization, the machine coordinates of the workpiece axis and EGB axis are updated as synchronous motion proceeds. On the other hand, a synchronous move command has no effect on the absolute and relative coordinates.

3 Termination of tool axis rotation
In synchronism with gradual stop of the tool axis, the workpiece axis is decelerated and stopped. By specifying the command below after the spindle stops, synchronization is canceled, and the EGB synchronization switch is opened. At this time, the synchronization mode signal (SYNMOD) is turned off.

4 Cancellation of synchronization
The position of the workpiece axis after travel during synchronization is reflected in the absolute coordinates when synchronization is canceled: from this point, absolute command programming is enabled for the workpiece axis. By setting bit 0 (HOBRST) of parameter No. 7700 to 0, synchronization can also be canceled upon reset.

* The synchronization mode is canceled by a servo alarm, PS000 alarm, or emergency stop.
• **Helical gear compensation**

When a helical gear is to be produced, the compensation of workpiece axis rotation is needed according to the travel distance on the Z–axis (axial feed).

Helical gear compensation is performed by adding compensation pulses calculated from the formula below to the workpiece axis:

\[
\text{Compensation angle} = \frac{Z \times \sin(P)}{\pi \times T \times Q} \times 360 \text{ (For metric input)}
\]

or

\[
\text{Compensation angle} = \frac{Z \times Q \times \sin(P)}{\pi \times T} \times 360 \text{ (For inch input)}
\]

where
- **Compensation angle**: Signed absolute value (deg)
- **Z**: Amount of travel on the Z–axis after the specification of G81 (mm or inch)
- **P**: Signed gear helix angle (deg)
- **T**: Number of teeth
- **Q**: Module (mm) or diametral pitch (inch⁻¹)

The values of **P**, **T**, and **Q** are to be programmed.
• Direction of helical gear compensation

1 When bit 2 (HDR) of parameter No. 7700 = 1

<table>
<thead>
<tr>
<th>Item</th>
<th>Compensation direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a)</td>
<td>+C, +Z, +P</td>
</tr>
<tr>
<td>(b)</td>
<td>+C, +Z, +P</td>
</tr>
<tr>
<td>(c)</td>
<td>+C, +Z, +P</td>
</tr>
<tr>
<td>(d)</td>
<td>+C, +Z, +P</td>
</tr>
<tr>
<td>(e)</td>
<td>-C, +Z, +P</td>
</tr>
<tr>
<td>(f)</td>
<td>-C, +Z, +P</td>
</tr>
<tr>
<td>(g)</td>
<td>-C, +Z, +P</td>
</tr>
<tr>
<td>(h)</td>
<td>-C, +Z, +P</td>
</tr>
</tbody>
</table>

2 When bit 2 (HDR) of parameter No. 7700 = 0 (Items (a) to (d) are the same as for 1.)

<table>
<thead>
<tr>
<th>Item</th>
<th>Compensation direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>(e)</td>
<td>-C, +Z, +P</td>
</tr>
<tr>
<td>(f)</td>
<td>-C, +Z, +P</td>
</tr>
<tr>
<td>(g)</td>
<td>-C, +Z, +P</td>
</tr>
<tr>
<td>(h)</td>
<td>-C, +Z, +P</td>
</tr>
</tbody>
</table>
In helical compensation, the machine coordinates and absolute coordinates of the workpiece axis (4th axis) are updated by the amount of helical compensation.

Retraction

By turning on the retract signal RTRCT (on a rising edge) in automatic operation mode or manual operation mode, a retract movement can be made over the distance specified in parameter No. 7741 on the axis set in bit 0 (RTRx) of parameter No. 7730. Upon completion of retract operation, the retract completion signal RTRCTF is output.

Feedrate at retraction

For retract operation, the feedrate specified in parameter No. 7740 is used. During retract operation, the feedrate override capability is disabled.

Retraction during automatic operation

When the retract signal is turned on in automatic operation, retract operation is performed, and automatic operation is stopped at the same time.

Synchronization coefficient

A synchronization coefficient is internally represented using a fraction (K2/K1) to eliminate an error. The formula below is used for calculation.

\[
\text{Synchronization coefficient} = \frac{K_2}{K_1} = \frac{L}{T} \times \frac{\beta}{\alpha}
\]

In the formula above, K2/K1 is obtained by reducing the right side to lowest terms, but K1 and K2 must satisfy the following restriction:

\[ -2147483648 \leq K_2 \leq -2147483647 \\
1 \leq K_1 \leq 65535 \]

When this restriction is not satisfied, the PS181 alarm is issued when G81 is specified.

Manual handle interrupt

During synchronization, a manual handle interrupt can be used for the workpiece axis and other servo axes.

Move command during synchronization

During synchronization, a move command can be programmed for the workpiece axis and other servo axes. Note, however, that incremental command programming for cutting feed must be used to specify a workpiece axis move command.

Limitations

Feed hold during retraction

For retract movement, the feed hold capability is disabled.

Retraction when alarm is issued

This function does not include a retract function used when an alarm is issued.

Rapid traverse during synchronization

In synchronization mode, a cutting feedrate can be specified for the workpiece axis (4th axis). Rapid traverse cannot be specified using G00.

Maximum speed

The maximum speeds of the tool axis and workpiece axis depend on the detectors used.

G code command during synchronization

During synchronization, G00, G28, G27, G29, G30, G53, G20, and G21 cannot be specified.

Drilling canned cycle

When this function is used, the drilling canned cycle cannot be used.
Examples

O1000 ;
N0010 M19 ; Performs tool axis orientation.
N0020 G28 G91 C0 ; Performs reference position return operation of the workpiece axis.
N0030 G81 T20 L1 ; Starts synchronization between the tool axis and workpiece axis.
(The workpiece axis rotates 18° when the tool axis makes one rotation.)
N0040 S300 M03 ; Rotates the tool axis at 300 min⁻¹.
N0050 G01 X____ F____ ; Makes a movement on the X-axis (for cutting).
N0060 G01 Z____ F____ ; Makes a movement on the Z-axis (for machining).
N0100 G01 X____ F____ ; Makes a movement on the X-axis (for retraction).
N0110 M05 ; Stops the tool axis.
N0120 G80 ; Cancels synchronization between the tool axis and workpiece axis.
N0130 M30 ;

20.8.2 Skip Function for EGB Axis (G31.8)

This function provides the capability that skip function or high speed skip function can be commanded for work axis in the EGB (Electronic Gear Box) synchronization mode.

The features are as follows.

– The program block to enable the function is not interrupted until the total number of skip signal inputs reaches a value specified in the same block.

– The synchronization by EGB is not stopped by any of skip signal inputs.

– The machine coordinate position of the EGB axis (work axis) at each time of the signal inputs is stored in one of consecutive custom macro variables. The top number of the variables is specified in the block.

– The total number of the inputs is stored in another specified variable.

As for the EGB function, see the chapter “1.14 Simple Electric Gear Box” of the Connection Manual (Functions) B–63523EN–1.
Format

G81 T_ L_ ; (EGB mode on)
G31.8 G91 a0 P_ Q_ R_ ; (EGB skip command)

α: EGB axis (Work axis)
P: The top number of the consecutive custom macro variables in which the machine coordinate positions of the EGB axis (work axis) at the skip signal inputs are stored.
Q: The maximum allowable number of the skip signal inputs.
   (Range of command value: 1 – 200)
R: The number of the custom macro variable in which the total number of the inputs is stored.
   This data is usually the same as the value specified by Q. Therefore this is not necessarily specified. Specify it when the total number should be confirmed.

Explanations

G31.8 is a one-shot G code.

During the execution of the G31.8 block, the machine coordinate positions of the EGB axis (work axis) at the skip signal inputs are stored in the consecutive custom macro variables where the top number of the variables is specified by P and the maximum allowable number of the skip signal inputs is specified by Q.

The total number of the skip signal inputs (i.e. the same value specified by Q) is stored in the variable specified by R.

Examples

G81 T200 L2 ; (EGB mode on)
X_ ;
Z_ ;
G31.8 G91 C0 P500 Q200 R1 ; (EGB skip command)

After 200 times of skip signal inputs, 200 machine coordinate positions of the C axis are stored respectively in the consecutive custom macro variables #500 – #699.
The total number of skip signal inputs (i.e. 200) is stored in the custom macro variable #1.
NOTE
1 In the G31.8 block, only the EGB axis (work axis) should be commanded. When another axis is commanded, the P/S alarm (No.5068) will occur.
2 If P is not specified in the G31.8 block, the P/S alarm (No.5068) will occur.
3 If R is not specified in the G31.8 block, the total number of skip signal inputs is not stored in the custom macro variable.
4 The numbers of custom macro variables specified by P and R must be the existing ones. If any nonexistent variable is specified, the P/S alarm (No.115) will occur. If all the variables ranged by P and Q are not among the existing ones, the P/S alarm (No.115) will occur, too.
5 You can select the type of skip functions, normal skip function or high speed skip function, by the parameter HSS(No.6200#4). When high speed skip is selected, you can select a valid signal among high speed skip signals by setting parameter 9S1 to 9S8 (No.6208#0 to #7).
6 The parameters No.6201#0 and #1 are not effective for the G31.8 function. The machine coordinate positions stored in macro variables do not include any compensation amount based on position errors and servo time constant (loop gain).

Alarms

<table>
<thead>
<tr>
<th>Number</th>
<th>Message</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>5068</td>
<td>G31.8 FORMAT ERROR</td>
<td>When skip function for EGB axis (G31.8) is specified, there are wrong command as follows:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Movement command is specified for EGB axis (work axis).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- More than one axis has been specified</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- P has not been specified in G31.8 block.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Q has been specified out of range.</td>
</tr>
</tbody>
</table>
20.8.3 Spindle Electronic Gear Box

**General**

A gear can be shaped (grind/cut) by the synchronization of the workpiece axis rotation to the tool axis (grinding axis /hob) rotation by using two spindles as a tool axis and a workpiece axis. To synchronize these two axes, the Electronic gear box (EGB) is used.

In the Spindle EGB, the synchronous pulse is produced from the feedback pulse of the position detector attached to the tool axis (master axis) in the motor control, and the workpiece axis (slave axis) rotates with the pulse. Feedback pulse from Master side to Slave side is forwarded by the communication between spindle amplifiers.

The specifications of the Spindle EGB control are as follows:

1) The Spindle EGB synchronization is started by specifying T command (number of teeth) and L command (number of hob threads), which determine the synchronous ratio, in G81 block. The Spindle EGB synchronization is canceled by specifying G80.

2) The synchronous ratio is calculated from T and L command in G81 block and the number of position detector pulses per rotation about the tool and the workpiece axis (parameter setting).

3) This function has the retract function like the hobbing function.

4) The cutting helical gear is performed by specifying Q command (module or diametral pitch) and P command (gear helix angle) in G81 block.

5) The Spindle EGB synchronization is maintained regardless of whether the operation is automatic or manual.
* The master axis can use the rotation command with spindle mode.

**Fig. 20.8.3 (a) Block diagram for Spindle EGB control**

**Explanations**

**Format**

```
G81 T_L_Q_P_ ;          Starts synchronization.
G80 ;               Cancels synchronization.
```

- **T**: Number of teeth (Specifiable range: 1 to 1000)
- **L**: Number of hob threads (Specifiable range: -200 to 200 with 0 excluded)
- **Q**: Module or diametral pitch
  - Specify a module in the case of metric input.
  - (Unit: 0.00001mm, Specifiable range: 0.01 to 25.0mm)
  - Specify a diametral in the case of inch input.
  - (Unit: 0.00001inch⁻¹, Specifiable range: 0.01 to 25.0inch⁻¹)
- **P**: Gear helix angle
  - (Unit: 0.0001deg, Specifiable range: -90.0 to 90.0deg)
• **Parameter setting**

The following parameters should be set for the Spindle EGB control.

1. Master axis number (Parameter No.7771) * Only Cs contour axis
2. Slave axis number (Parameter No.7710)
3. Number of position detector pulses per rotation about master axis (Parameter No.7772)
4. Number of position detector pulses per rotation about slave axis (Parameter No.7773)
5. Spindle EGB master axis enable (Parameter No.4352#7)
6. Spindle EGB slave axis enable (Parameter No.4352#6)
7. Number of sinusoidal waves from master spindle position detector (Parameter No.4386)

**NOTE**
The master axis number should be set smaller than the slave axis number.

• **Starting/canceling of synchronization**

When the rotation of the tool axis (master axis) starts after G81 is specified, the EGB synchronization starts with the synchronous relationship specified in G81 block, and the rotation of the workpiece axis (slave axis) starts. When the EGB synchronization starts, the synchronization mode signal SYNMOD<F65#6> is turned to “1”.

When the rotation of the tool axis is stopped, the workpiece axis stopped in synchronism. Then the EGB synchronization is canceled by specifying G80. When the EGB synchronization is canceled, the synchronization mode signal SYNMOD<F65#6> is turned to “0”.

G81 cannot be specified again during the EGB synchronization. Moreover, the specification of T, L, Q, and P cannot be modified during the synchronization. Specify the starting and canceling of synchronization at the tool axis (master axis) stopping.

**NOTE**
Specify G81 and G80 code only in a block.
Program example

O1000 ;
N00010 G80 ;
N00020 G28 G91 B0 C0 ; Performs reference position return operation of the tool and the workpiece axis.
N00030 G81 T20 L1 ; Starts synchronization.
N00040 Mxx ; Rotates the tool axis by velocity command of PMC axis control.
N00050 G04 X1000 ; Waits until rotation of the tool axis is constant.
N00060 G01 X_ F_ ; Makes movement on the X–axis(for cutting).
N00070 G01 Z_ F_ ; Makes movement on the Z–axis(for machining).

Fig. 20.8.3 (b) Example timing for starting/canceling synchronization
N00100 G01 X_ F_ ;  
N00110 Myy ;  
N00120 G80 ;  
N00130 M30 ;

Makes movement on the X–axis(for retraction).

Stops the tool axis.

Cancels synchronization.

---

**Helical gear compensation**

When a helical gear is to be produced, the compensation of the workpiece axis rotation is needed according to the travel distance on the Z–axis (axial feed axis: parameter No. 7709 setting). Helical gear compensation is performed by adding compensation pulses calculated from the formula below to the workpiece axis.

\[
\text{Compensation angle} = \frac{Z \times \sin(P)}{\pi \times T \times Q} \times 360 \quad \text{(For metric input)}
\]

or

\[
\text{Compensation angle} = \frac{Z \times Q \times \sin(P)}{\pi \times T} \times 360 \quad \text{(For inch input)}
\]

where

- Compensation angle : Signed absolute value (deg)
- Z : Amount of travel on the Z–axis after the specification of G81 (mm or inch)
- P : Signed gear helix angle (deg)
- T : Number of teeth
- Q: Module (mm) or diametral pitch (inch\(^{-1}\))

The values of P, T, Q, are to be programmed.

In helical gear compensation, the machine coordinates and absolute coordinates of the workpiece axis are updated by the amount of helical gear compensation. When P command and Q command are not specified in G81 block, helical gear compensation is not performed.

The direction of helical gear compensation is determined by bit 2 (HDR) of parameter No.7700 (1 is usually specified). The compensation direction is shown in figure 2.4.
(1) When bit 2 (HDR) of parameter No.7700 is 1.

(2) When bit 2 (HDR) of parameter No.7700 is 0. (Items (a) to (d) are the same as for (1))

Fig. 20.8.3 (c) Direction of helical gear compensation
Synchronous ratio

The synchronous ratio of the Spindle EGB control is internally represented using a fraction. The fraction is calculated from T and L command in G81 block and the number of position detector pulses per rotation about the tool and the workpiece axis (parameter setting).

\[
\text{Synchronous ratio } : \quad \frac{K_2}{K_1} = \frac{L}{T} \times \frac{\beta}{\alpha}
\]

- **L**: Hob threads
- **T**: Number of teeth of the work
- **\(\alpha\)**: Number of position detector pulses per revolution about the tool axis (Parameter No.7772)
- **\(\beta\)**: Number of position detector pulses per revolution about the workpiece axis (Parameter No.7773)

This synchronous ratio is reduced to the lowest term, and it has the following limit.

\[-32767 < K_2 < 32767\]
\[1 < K_1 < 65535\]

When \(K_2\) or \(K_1\) is out of this range, P/S alarm (No.181) occurs.

The values of \(K_2\) and \(K_1\) are set to the parameter No.4387 and No.4388 automatically when G81 is specified. If T is not specified in G81 block, P/S alarm (No.181) occurs. If L is not specified in G81 block, the synchronous ratio is calculated as \(L = 1\).

Example) When the pulses for one rotation (360000) are specified to the tool axis (master axis) on the following conditions, the pulses for position control are distributed as Fig. 20.8.3(d).

- Hob threads \(L : 10\)
- Number of teeth of the work \(T : 100\)
- Number of pulse per one revolution of position detector on the tool axis \(\alpha : 360000\)
- Number of pulse per one revolution of position detector on the work axis \(\beta : 360000\)

\[
\text{Synchronous ratio } : \quad \frac{K_2}{K_1} = \frac{L}{T} \times \frac{\beta}{\alpha} = \frac{10}{100} \times \frac{360000}{360000} = \frac{1}{10}
\]
As Fig. 20.8.3 (d), when 360000 pulses (Number of pulse for one rotation of the master axis) are specified, the pulses for slave axis by EGB are equal to the value which is multiplied to the number of pulse for one rotation of the slave axis by the ratio of Hob thread and number of teeth (rotation ratio between master axis and slave axis).

\[
360000 \div \text{(slave axis rotation)} = 36000
\]

**Retract function**

When the retract signal RTRCT<G66#4> is turned to “1” in auto mode (MEM, MDI, etc.) or manual mode (HNDL, JOG etc.), the axis set in bit 0 (RTR) of the parameter No.7730 moves (retracts) by the amount set in the parameter No.7741.

**NOTE**

1. Feedrate in retract is set to the parameter No.7740. Then the feedrate override is not effective.
2. During the movement in retract, feed hold is not effective.
3. In case that retract signal is turned to “1” in auto mode, the movement of the auto mode is hold and the retract movement is done.

**Limitations**

1. The EGB synchronization is not canceled by RESET when bit 0 (HBR) of parameter No.7700 is set to 1. Set 1 to this parameter usually.
2. The EGB synchronization performed even under the following operation of the slave axis.
3) The EGB synchronization should be started and canceled at the stop of the master and the slave axis. It means that the tool axis (master axis) rotation should be started while the synchronization mode signal SYNMOD<F065#6> is “1” (Refer to Fig.2.3 Example timing for starting/canceling synchronization). If the tool axis (master axis) starts to rotate before the synchronization mode signal SYNMOD<F065#6> is “1”, the synchronization does not perform correctly.

4) Reference position return of Cs contouring control axis for master and slave axis should be performed before G81 is specified. In the synchronization mode, reference position return cannot be performed. Do not change to reference position return mode in the synchronization mode.

5) In case that the parameters for axis setting (No.7710,7771,4352) are not set correctly, P/S alarm (No.010) occurs when G81 specified.


7) During HPCC mode with RISC, the high-speed cycle cutting, the high-speed liner interpolation, the high-speed remote buffer A, the high-speed remote buffer B of DNC operation, and AI contour control, this function is not available.

8) The slave axis position display is updated by synchronous pulse as follows:
- Machine position display is updated.
- Absolute position display and relative position display are not updated. When the synchronization is canceled, the pulses of the synchronization are added to the absolute position display of the slave axis.

9) The rotation direction of the workpiece axis depends on the rotation direction of the tool axis. That is, when the rotation direction of the tool axis is positive, the rotation direction of the workpiece axis is also positive; when the rotation direction of the tool axis is negative, the rotation direction of the workpiece axis is also negative. However, by specifying a negative value for L, the rotation direction of the workpiece axis can be made opposite to the rotation direction of the tool axis.

10) During synchronization, a move command can be programmed for the workpiece axis. Note, however, that incremental command programming for cutting feed must be used to specify the workpiece axis move command.

11) The synchronization mode is canceled by servo alarm, spindle alarm, P/S alarm (No.000), or emergency stop.

12) The synchronization is not maintained in servo off status of the slave axis.

13) When the EGB control is used, the drilling canned cycle cannot be used.

14) The actual feedrate is displayed without the flexible synchronous pulse.
Alarms

<table>
<thead>
<tr>
<th>Number</th>
<th>Message</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>010</td>
<td>IMPROPER G–CODE</td>
<td>Parameters for axis setting are not set correctly regarding G81. (No.7710,7771,4352, or Cs axis setting). Confirm the parameter setting.</td>
</tr>
<tr>
<td>181</td>
<td>FORMAT ERROR IN G81 BLOCK</td>
<td>G81 block format error 1)T(number of teeth) has not been instructed. 2)Data outside the command range was instructed by either T, L, Q, or P. 3)Calculation of the synchronous ratio has overflowed. Modify the program.</td>
</tr>
<tr>
<td>184</td>
<td>ILLEGAL COMMAND IN G81</td>
<td>A command not to be instructed during synchronization was instructed. 1)The slave axis is specified by G00, G28, G27, G29, G30. 2)Inch/metric conversion by G20, G21 was instructed. 3)Cs contour control mode is not selected.</td>
</tr>
<tr>
<td>186</td>
<td>PARAMETER SETTING ERROR</td>
<td>Parameter error regarding G81 1)The slave axis has not been set to be a rotate axis.</td>
</tr>
</tbody>
</table>

20.8.4
Electronic Gear Box Automatic Phase Synchronization

In the electronic gear box (EGB), when synchronization start or cancellation is specified, synchronization is not started or canceled immediately. Instead, acceleration/deceleration is executed first. Therefore, synchronization can be started or canceled while the spindle is rotating. Also, synchronization ratio can be changed while the spindle is rotating. At synchronization start, automatic phase synchronization is performed such that the workpiece axis position matches the position corresponding to the spindle one–rotation signal. With this synchronization, the same operation is performed as synchronization start caused by a one–rotation signal in hobbing synchronization when using the functions of a hobbing machine.

The spindle corresponds to the EGB master axis and the workpiece axis corresponds to an EGB slave axis (Servo axis or Cs contouring axis).
### Acceleration/deceleration type

- **Spindle speed**
- **Workpiece axis speed**
- **Synchronization start command**
- **Synchronization cancellation command**

### Acceleration/deceleration plus automatic phase synchronization type

- **Spindle speed**
- **Workpiece axis speed**
- **Synchronization start command**
- **Synchronization cancellation command**

### Format

#### Acceleration/deceleration type

```plaintext
G81 T_ L_ R1;  Synchronization start
G80 R1;  Synchronization end
```

- **T**: Number of teeth (range of valid settings: 1–1000)
- **L**: Number of hob threads (range of valid settings: −21 to +21, excluding 0)
  - When **L** is positive, the direction of rotation about the workpiece axis is positive (+ direction).
  - When **L** is negative, the direction of rotation about the workpiece axis is negative (− direction).
**Acceleration/deceleration plus automatic phase synchronization type**

**G81 T_ L_ R2;**  
Synchronization start  

**G80 R2;**  
Synchronization end

- **T**: Number of teeth (range of valid settings: 1–1000)
- **L**: Number of hob threads (range of valid settings: -21 to +21, excluding 0)
  
  When L is positive, the direction of rotation about the workpiece axis is positive (+ direction).
  
  When L is negative, the direction of rotation about the workpiece axis is negative (− direction).

**Explanations**

**• Acceleration/deceleration type**

1. Specify **G81R1** to start synchronization.
   
   When **G81R1** is specified, acceleration according to the acceleration rate set in the parameter (No.2135,2136 or No.4384,4385) is performed on the workpiece axis (slave axis). Once the synchronization feedrate is reached, synchronization mode signal SYNMOD <F065#6> is set to 1, and the **G81R1** block is terminated.

2. For cancellation, specify **G80R1** while the tool is moved away from the workpiece.
3. When G80R1 is specified, the EGB mode check signal is set to 0, and deceleration according to the acceleration rate set in the parameter (No. 2135, 2136 or No.4384, 4385) is started immediately. When the speed is reduced to 0, the G80R1 block is terminated.

**CAUTION**
1. Linear acceleration/deceleration applies to synchronization start/cancellation.
2. In automatic synchronization cancellation due to Reset or P/S alarm (No.000), deceleration is executed and synchronization is canceled.

- **Acceleration/deceleration plus automatic phase synchronization type**

![Diagram showing synchronization](image)

1. Move the workpiece axis to the position that corresponds to that of the one–rotation signal of the spindle.
2. Specify G81R2 to start synchronization.
   When G81R2 is specified, the workpiece axis is accelerated with the acceleration according to the acceleration rate set in the parameter (No.2135,2136 or No.4384,4385). When the synchronization speed is reached, phase synchronization is performed automatically. Upon the completion of phase synchronization, synchronization mode signal SYNMOD <F065#6> is set to 1, and the G81R2 block is terminated.

3. For cancellation, specify G80R2 while the tool is moved away from the workpiece.

4. When G80R2 is specified, the synchronization mode signal is set to 0, and deceleration according to the acceleration rate set in the parameter (No.2135,2136 or No.4384,4385) is started immediately. When the speed is reduced to 0, the G80R2 block is terminated.
CAUTION

1 In automatic phase synchronization, specify the speed in parameter No.7776 and the movement direction in parameter PHD, bit 7 of No. 7702.

   In phase synchronization, rapid–traverse linear acceleration/deceleration (with the time constant specified in parameter No. 1620) is performed.

   The workpiece–axis speed is obtained by superposing the speed in automatic phase synchronization onto the speed corresponding to spindle rotation.

   In consideration of this superposition, specify a position deviation limit in parameter No. 1828.

2 The one–rotation signal used for automatic phase synchronization is issued not by the spindle position coder but by the separate pulse coder attached to the spindle and used to collect EGB feedback information. This means that the orientation position based on the one–rotation signal issued by the spindle position coder does not match the position used as the reference for the workpiece axis when establishing phase synchronization for automatic phase synchronization based on G81R2.

   Moreover, the one–rotation signal of the separate pulse coder must be turned on for each rotation of the spindle.

3 With the use of parameter No.7777, the position at which the phase of the workpiece axis is matched can be shifted from the position corresponding to the one–rotation signal in automatic phase matching.

4 In automatic phase synchronization, when a synchronization command is issued again in a synchronization state, movement about the workpiece axis is performed such that the position corresponding to the one–rotation signal of the spindle matches the position about the workpiece axis specified in the G81R2 synchronization start command executed first.

5 In automatic phase synchronization, movement is performed about the workpiece axis from the current position to the nearest phase position in the phase synchronization movement direction specified by the parameter.

6 Linear acceleration/deceleration applies to synchronization start/cancellation.

7 The acceleration/deceleration plus automatic phase synchronization type can be executed by the PHS parameter, bit 6 of No.7702, without specifying an R2 command in a G81 or G80 block.

8 In automatic synchronization cancellation due to Reset or P/S alarm (No.000), deceleration is executed and synchronization is canceled.

9 This item is for spindle EGB.

   If the control mode of the master axis is the speed control, it is necessary to execute the position coder orientation before that the automatic phase synchronization is started. In this case, RFCHK3 (PRM4016#7) of the master axis must be set “0” to keep memorizing the one–rotation signal position of the spindle in the speed control mode.

10 This item is for spindle EGB.

   If the control mode of the master axis is Cs contouring, it is necessary to execute the reference point return before that the automatic phase synchronization is started.

11 The acceleration rate parameter(No.2135,2136 or No.4384,4385) must not be changed in the synchronization mode.

12 Do not cancel the synchronous mode by the reset when this function is used. (Set “1” in parameter No.7700#0 HBR.)
Examples

- **Acceleration/deceleration type**

  M03 ;  
  G81 T_ L_ R1 ;  
  G00 X_ ;  

  Machining in the synchronous state

  G00 X_ ;  
  G81 T_ L_ R1 ;  
  G00 X_ ;  

  Machining in the synchronous state

- **Acceleration/deceleration plus automatic phase synchronization type**

  M03 ;  
  G00 G90 C_ ;  
  G81 T_ L_ R2 ;  
  G00 X_ ;  

  Machining in the synchronous state

  G00 X_ ;  
  G81 T_ L_ R2 ;  
  G00 X_ ;  

  Machining in the synchronous state

  G00 X_ ;  
  G80 R2 ;  

  Synchronization cancel command
• **About the direction of the rotation (This item is for spindle EGB.)**

The EGB automatic phase synchronization is made on the premise that the rotation of the slave axis is the same direction as the master axis. Refer to the following chart.

When this function is used, the SFR/SRV function in Cs contouring mode (*) can not use. If you want to change the rotary direction of the master axis, you should change the sign of the master axis command.

(*) The SFR/SRV function in Cs contouring mode
The SFR/SRV signal is a serial spindle control signal that determines the direction of rotation of the spindle in Cs contouring mode.

### Alarms

<table>
<thead>
<tr>
<th>Number</th>
<th>Message</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>181</td>
<td>EGB AUTO PHASE FORMAT ERROR</td>
<td>Format error in block in which G80 or G81 was specified by EGB automatic phase synchronization</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1) R is data outside of the instruction range.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2) Before the G81R2 command, the master spindle isn’t returned to in the reference point. (In case of Spindle EGB)</td>
</tr>
</tbody>
</table>
20.8.5
Electronic Gear Box 2
Pair

General

The Electronic Gear Box is a function for rotating a workpiece in sync with a rotating tool, or to move a tool in sync with a rotating workpiece. With this function, the high-precision machining of gears, threads, and the like can be implemented. A desired synchronization ratio can be programmed. Up to two sets of axes can be synchronized. A gear grinding machine can be controlled, for instance, by using one axis for rotating the workpiece in sync with the tool and another axis for performing dressing in sync with the tool.

The electronic gear box is hereinafter called an EGB function.

- Configuration examples of controlled axes

  Spindle : EGB master axis serving as a tool axis
  First axis : X
  Second axis : Y
  Third axis : C axis (EGB slave axis serving as a workpiece axis)
  Fourth axis : C axis (EGB dummy axis, which cannot be used as a usual controlled axis)
  Fifth axis : V axis (EGB slave axis serving as a dressing axis)
  Sixth axis : V axis (EGB dummy axis, which cannot be used as a usual controlled axis)
NOTE
A sampling period of 1 ms is applied when feedback pulses are read from the master axis; the synchronization pulses for a slave axis are calculated according to synchronization coefficient K; and the pulses are specified for position control of the slave axis.

Explanations

• Synchronization start
  When the ratio of the master–axis travel to the slave–axis travel is specified, synchronization starts.

Format

```
G81.5  \{ T_t \}  \{ P_p \}  \{ \beta \ j \}  \{ \beta \ 0 \ L \} ;
```

<table>
<thead>
<tr>
<th>Master–axis travel</th>
<th>Slave–axis travel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specify the master–axis travel in either of the following ways.</td>
<td>Specify the slave–axis travel in either of the following ways.</td>
</tr>
<tr>
<td>( T_t ) : Master–axis speed (1 ≤ t ≤ 1000)</td>
<td>( \beta \ j ) : Slave–axis address</td>
</tr>
<tr>
<td>2. Master–axis pulse count</td>
<td>( j ) : Slave–axis travel indicated in units of the minimum travel increments (the range of valid settings for usual axis movement applies)</td>
</tr>
<tr>
<td>( P_p ) : Master–axis pulse count (1 ≤ p ≤ 999999999)</td>
<td>When ( j = 0 ), the specified command is regarded as being a command for the slave–axis speed, described below. In this case, if ( L ) is not specified, an alarm is output.</td>
</tr>
<tr>
<td>Specify a pulse count on the condition that four pulses correspond to one period in the A and B phases.</td>
<td>2. Slave–axis speed</td>
</tr>
</tbody>
</table>

```
\( \beta \ 0 \ L \) ;
```

<table>
<thead>
<tr>
<th>Slave–axis address</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \beta ) : Slave–axis address</td>
</tr>
<tr>
<td>( L ) : Slave axis speed (1 ≤ l ≤ 21)</td>
</tr>
</tbody>
</table>

CAUTION
1. A move command can be issued by a program to the slave axis or other axes during synchronization. In this case, the command shall be an incremental command.
2. A G00, G27, G28, G29, G30, G30.1, G33 or G53 command cannot be issued to the slave axis in synchronization mode.
3. Controlled–axis detach cannot be used for the master axis or the slave axis.
**NOTE**

1. A manual handle interruption can be issued to the slave axis or other axes during synchronization.
2. The maximum feedrates for the master axis and the slave axis are limited according to the position detectors used.
3. An inch/metric conversion command (G20 or G21) cannot be specified in synchronization mode.
4. The machine coordinates for the slave/dummy axis are updated in synchronization mode.

**Synchronization end**

**Format**

With a G80.5 β 0 command, synchronization is canceled. 
β is the address of the slave axis.

1. Canceling synchronization for each axis by issuing a command

   Synchronization of the slave axis specified by ? is canceled. 
   A cancellation command can be issued only for one axis in one block. 
   When β 0 is not specified, the synchronization of all currently synchronized axes is canceled. 
   When a synchronization cancellation command is issued, the absolute coordinates for the slave axis are updated according to the amount of travel during synchronization. For a rotation axis, the value obtained by rounding off the amount of travel during synchronization to the nearest 360 degrees is added to the absolute coordinates.

2. Canceling synchronization by a reset

   For an axis for which a parameter is set to allow synchronization to be canceled by a reset, HBR, bit 0 of No. 7700, is set to 0, allowing synchronization to be canceled by a reset. When a manual absolute signal is on, the absolute coordinates are updated.

3. Others

   Synchronization is automatically canceled under the following conditions.
   (1) Emergency stop
   (2) Servo alarm
   (3) P/S alarm No.000 (indicating that the power should be turned off)

**Description of commands compatible with those for a hobbing machine**

A command compatible with that for a hobbing machine can be used as a synchronization command. 
Such a command cannot be used when a canned–cycle option is provided. 
Specify which axes starts synchronization with such a command by using parameter No. 7710.

(1) Synchronization start

   When the following command is specified, synchronization of spindle axis and C axis starts
G81 T_(L_)(Q_P_);

T : Number of teeth (range of valid settings: 1 to 1000)
L : Number of hob threads (range of valid settings: -21 to +21, excluding 0)
The sign of L determines the direction of rotation for the workpiece axis.
When L is positive, the direction of rotation for the workpiece axis is positive (+ direction).
When L is negative, the direction of rotation for the workpiece axis is negative (– direction).
When L is not specified, the number of hob threads is regarded as being 1.
Q : Module or diametral pitch
   In metric input, specify a module (unit : 0.00001 mm, range of valid settings : 0.1 to 25.0 mm).
   In inch input, specify a diametral pitch (unit : 0.00001 [1/inch], range of valid settings: 0.1 to 254.0 [1/inch])
P : Twisted angle of a gear
   (unit : 0.00001 degrees, range of valid settings : -90.0 to 90.0 degrees)

Specify P and Q to use helical gear compensation. In this case, if only one of P and Q is specified, an alarm (P/S 181) is generated.
The decimal point can be specified in Q and P.
When a G81 command is issued to change to synchronization mode, the EGB mode confirmation signal for the workpiece axis becomes “1” and synchronization starts between the spindle and the workpiece axis.
During synchronization, control is performed such that the ratio of the spindle speed to the workpiece-axis speed is the same as that of T (number of teeth) to L (number of hob threads).
When a G81 command is again specified during synchronization without canceling synchronization, an alarm (P/S 181) is generated.

(2) Synchronization end
When the following command is specified, synchronization is cancelled.

G80;

Synchronization of all synchronized axes is canceled.
When a synchronization cancellation command is issued, the absolute coordinates for the slave axis are updated according to the amount of travel during synchronization.
For a rotation axis, the value obtained by rounding off the amount of travel during synchronization to the nearest 360 degrees is added to the absolute coordinates.
In a G80 block, do not specify addresses other than O or N.

(3) Helical gear compensation
For a helical gear, the workpiece axis is subjected to compensation for movement along the Z axis (axial feed axis) according to the twisted angle of the gear.
Helical gear compensation is performed with the following data.

\[
\text{Compensation angle} = \frac{Z \times \sin(P)}{\pi \times T \times Q} \times 360 \quad \text{(In metric input)}
\]
Compensation angle = \( \frac{Z \times Q \times \sin(P)}{\pi \times T} \times 360 \) (In inch input)

Where,
- Compensation angle: Absolute value with sign (degrees)
- Z: Amount of travel along the Z axis after a G81 command is issued (mm or inch)
- P: Twisted angle of the gear with sign (degrees)
- \( \pi \): Ratio of the circumference of a circle to its diameter
- T: Number of teeth
- Q: Module (mm) or diametral pitch (1/inch)

Use P, T, and Q specified in the G81 block.

**Compensation direction in helical gear compensation**

Parameter HDR (bit 2 of No. 7700)

<table>
<thead>
<tr>
<th>HDR bit set to 1</th>
<th>HDR bit set to 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>+C, Z, P : +</td>
<td>-C, Z, P : -</td>
</tr>
<tr>
<td>Compensation direction: +</td>
<td>Compensation direction: -</td>
</tr>
<tr>
<td>Compensation direction: -</td>
<td>Compensation direction: +</td>
</tr>
<tr>
<td>(a), (b), (c), (d)</td>
<td>(e), (f), (g), (h)</td>
</tr>
</tbody>
</table>

When the HDR bit is set to 1

When the HDR bit is set to 0 (a), (b), (c), and (d) are the same as when the HDR bit is set to 1
Examples

(1) When the master axis is the spindle, and the slave axis is the C-axis

1. \texttt{G81.5 T10 C0 L1 ;}
   Synchronization between the master axis and C-axis is started at the ratio of one rotation about the C-axis to ten rotations about the master axis.

2. \texttt{G81.5 T10 C0 L-1 ;}
   Synchronization between the master axis and C-axis is started at the ratio of one rotation about the C-axis to ten rotations about the master axis.
   In this case, however, the direction of rotation is opposite to that of 1. above.

3. \texttt{G81.5 T1 C3.26 ;}
   Synchronization between the master axis and C-axis is started at the ratio of a 3.26-degree rotation about the C-axis per one rotation about the master axis.

4. \texttt{G81.5 P10000 C-0.214 ;}
   Synchronization between the master axis and C-axis is started at the ratio of a \(-0.214\) degree rotation about the C-axis to 10,000 feedback pulses from the pulse coder of the master axis.

(2) When the master axis is the spindle, the slave axis is the V-axis (linear axis), and inch/metric conversion is performed

1. For a millimeter machine and metric input
   \texttt{G81.5 T1 V1.0 ;}
   Synchronization between the master axis and V-axis is started at the ratio of a 1.00 mm movement along the V-axis per rotation about the master axis.

2. For a millimeter machine and inch input
   \texttt{G81.5 T1 V1.0 ;}
   Synchronization between the master axis and V-axis is started at the ratio of a 1.0 inch movement (25.4 mm) along the V-axis per rotation about the master axis.

(3) When two groups of axes are synchronized simultaneously

Based on the controlled axis configuration described in Fig.20.8.5, the sample program below synchronizes the spindle with the V-axis while the spindle is synchronized with the C-axis.
Performs spindle orientation.
Positions the C-axis.
Starts synchronization at the ratio of one rotation about the C-axis to ten spindle rotations.
Rotates the spindle.
Makes movements for grinding.
Stops the spindle.
Positions the dressing axis.
Starts synchronization at the ratio of a 0.5 mm movement along the V-axis every 12,000 pulses on the spindle.
Rotates the spindle.
A subprogram for dressing is called.
Stops the spindle.
Cancels V-axis synchronization.
Rotates the spindle
Makes movements for grinding
Stops the spindle.
Cancels C-axis synchronization.

Thus, the synchronizations of two groups can be started and canceled independently of each other.

(4) Command specification for hobbing machines
Based on the controlled axis configuration described in Fig.20.8.5, the sample program below sets the C-axis (in parameter 7710) for starting synchronization with the spindle according to the command specification method for hobbing machines.

```
O0100;
........
N01 Mxx;
N02 G00 G90 C...;
N03 G81.5 T10 C0 L1;
N04 Myy S300
N05 G01 G91 X... Y... F...;
......
N06 Mzz;
......
N10 G00 G90 V...;
N11 G81.5 P12000 V0.5;
N12 Myy S300
N20 M98 P9500;
N21 Mzz;
N30 G80.5 V0;
......
N31 Myy S300;
N32 G01 G91 X... Y... F...;
......
N40 Mzz;
N41 G80.5 C0;
```

Grinding
Dressing
Grinding
V-axis synchronization mode
C-axis synchronization mode
O1234 ;
..........
..........
N01 G81 T20 L1 ; Starts synchronization with the spindle and C–axis at the ratio of a 1/20 rotation about the C–axis to one spindle rotation.
N02 Mxx S300 ; Rotates the spindle at 300 min⁻¹.
N03 X... F... ; Makes a movement along the X–axis (for cutting).
N04 Y... F... ; Makes a movement along the Y–axis (for grinding). Axes such as the C–axis, X–axis, and Y–axis can be specified as required.
N05 X... F... ; Makes a movement along the X–axis (for retraction).
N06 Mzz ; Stops the spindle.
N07 G80 ; Cancels the synchronization between the spindle and C–axis.

• **Synchronization Ratio Specification Range**

The programmed ratio (synchronization ratio) of a movement along the slave axis to a movement along the master axis is converted to a detection unit ratio inside the NC. If such converted data (detection unit ratio) exceeds a certain allowable data range in the NC, synchronization cannot be established correctly, and an alarm (P/S 181) is issued. Even when a programmed master axis movement and a programmed slave axis movement are within specifiable ranges, a detection unit ratio obtained by conversion can exceed the allowable range, thus resulting in an alarm.

Let K be a synchronization ratio. The internal data corresponding K is the amount of slave axis movement (Kn) represented in the detection unit divided by the amount of master axis movement (Kd) represented in the detection unit; this fraction is represented as Kn/Kd (reduced to its lowest terms) as indicated below.

\[
K = \frac{Kn}{Kd} = \frac{\text{Amount of slave axis movement represented in the detection unit}}{\text{Amount of master axis movement represented in the detection unit}}
\]

Kn and Kd must lie within the following ranges:

\[
-2147483648 \leq Kn \leq 2147483647
\]

\[
1 \leq Kd \leq 65535
\]

When Kn or Kd exceeds its allowable range above, an alarm is issued. In conversion to the detection unit, when the CMR (command multiplication: parameter 1820) is a fraction or when inch/millimeter conversion is used, the fraction is directly converted without modification so that no error can occur in the conversion of specified amounts of movement.

During conversion, the amount of movement is multiplied by 254/100 for inch input on a millimeter machine, and 100/254 for metric input on an inch machine. Thus, Kn and Kd can become large numbers. If a synchronization ratio cannot be reduced to its lowest terms, an alarm condition is likely to occur.
Based on the controlled axis configuration described in Fig.20.8.5, suppose that the spindle and V-axis are as follows:

- **Spindle pulse coder**: 72000 pulse/rev (4 pulses for one A/B phase cycle)
- **C-axis least command increment**: 0.001 degree
- **C-axis CMR**: 5
- **V-axis least command increment**: 0.001 mm
- **V-axis CMR**: 5

Then, the C-axis detection unit is 0.0002 degree. The V-axis detection unit is 0.0002 mm. In this case, the synchronization ratio \((K_n, K_d)\) is related with a command as indicated below. Here, let \(P_m\) and \(P_s\) be the amounts of movements represented in the detection unit on the master axis and slave axis specified in a synchronization start command, respectively.

1. **When the master axis is the spindle, and the slave axis is the C-axis**
   
   (a) **Command**: G81.5 T10 C0 L1 ;
   
   **Operation**: Synchronization between the spindle and C-axis is started at the ratio of one rotation about the C-axis to ten spindle rotations.

   \[
   P_m : \frac{(\text{Number of pulses per spindle rotation}) \times 10}{\text{rotations}} \rightarrow 72000 \times 10
   \]

   \[
   P_s : \frac{(\text{Amount of movement per rotation about the C-axis}) \times \text{CMR}}{\text{(one rotation)}} \rightarrow 360000 \times 5 \times 1
   \]

   \[
   K_n = \frac{360000 \times 5 \times 1}{72000 \times 10} = \frac{5}{2}
   \]

   Both \(K_n\) and \(K_d\) are within the allowable range. No alarm is output.

   (b) **Command**: G81.5 T10 C0 L–1 ;

   **Operation**: Synchronization between the spindle and C-axis is started at the ratio of one rotation about the C-axis to ten spindle rotations.
   
   In this case, however, the direction of rotation is opposite to that of (a) above.

   \[
   P_m : \frac{(\text{Number of pulses per spindle rotation}) \times 10}{\text{revolutions}} \rightarrow 72000 \times 10
   \]

   \[
   P_s : \frac{(\text{Amount of movement per rotation about the C-axis}) \times \text{CMR}}{\text{(one rotation)}} \rightarrow -360000 \times 5 \times 1
   \]

   \[
   K_n = \frac{-360000 \times 5 \times 1}{72000 \times 10} = -\frac{5}{2}
   \]

   Both \(K_n\) and \(K_d\) are within the allowable range. No alarm is output.

   (c) **Command**: G81.5 T1 C3.263 ;

   **Operation**: Synchronization between the spindle and C-axis is started at the ratio of a 3.263-degree rotation about the C-axis to one spindle rotation.

   \[
   P_m : \frac{(\text{Number of pulses per spindle rotation}) \times 1}{\text{rotation}} \rightarrow 72000 \times 1
   \]

   \[
   P_s : \frac{(\text{Amount of C-axis movement}) \times \text{CMR}}{\text{3263 \times 5}} \rightarrow 3263 \times 5
   \]

   \[
   K_n = \frac{3263 \times 5}{72000 \times 1} = \frac{3263}{14400}
   \]
Both Kn and Kd are within the allowable range. No alarm is output.

In this sample program, when T1 is specified for the master axis, the synchronization ratio (fraction) of the CMR of the C-axis to the denominator Kd can always be reduced to lowest terms, thus Kd falls in the allowable range. So, the specifiable range of C is as follows:

\[-99999999 \leq C \leq 99999999\]

(d) Command : G81.5 T10 C3.263 ;
Operation : Synchronization between the spindle and C-axis is started at the ratio of a 3.263-degree rotation about the C-axis to ten spindle rotations.

\[
\frac{Kn}{Kd} = \frac{3263 \times 5}{72000 \times 10} = \frac{3263}{14400}
\]

In this case, an alarm is issued because Kd exceeds the specifiable range.

(e) Command : G81.5 P10000 C–0.214 ;
Operation : Synchronization between the spindle and C-axis is started at the ratio of a –0.214 degree rotation of the C-axis to 10,000 feedback pulses from the pulse coder of the spindle.

\[
\frac{Kn}{Kd} = \frac{-214 \times 5}{10000} = \frac{-107}{1000}
\]

Both Kn and Kd are within the allowable range. No alarm is output.

(2) When the master axis is the spindle, the slave axis is the V-axis (linear axis), and inch/metric conversion is performed

(a) For a millimeter machine and metric input
Command : G81.5 T1 V1.0 ;
Operation : Synchronization between the spindle and V-axis is started at the ratio of a 1.00 mm movement along the V-axis per spindle rotation.

\[
\frac{Kn}{Kd} = \frac{1000 \times 5}{72000} = \frac{5}{72}
\]

Both Kn and Kd are within the allowable range. No alarm is output.

(b) For a millimeter machine and inch input
Command : G81.5 T1 V1.0 ;
Operation : Synchronization between the spindle and V-axis is started at the ratio of a 1.0 inch movement (25.4 mm) along the V-axis per spindle rotation.

\[
\frac{Kn}{Kd} = \frac{1000 \times 5}{72000} = \frac{5}{72}
\]

Both Kn and Kd are within the allowable range. No alarm is output.
Ps : (Amount of V-axis movement) × CMR × 254 ÷ 100 → 10000 × 5 × 254 ÷ 100

\[
\frac{Kn}{Kd} = \frac{10000 \times 5 \times 254}{72000 \times 100} = \frac{127}{72}
\]

Both Kn and Kd are within the allowable range. No alarm is output.

(c) For a millimeter machine and inch input

Command : G81.5 T1 V0.0013 ;
Operation : Synchronization between the spindle and V-axis is started at the ratio of a 0.0013 inch (0.03302 mm) movement along the V-axis per spindle rotation.

\[
\frac{Kn}{Kd} = \frac{13 \times 5 \times 254}{72000 \times 100} = \frac{1651}{72000}
\]

In this case, an alarm is issued because Kd exceeds the specifiable range.

• Example 2)

Based on the controlled axis configuration described in Fig.20.8.5, suppose that the spindle and V-axis are as follows:

Spindle pulse coder : 72000 pulse/rev (4 pulses for one A/B phase cycle)
C-axis least command increment : 0.001 degree
C-axis CMR : 1/2
V-axis least command increment : 0.001 mm
V-axis CMR : 1/2

Then, the C-axis detection unit is 0.002 degree. The V-axis detection unit is 0.002 mm. In this case, the synchronization ratio (Kn, Kd) is related with a command as indicated below. Here, let Pm and Ps be the amounts of movements represented in the detection unit for the master axis and slave axis specified in a synchronization start command, respectively.

(1) When the master axis is the spindle, and the slave axis is the C-axis

(a) Command : G81.5 T1 C3.263 ;
Operation : Synchronization between the spindle and C-axis is started at the ratio of a 3.263-degree rotation about the C-axis per spindle rotation.

\[
Pm : (\text{Number of pulses per spindle rotation}) \times 1 \quad \text{rotation} \rightarrow 72000 \times 1
\]

\[
Ps : (\text{Amount of V-axis movement}) \times \text{CMR} \rightarrow 3263 \times 1 \div 2
\]

\[
\frac{Kn}{Kd} = \frac{3263 \times 1}{72000 \times 2} = \frac{163}{7200}
\]

In this case, an alarm is issued because Kd exceeds the specifiable range.

(b) Command : G81.5 T1 C3.26 ;
Operation : Synchronization between the spindle and C-axis is started at the ratio of a 3.26-degree rotation about the C-axis per spindle rotation.

\[
Pm : (\text{Number of pulses per spindle rotation}) \times 1 \quad \text{revolution} \rightarrow 72000 \times 1
\]
Ps : (Amount of C-axis movement) \times \text{CMR} \\
\rightarrow 3260 \times 1 \div 2

\frac{K_n}{K_d} = \frac{3260 \times 1}{72000 \times 2} = \frac{163}{7200}

(a) causes an alarm to be output because the values cannot be abbreviated. (b) causes no alarm because the ratio of the travel distances can be abbreviated to a simple ratio.

• Retraction function

When retract signal RTRCT is set to 1 (on the rising edge of the signal), retraction is performed according to the retract value set in parameter No. 7741 and the feedrate set in parameter No. 7740.

The tool does not move along an axis for which the amount of retraction is set to 0.

After retraction, retraction completion signal RTRCTF is output.

CAUTION
1 Retract operation is performed at the feedrate specified in parameter No. 7740.
2 Feed hold cannot be applied to retraction.
3 In this case, the feedrate override capability is disabled.

NOTE
1 When the retract signal goes on during automatic operation, retract operation is performed, and automatic operation is stopped.
2 Automatic operation cannot be performed in retraction.

• Notes on parameter settings

Note the following points when specifying parameters for the electronic gear box.

1. Arrange the controlled axes such that a slave axis appears before a dummy axis.

(Example)

<table>
<thead>
<tr>
<th>Axis name</th>
<th>Servo axis number (No.1023)</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>1</td>
</tr>
<tr>
<td>Y</td>
<td>2</td>
</tr>
<tr>
<td>C (dummy axis)</td>
<td>3</td>
</tr>
<tr>
<td>C (slave axis)</td>
<td>4</td>
</tr>
</tbody>
</table>

Note: Example of incorrect setting

<table>
<thead>
<tr>
<th>Axis name</th>
<th>Servo axis number (No.1023)</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>1</td>
</tr>
<tr>
<td>Y</td>
<td>2</td>
</tr>
<tr>
<td>C (dummy axis)</td>
<td>3</td>
</tr>
<tr>
<td>C (slave axis)</td>
<td>4</td>
</tr>
</tbody>
</table>

2. Do not use a name which is usually not allowed to be used as an axis address, such as D.

3. Specify the same values for an EGB slave axis and an EGB dummy axis in the following parameters.
4. Specify the amount of travel per rotation about a rotation axis for a slave axis in a parameter No. 1260.

5. Make the specification for a dummy axis in the following way.

   1815#1 Whether to use separate detectors. Although an EGB dummy axis uses the interface of a separate detector, set these parameters to 0.

6. If the following parameters are not specified, an alarm (SV 417 servo parameter invalid) may be generated. In such a case, make the specification as described below.

   20XX Specify the same value for both a slave axis and a dummy axis.

   2084, 2085 Flexible feed gear.
   Set parameters Nos. 2084 and 2085 to 1 for the dummy axis.

7. Specify as large a feed-forward coefficient as possible to reduce the synchronization error. For details of parameter setting, see Feed-forward setting of Geometric error suppression function in FANUC AC SERVO MOTOR \( \alpha i \) series Parameter Manual (B–65270EN) or FANUC AC SERVO MOTOR \( \alpha \) series Parameter Manual (B–65150EN).
# Alarms

<table>
<thead>
<tr>
<th>Number</th>
<th>Message</th>
<th>Contents</th>
</tr>
</thead>
</table>
| P/S 181 | FORMAT ERROR IN G81 BLOCK | Format error in the block in which EGB was specified  
| | | (1) The axis during synchronization by EGB is specified by G81.5 again.  
| | | (2) U-axis is specified by G81.5/G80.5 with U-axis control.  
| | | (3) Format error in the block in which G81.5/G80.5 was specified.  
| | | - Data is specified to more than 2 slave axes in one block. Or nothing is specified to the slave axis.  
| | | - Data specified to the slave axis is neither ‘/C0098 0 Lxx’ nor ‘/lx’.  
| | | - Data is specified to more than 2 master axes in one block.  
| | | - Data is specified to the axis which is neither the master nor the slave axis.  
| | | - One of T, P or a codes is specified redundantly.  
| | | - Out of range data is specified by one of T or L codes  
| | | - An overflow occurred during calculation of the synchronization coefficient. |
| P/S 184 | ILLEGAL COMMAND IN G81 | An illegal instruction was issued during synchronization by EGB.  
| | | (1) Slave axis was specified by G00, G27, G28, G29, and G30 G codes.  
| | | (2) Inch/metric conversion was specified by G20 or G21 G codes. |
| P/S 186 | PARAMETER SETTING ERROR | Erroneous EGB parameter setting  
| | | The number of pulses (parameter Nos. 7782, 7783) per rotation is not set. |
21. TWO-PATH CONTROL FUNCTION
21.1 GENERAL

- Controlling two path independently at the same time

The two-path control function is designed for use on a machining center where two systems are operated independently to simultaneously perform cutting.

The operations of two path are programmed independently of each other, and each program is stored in program memory for each path. When automatic operation is to be performed, each path is activated after selecting a program for machining with path 1 and a program for machining with path 2 from the programs stored in program memory for each path. Then the programs selected for the paths are executed independently at the same time. When path 1 and path 2 need to wait for each other during machining, the waiting function is available (Section 21.2)

Just one MDI is provided for the two paths. Before operation and display on the MDI, the path selection signal is used to switch between the two paths.

WARNING
Simultaneous operation of the two paths or the operation of only a single tool post can be selected by pressing a key on the machine operator’s panel. For details, refer to the manual supplied by the machine tool builder.
## 21.2 WAITING FOR PATHS

### Explanations

Control based on M codes is used to cause one path to wait for the other during machining. By specifying an M code in a machining program for each path, the two paths can wait for each other at a specified block. When an M code for waiting is specified in a block for one path during automatic operation, the other path waits for the same M code to be specified before starting the execution of the next block. This function is called the paths waiting function.

A range of M codes used as M codes for waiting is to be set in the parameters (Nos. 8110 and 8111) beforehand.

- **M100** to **M103** are used as M codes for waiting.
- **Parameter setting:**
  - No. 8110 = 100 (Minimum M code for waiting: **M100**)
  - No. 8111 = 103 (Maximum M code for waiting: **M103**)

### Example

M100 to M103 are used as M codes for waiting.

- **Parameter setting:**
  - No. 8110 = 100 (Minimum M code for waiting: **M100**)
  - No. 8111 = 103 (Maximum M code for waiting: **M103**)

### Path 1 program

```plaintext
G01357 ;
G50 X_Z_ ;
G00 X_Z_T0101 ;
S1000 M03 ;
M100 ;
N1100 G01 X_Z_F_;
N1199 M101 ;
M102 ;
N1300 G00 X_Z_T0505 ;
N1399 M103 ;
M30 ;
```

### Path 2 program

```plaintext
G02468 ;
G50 X_Z_ ;
G00 X_Z_T0202 ;
S2000 M03 ;
M100 ;
N2100 G01 X_Z_F_;
N2199 M101 ;
N2300 G00 X_Z_T0707 ;
N2399 M103 ;
M30 ;
```

#### Simultaneous, independent operation of path 1 (N1100 to N1199) and path 2 (N2100 to N2199)

- **Waiting: (M101)**
- **Operation of path 2 (N2200 to N2299) only**

#### Simultaneous, independent operation of path 1 (N1300 to N1399) and path 2 (N2300 to N2399)

- **Waiting: (M102)**

#### End of program
NOTE
1 An M code for waiting must always be specified in a single block.
2 If one path is waiting because of an M code for waiting specified, and a different M code for waiting is specified with the other path, an P/S alarm (No. 160) is raised. In this case, both paths stop operation.
3 PMC–CNC interface
   Unlike other M codes, the M code for waiting is not output to the PMC.
4 Operation of a single path
   If the operation of a single path is required, the M code for waiting need not be deleted. By using the NOWT signal to specify that waiting be ignored (G0063, #1), the M code for waiting in a machining program can be ignored. For details, refer to the manual supplied by the machine tool builder.
21.3 MEMORY COMMON TO PATH

A machine with two paths have different custom macro common variables and tool compensation memory areas for path 1 and 2. Paths 1 and 2 can share the custom macro common variables and tool compensation memory areas provided certain parameters are specified accordingly.

Explanations

- Custom macro common variables

Paths 1 and 2 can share all or part of custom macro common variables #100 to #149 and #500 to #531, provided parameters 6036 and 6037 are specified accordingly. (The data for the shared variables can be written or read from either path.) See Section 15.1 of Part II.
21.4 COPYING A PROGRAM BETWEEN TWO PATHS

In a CNC supporting two-path control, specified machining programs can be copied between the two paths by setting bit 0 (PCP) of parameter No. 3206 to 1. A copy operation can be performed by specifying either a single program or a range. For information about operations, see Section 9.10 in Part III.

Explanations

• Single-program copy

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<tr>
<th>Copy source number</th>
<th>Copy destination number</th>
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</thead>
<tbody>
<tr>
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</table>

<table>
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<th>Copy destination number</th>
</tr>
</thead>
<tbody>
<tr>
<td>0001</td>
<td>0010</td>
</tr>
</tbody>
</table>

• Specified-range copy

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<th>Copy destination number</th>
</tr>
</thead>
<tbody>
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<tr>
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<td>O1000</td>
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<tbody>
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<td>1000</td>
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<th>Copy destination number</th>
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<tr>
<td>0010</td>
<td>1001</td>
</tr>
<tr>
<td>0100</td>
<td>1002</td>
</tr>
<tr>
<td>O1000</td>
<td>O1002</td>
</tr>
</tbody>
</table>
The following functions are executed at high speed with RISC processor.

- AI high precision contour control
- AI NANO high precision contour control
- Cylindrical interpolation cutting point control
- Tool center point control
- Tool axis compensation in tool axis direction
- 3–dimensional cutter compensation
- 3–dimensional circular interpolation

The parameter (No. 19600#0–#5) setting expands the following functions which is executed with RISC processor.

<table>
<thead>
<tr>
<th>5–axis control mode</th>
<th>function</th>
</tr>
</thead>
<tbody>
<tr>
<td>mode ON</td>
<td>mode OFF</td>
</tr>
<tr>
<td>G51</td>
<td>G50</td>
</tr>
<tr>
<td>G51.1</td>
<td>G50.1</td>
</tr>
<tr>
<td>G54.2 Pn (n=1–8)</td>
<td>G54.2 P0</td>
</tr>
<tr>
<td>G68</td>
<td>G69</td>
</tr>
<tr>
<td>G68 I_J_K_</td>
<td>G69</td>
</tr>
<tr>
<td>G41,G42</td>
<td>G40</td>
</tr>
</tbody>
</table>

AI high precision contour control, AI NANO high precision contour control, Tool center point control, Tool axis compensation in tool axis direction, 3–dimensional cutter compensation and 3–dimensional circular interpolation can be used in the mode of above mentioned functions when the above mentioned function is set to be executed with RISC processor.

Please refer to paragraph of restrictions for the restriction in this case.

AI high precision contour control, AI NANO high precision contour control, Tool center point control, Tool axis compensation in tool axis direction, 3–dimensional cutter compensation and 3–dimensional circular interpolation can be used only when the state of the above mentioned functions is canceling when the above mentioned function is set to be executed with CNC.

The alarm (P/S5012) occurs if AI high precision contour control, AI NANO high precision contour control, Tool center point control, Tool axis compensation in tool axis direction, 3–dimensional cutter compensation and 3–dimensional circular interpolation is used when the state of the above mentioned function is not canceling.
5–axis control mode

The state to execute the each function of AI high precision contour control, AI NANO high precision contour control, Tool center point control, Tool axis compensation in tool axis direction, 3–dimensional cutter compensation and 3–dimensional circular interpolation is generically called five axis control mode.

The function set in the expansion of RISC command is included, too.

Restriction –1

The following commands can not be used in the AI High Precision Contour Control mode or AI NANO High Precision Contour Control mode. The alarm is issued if the function was used.

- Custom macro
- Exponential interpolation – G02.3, G03.3
- Dwell – G04
- High Speed Cutting Function relation – G05
  (G05P10000 and G05P0 are excluded)
- AI contour control – G05.1Q1, G5.1Q0
- Hypothetical axis interpolation – G07
- Advanced preview control – G08
  (Please use AI High Precision Contour Control)
- Polar coordinate interpolation – G12.1, G13.1
- Polar coordinate command – G15, G16
- Reference position return check – G27
- Reference point return – G28
- 2nd. Reference point return – G30
- 3rd/4th reference point return – G30
- Skip – G31
- Thread cutting – G33
- Automatic tool length measurement – G37
- Normal direction control – G40.1, G41.1, G42.1
- Cutter compensation B – G41, G42, G39
  (Cutter compensation C is available)
- 3–dimensional tool compensation – G41
- Wheel wear compensation – G41
- Tool offset – G45, G46, G47, G48
- Local coordinate system – G52
- Machine coordinate system – G53
- Single direction positioning – G60
- Automatic corner override – G62
- Tapping mode – G63
- Macro call – G65, G66, G67
  (SubProgram call is available)
- Figure copying – G72.1, G72.2
- Simple electric gear box – G80, G81
- Functions for hobbing machine – G80, G81
Restriction –2

The following functions can not be used in the AI High Precision Contour Control mode, the AI NANO High Precision Contour Control mode or the 5-axis control mode.

- Flexible synchronous control
- Sequence number comparison and stop
  
  It is not possible to stop by the sequence number in the AI High Precision Contour Control mode, in the AI Nano High Precision Contour Control mode or in the 5-axis control mode.
- Index table indexing
- Retrace function
  
  Do not use retrace function in the program which uses the AI High Precision Contour Control mode or the AI Nano High Precision Contour Control or 5-axis control mode.
- Rotary axis control
- Gentle curve normal direction control
- Tool life management
  
  Tool life value is counted in the AI High Precision Contour Control mode or in the AI Nano AI High Precision Contour Control mode. However, do not use the command related to the tool life management function.
- Macro executor (Execution macro)
- Manual handle interruption
- Feedrate change of F1 digit feed by manual pulse generator
- External deceleration (External deceleration is not available)

Restriction –3

The following commands can not be used in the 5-axis control mode. The alarm is issued if the function was used.

- M,S,T and B function with motion command
- NURBS interpolation –G06,2
- Workpiece coordinate system –G54–G59, G54.1
- Canned cycle
  
  –G73 to G79,
  
  G80 to G89,G98,G99
- Manual interruption operaton
- Tool retract and recover

Restriction –4

In the 5-axis control mode, the following functions cannot be used. The warning message is displayed on the screen when the following functions are used.

- External operation function –G81
- Chopping function –G81.1
- Setting a workpiece coordinate system –G92
- Workpiece coordinate system preset –G92.1
- Feed per revolution –G95
- Constant surface speed control –G96,G97
- Infeed control –G160,G161
When the following function is used, the function which executed with RISC processor cannot be used.

- Angular axis control
- Arbitrary angular axis control

The following modal G code are placed in the cleared state when the reset is executed in AI high precision contour control mode, AI NANO high precision contour control mode or 5-axis control mode,

<table>
<thead>
<tr>
<th>[Modal status]</th>
<th>[Clear status]</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-dimensional circular interpolation</td>
<td>G02.4/G03.4</td>
</tr>
<tr>
<td>NURBS interpolation</td>
<td>G06.2</td>
</tr>
<tr>
<td>Cutter compensation C</td>
<td>G41/G42</td>
</tr>
<tr>
<td>3-dimensional cutter compensation</td>
<td>G41.2,G42.2,G41.3–G40</td>
</tr>
<tr>
<td>Tool axis compensation in tool axis direction</td>
<td>G43.1</td>
</tr>
<tr>
<td>Tool center point control</td>
<td>G43.4</td>
</tr>
<tr>
<td>Scaling</td>
<td>G51</td>
</tr>
<tr>
<td>Programmable mirror image</td>
<td>G51.1</td>
</tr>
<tr>
<td>Rotary table dynamic fixture offset</td>
<td>G54.2Pn</td>
</tr>
<tr>
<td>Coordinate system rotation</td>
<td>G68</td>
</tr>
<tr>
<td>3-dimensional coordinate conversion</td>
<td>G68</td>
</tr>
</tbody>
</table>

(The alarm (P/S5453) occur when the program is restart after reset is executed if the parameter D3R(No. 5400#2) = 1 in 3-dimensional coordinate system conversion mode. This alarm can be canceled by both <RESET> key and <CAN> key operations pushed at the same time.)

The alarm (P/S5000) occurs if, in any of the following modes, an attempt is made to issue a command that will cause the system to enter 5-axis control mode (tool center point control, tool axis compensation in tool axis direction, 3-dimensional cutter compensation, 3-dimensional circular interpolation, or a function expanded with bits 0 to 5 of parameter No. 19600 to be executed on a RISC processor).

- Advanced preview control
- AI contour control
- AI namo contour control

The limitation may be attached about the combination of the NC instructions occasionally. Refer the description of the each functions.
### The Function list which can be used

<table>
<thead>
<tr>
<th>Item</th>
<th>Specifications</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Axis control</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Controlled axes</td>
<td>3 axes</td>
<td></td>
</tr>
<tr>
<td>Controlled paths</td>
<td>1–path</td>
<td></td>
</tr>
<tr>
<td>Simultaneously controlled axes</td>
<td>2 axes</td>
<td></td>
</tr>
<tr>
<td>Controlled axis expansion</td>
<td>Up to 8 axes</td>
<td></td>
</tr>
<tr>
<td>Simultaneously controlled axis expansion</td>
<td>Up to 6 axes</td>
<td></td>
</tr>
<tr>
<td>Axis control by PMC</td>
<td></td>
<td>The axis which is used in the AI High Precision Contour Control mode or in the AI nano High Precision Contour Control mode can not be used as the control axis of the PMC Axis Control in the AI High Precision Contour Control mode or in the AI nano High Precision Contour Control mode</td>
</tr>
<tr>
<td>Cs contour control</td>
<td></td>
<td>The nano interpolation and the Advanced preview feed–forward function are canceled once when the command for Cs axis in AI high precision contour control mode or AI nano high precision contour control mode</td>
</tr>
<tr>
<td>Axis name</td>
<td>3 basic axes: X,Y,Z; Additional axes: U,V,W,A,B, or C</td>
<td></td>
</tr>
<tr>
<td>Twin table control</td>
<td></td>
<td>Synchronized operation/individual operation/a normal drive cannot be changed in the AI high precision contour control mode or in the AI nano high precision contour control mode Please include all the twin table control axes to the maximum control axis number (parameter No.7510) of RISC.</td>
</tr>
<tr>
<td>Simple synchronous control</td>
<td></td>
<td>Synchronized operation/individual operation/a normal drive cannot be changed in the AI high precision contour control mode or in the AI nano high precision contour control mode Please include all the simple synchronous control axes to the maximum control axis number (parameter No.7510) of RISC.</td>
</tr>
<tr>
<td>Least input increment</td>
<td>0.001mm,0.001deg,0.0001inch</td>
<td></td>
</tr>
<tr>
<td>Incremental System 1/10</td>
<td>0.0001mm,0.0001deg,0.00001inch</td>
<td></td>
</tr>
<tr>
<td>Inch/metric conversion</td>
<td></td>
<td>Inch mode / metric mode cannot be changed in the AI high precision contour control mode or in the AI nano high precision contour control mode.</td>
</tr>
<tr>
<td>Item</td>
<td>Specifications</td>
<td>Note</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-----------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Axis control</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interlock</td>
<td>All axes/each axis</td>
<td></td>
</tr>
<tr>
<td>Machine lock</td>
<td>All axes/each axis</td>
<td></td>
</tr>
<tr>
<td>Emergency stop</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stored stroke check 1</td>
<td></td>
<td>The stroke limit cannot be set by the stroke limit external setting signal in the AI high precision contour control mode or in the AI nano high precision contour control mode. Overrun on the OT limit does not occur in the AI high precision contour control mode or in the AI nano high precision contour control mode.</td>
</tr>
<tr>
<td>Stored stroke check 2</td>
<td></td>
<td>The AI high precision contour control mode or the AI nano high precision contour control mode is automatically canceled once and the buffering is inhibited if G22 or G23 is used in the AI high Precision Contour Control mode or in the AI high Precision Contour Control mode.</td>
</tr>
<tr>
<td>Mirror image</td>
<td></td>
<td>Do not change the state of the signal in the AI High Precision Contour Control mode or AI nano High Precision Contour Control mode.</td>
</tr>
<tr>
<td>Backlash compensation for each rapid traverse and cutting feed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Automatic operation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MDI operation</td>
<td></td>
<td>The AI high precision contour control mode or the AI nano high precision contour control mode is automatically canceled once and the buffering is inhibited if the MDI operation is used in the AI high Precision Contour Control mode or in the AI high Precision Contour Control mode. At this time, G05P10000 or G05P0 can not be used by the MDI operation.</td>
</tr>
<tr>
<td>Cycle start/Feed hold</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Program stop/Program end</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reset</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Program restart</td>
<td></td>
<td>Program restart function is performed with folowing functions: NURBS interpolation, and Cylindrical interpolation</td>
</tr>
<tr>
<td>Dry run</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single block</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Item</td>
<td>Specifications</td>
<td>Note</td>
</tr>
<tr>
<td>----------------------</td>
<td>----------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Interpolation functions</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Positioning</td>
<td>G00</td>
<td>The AI high precision contour control function or AI nano high precision contour control functions except the advanced preview feed-forward function, multi buffer function, and the nano interpolation become invalid.</td>
</tr>
<tr>
<td>Cutting mode</td>
<td>G64</td>
<td></td>
</tr>
<tr>
<td>Linear interpolation</td>
<td>G01</td>
<td></td>
</tr>
<tr>
<td>Circular interpolation</td>
<td>G02,G03</td>
<td></td>
</tr>
<tr>
<td>Helical interpolation</td>
<td>(Circular interpolation) + (Linear interpolation for up to 2 axes)</td>
<td></td>
</tr>
<tr>
<td>Helical interpolation B</td>
<td>(Circular interpolation) + (Linear interpolation for up to 4 axes)</td>
<td></td>
</tr>
<tr>
<td>Involute interpolation</td>
<td>G02.2,G03.2</td>
<td></td>
</tr>
<tr>
<td>3–dimensional circular interpolation</td>
<td>G02.4,G03.4</td>
<td>The position is checked at the end point of the block which cancel 3 dimensional circular interpolation or at the end point of the previous block of the 3 dimensional circular interpolation if 3 dimensional circular interpolation is used except in AI high precision contour control mode or AI nano high precision contour control mode.</td>
</tr>
<tr>
<td>Smooth interpolation</td>
<td>G05.1</td>
<td>This function can be used in AI high precision contour control mode or AI nano high precision contour control mode.</td>
</tr>
<tr>
<td>NURBS interpolation</td>
<td>G06.2</td>
<td>This function can be used in AI high precision contour control mode or AI nano high precision contour control mode.</td>
</tr>
<tr>
<td>Cylindrical interpolation</td>
<td>G07.1</td>
<td>This function can be used in AI high precision contour control mode or AI nano high precision contour control mode.</td>
</tr>
<tr>
<td>Cylindrical interpolation cutting point control</td>
<td>G07.1</td>
<td>This function can be used in AI high precision contour control mode or AI nano high precision contour control mode.</td>
</tr>
<tr>
<td>Conical / spiral interpolation</td>
<td>G02,G03</td>
<td></td>
</tr>
<tr>
<td><strong>Feed functions</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feed per minute</td>
<td>G94</td>
<td></td>
</tr>
<tr>
<td>Cutting feedrate clamp</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linear acceleration/deceleration of cutting feed after interpolation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Item</td>
<td>Specifications</td>
<td>Note</td>
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<tr>
<td>Feed functions</td>
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</tr>
<tr>
<td>Bell–type acceleration/deceleration of cutting feed after interpolation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feedrate override</td>
<td>0 to 254% (1% step)</td>
<td></td>
</tr>
<tr>
<td>2nd. Feedrate override</td>
<td>0 to 254% (1% step)</td>
<td></td>
</tr>
<tr>
<td>F1 digit feed</td>
<td></td>
<td>Using the manual pulse generator can not change Feedrate.</td>
</tr>
<tr>
<td>Inverse time feed</td>
<td>G93</td>
<td></td>
</tr>
<tr>
<td>Look–ahead liner–type acceleration/deceleration before interpolation.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Look–ahead bell–type acceleration/deceleration before interpolation.</td>
<td>Acceleration change time constant type</td>
<td></td>
</tr>
<tr>
<td>AI high–precision contour control</td>
<td></td>
<td>AI high precision contour control mode or the AI nano high precision contour control mode is automatically canceled once and the buffering is inhibited if this function is used in the AI high Precision Contour Control mode.</td>
</tr>
<tr>
<td>AI nano high–precision contour control</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Program input</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tape code</td>
<td>Automatic recognition of EIA/ISO</td>
<td></td>
</tr>
<tr>
<td>Program format</td>
<td>Word address format</td>
<td></td>
</tr>
<tr>
<td>Control in/out</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Optional block skip</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Absolute/incremental programming</td>
<td>G90/G91</td>
<td></td>
</tr>
<tr>
<td>Input unit 10 time multiply</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plane selection</td>
<td>G17,G18,G19</td>
<td></td>
</tr>
<tr>
<td>Rotary axis roll over</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Workpiece coordinate system selection</td>
<td>G54 to G59</td>
<td>The AI high precision contour control mode or the AI nano high precision contour control mode is automatically canceled once and the buffering is inhibited if this function is used in the AI high Precision Contour Control mode or in the AI high Precision Contour Control mode.</td>
</tr>
<tr>
<td>Addition of workpiece coordinate system pair</td>
<td>48 sets / 300 sets</td>
<td>The AI high precision contour control mode or the AI nano high precision contour control mode is automatically canceled once and the buffering is inhibited if this function is used in the AI high Precision Contour Control mode or in the AI high Precision Contour Control mode.</td>
</tr>
<tr>
<td>Manual absolute ON/OFF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Item</td>
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<td>Note</td>
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</tr>
<tr>
<td>Programmable parameter input</td>
<td>G10</td>
<td>The AI high precision contour control mode or the AI nano high precision contour control mode is automatically canceled once and the buffering is inhibited if this function is used in the AI high Precision Contour Control mode or in the AI high Precision Contour Control mode.</td>
</tr>
<tr>
<td>External memory and sub program calling function</td>
<td>M198</td>
<td></td>
</tr>
<tr>
<td>Subprogram call</td>
<td>M98</td>
<td></td>
</tr>
<tr>
<td>Circular interpolation by R programming</td>
<td>G50,G51</td>
<td>The mode of AI high precision contour control or of AI nano high precision contour control is permitted to change ON and OFF in scaling mode by setting the parameter. The alarm (P/S5012) occurs if the mode of AI high precision contour control or of AI nano high precision contour control is changed in scaling mode (G51) when the parameter is not set. The scaling mirror image by a negative magnification can not be done.</td>
</tr>
<tr>
<td>Coordinate system rotation</td>
<td>G68,G69</td>
<td>The mode of AI high precision contour control or of AI nano high precision contour control is permitted to change ON and OFF in coordinate system rotation mode by setting the parameter. The alarm (P/S5012) occurs if the mode of AI high precision contour control or of AI nano high precision contour control is changed in coordinate system rotation mode (G51) when the parameter is not set.</td>
</tr>
<tr>
<td>3–dimensional coordinate system conversion</td>
<td>G68,G69</td>
<td>The mode of AI high precision contour control or of AI nano high precision contour control is permitted to change ON and OFF in 3–dimensional coordinate system conversion mode by setting the parameter. The alarm (P/S5012) occurs if the mode of AI high precision contour control or of AI nano high precision contour control is changed in 3–dimensional coordinate system conversion when the parameter is not set.</td>
</tr>
<tr>
<td>Item</td>
<td>Specifications</td>
<td>Note</td>
</tr>
<tr>
<td>----------------------</td>
<td>-------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------</td>
</tr>
<tr>
<td>Miscellaneous/spindle functions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Miscellaneous function</td>
<td>The AI high precision contour control mode or the AI nano high precision contour control mode is automatically canceled once and the buffering is inhibited if this function is used in the AI high Precision Contour Control mode or in the AI high Precision Contour Control mode.</td>
<td></td>
</tr>
<tr>
<td>2nd. Auxiliary function</td>
<td>The AI high precision contour control mode or the AI nano high precision contour control mode is automatically canceled once and the buffering is inhibited if this function is used in the AI high Precision Contour Control mode or in the AI high Precision Contour Control mode.</td>
<td></td>
</tr>
<tr>
<td>1 block plural M commands</td>
<td>The AI high precision contour control mode or the AI nano high precision contour control mode is automatically canceled once and the buffering is inhibited if this function is used in the AI high Precision Contour Control mode or in the AI high Precision Contour Control mode.</td>
<td>It is possible to command up to 3.</td>
</tr>
<tr>
<td>Spindle speed function</td>
<td>The AI high precision contour control mode or the AI nano high precision contour control mode is automatically canceled once and the buffering is inhibited if this function is used in the AI high Precision Contour Control mode or in the AI high Precision Contour Control mode.</td>
<td></td>
</tr>
<tr>
<td>Tool functions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tool function (T8-digit)</td>
<td>The AI high precision contour control mode or the AI nano high precision contour control mode is automatically canceled once and the buffering is inhibited if this function is used in the AI high Precision Contour Control mode or in the AI high Precision Contour Control mode.</td>
<td></td>
</tr>
<tr>
<td>Tool length compensation</td>
<td>G43</td>
<td></td>
</tr>
<tr>
<td>Cutter compensation</td>
<td>G38,G39,G40,G41,G42</td>
<td>The buffering is inhibited when the command which automatically cancels AI high precision contour control mode or AI nano high precision contour control mode is used. So the tool offset vector is held.</td>
</tr>
<tr>
<td>Item</td>
<td>Specifications</td>
<td>Note</td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>----------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>3–dimensional tool compensation</td>
<td>G41.2,G42.2</td>
<td>The command which automatically cancel AI high precision contour control mode or AI nano high precision contour control mode can not be used. However M,S,T and B command can be used without the command that move some axes. In this case, the offset vector is held because the buffering is inhibited.</td>
</tr>
<tr>
<td></td>
<td>G41.3</td>
<td></td>
</tr>
<tr>
<td>Tool axis direction tool length compensation</td>
<td>G43.1</td>
<td>The command which automatically cancel AI high precision contour control mode or AI nano high precision contour control mode can not be used. However M,S,T and B command can be used without the command that move some axes. In this case, the offset vector is held because the buffering is inhibited.</td>
</tr>
<tr>
<td>Tool center point control</td>
<td>G43.4,G43.5</td>
<td>The command which automatically cancel AI high precision contour control mode or AI nano high precision contour control mode can not be used. However M,S,T and B command can be used without the command that move some axes. In this case, the offset vector is held because the buffering is inhibited.</td>
</tr>
<tr>
<td>Rotary table dynamic fixture offset</td>
<td>G54.2</td>
<td>The mode of AI high precision contour control or of AI nano high precision contour control is permitted to change ON and OFF in rotary table dynamic fixture offset mode by setting the parameter. The alarm (P/S5012) occurs if the mode of AI high precision contour control or of AI nano high precision contour control is changed in rotary table dynamic fixture offset mode when the parameter is not set.</td>
</tr>
</tbody>
</table>
22.1
AI HIGH PRECISION
CONTOUR CONTROL/
AI NANO HIGH
PRECISION CONTOUR
CONTROL

General

This function is designed to achieve high–speed, high–precision machining with a program involving a sequence of very small straight lines and NURBS curved lines, like those used for metal die machining. This function can suppress the servo system delay and delay caused by acceleration/deceleration that increase as a higher feedrate is used.

This function can be used to ensure that the tool strictly traces the specified values, thus minimizing machining profile errors and achieving high–speed, high–precision machining.

HPCC stands for high precision contour control. In AI High Precision Contour Control mode, acceleration/deceleration is performed more precisely than in the conventional HPCC mode, resulting in an increase in the cutting speed.

AI Nano High Precision Contour Control can use the Nano interpolation with all functions of AI High Precision Contour Control. The output from the NC to the servo is usually in units of detection units. This function allows output to the servo in units of thousandths of detection units, thereby improving machining precision. This is particularly effective for improving the surface roughness.

Note that the positioning precision depends on the machine conditions, such as the resolution of the detector.

AI Nano High Precision Contour Control is the same as a AI High Precision Contour Control excluding being able to use the Nano interpolation.

In the following explanations, only AI High Precision Contour Control is described.

Format

The following command turns AI high precision contour control mode on and off.

In AI high precision contour control mode, "AI HPCC" flashes at the lower right corner of the screen.

In AI nano high precision contour control mode, "NANO HP" flashes.

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>G05 P10000</td>
<td>AI High Precision Contour Control mode on</td>
</tr>
<tr>
<td>G05 P0</td>
<td>AI High Precision Contour Control mode off</td>
</tr>
</tbody>
</table>

Specify G05 alone in a block.

Functions enabled

In AI High Precision Contour Control mode, the following functions are enabled:

Thus, this function can be used to ensure that the tool strictly traces the specified values, thus minimizing machining profile errors for higher–speed, higher–precision machining.
(1) Linear acceleration/deceleration before interpolation or bell–shaped
acceleration/deceleration before interpolation
(Acceleration change time constant type)
(2) Deceleration function based on feedrate differences at corners
(3) Advanced feed–forward function
(4) Feedrate determination based on acceleration on each axis
(5) Deceleration function based on Z–axis fall angle
(6) 200–block multi–buffer function

22.1.1
Look–ahead Acceleration/Deceleration Before Interpolation

Acceleration/deceleration types
There are two types of acceleration/deceleration, the linear acceleration/deceleration type and the bell–shaped acceleration/deceleration type. When bit 7(BDO) and bit 1(NBL) of parameter No.8402 is set to 1 or bit 3(RSB) of parameter No.1603 is set to 1, bell–shaped acceleration/deceleration is assumed. Bell–shaped acceleration/deceleration produces smoother acceleration/deceleration.

Look–ahead linear acceleration/deceleration before interpolation

• Example of deceleration
Deceleration starts in advance so that the feedrate specified for a block can be attained when the block is executed.

To decrease the feedrate from F3 to F2, deceleration must be started from P1.
To decrease the feedrate from F2 to F1, deceleration must be started from P2.
Because multiple blocks are read in advance, deceleration can be performed over all those blocks.
- **Example of acceleration**

Acceleration is performed so that the feedrate specified for a block is attained when the block is executed.

![Graph showing programmed speed and feedrate obtained by acceleration/deceleration before interpolation](image)

- **Look-ahead bell-shaped acceleration/deceleration before interpolation**

If “1” is set to bit 7(BDO) and bit 1(NBL) of parameter No.8402 or bit 3(RSB) of parameter No.1603, bell-shaped acceleration/deceleration is applied as the acceleration/deceleration before interpolation.

- **Setting an acceleration**

A permissible acceleration for the linear acceleration/deceleration of each axis is set in parameter 19510. Acceleration change time (B) (period of transition from constant speed state (A) to constant acceleration/deceleration state (C)) is set in parameter 8416 (common to all axes). In the constant acceleration/deceleration state (C), acceleration/deceleration is performed with the maximum tangential acceleration not exceeding the permissible acceleration of each axis specified in parameter 19510. The acceleration change time specified in parameter 8416 is held constant, regardless of the tangential acceleration.

![Graph showing tangential feedrate and time set in parameter 8416](image)
• Method of determining the tangent acceleration

Acceleration/deceleration is performed with the largest tangent acceleration/deceleration that does not exceed the acceleration set for each axis.

(Example)
X–axis permissible acceleration: 1000 mm/sec²
Y–axis permissible acceleration: 1200 mm/sec²
Acceleration change time: 20 msec

Program:
G04 X0.01
G04 X0.01

The acceleration in N3 is 1414 mm/sec². At this point, the acceleration on the X–axis is equal to the set value (1000 mm/sec²).

• Acceleration

Acceleration is performed so that the feedrate programmed for a block is attained at the beginning of the block.
- **Deceleration**

Deceleration starts in advance so that the feedrate programmed for a block is attained at the beginning of the block. Deceleration can be performed over several blocks.

![Deceleration Diagram](image)

- **Deceleration based on a distance**

If the total distance of the blocks read ahead becomes shorter than or equal to the deceleration distance obtained from the current feedrate, deceleration starts.

If the total distance of the blocks read ahead during deceleration increases, acceleration is performed.

If the blocks of a small amount of travel are successively specified, deceleration and acceleration may be performed alternately, making the feedrate inconsistent. To avoid this, decrease the programmed feedrate.

- **Single–block commands during look–ahead bell–shaped acceleration/deceleration before interpolation control**

If a single–block command is executed during look–ahead bell–shaped acceleration/deceleration control, the following control is applied.

1. If acceleration/deceleration is performed when the single–block command is executed
   - (a) If $A + B \leq \text{Remaining amount of travel in the block executed when the single–block command is executed}$
     Deceleration is performed for a stop so that the feedrate falls to zero at the point at which the block executed when the single–block command was executed terminates.

![Single-block Command Diagram](image)

A: Amount of travel to a point where the target feedrate is attained and the current acceleration/deceleration ends

B: Amount of travel corresponding to deceleration from the feedrate attained at the end of acceleration/deceleration to 0
(b) If $A + B > \text{Remaining amount of travel in the block being executed when the single-block command is executed}$

A stop state may continue over several blocks.

The stop is made as described later.

A: Amount of travel to a point where the target feedrate is attained and the current acceleration/deceleration ends

B: Amount of travel corresponding to deceleration from the feedrate attained at the end of acceleration/deceleration to 0

(2) If acceleration/deceleration is not performed when the single-block command is executed

(a) $A \leq \text{Remaining amount of travel in the block being executed when the single-block command is executed}$

Movement is decelerated and stopped so that the feedrate falls to zero at the end of the block which was being executed when the single-block command was executed.

A: Amount of travel corresponding to deceleration from the current feedrate to 0
(b) If \( A > \) Remaining amount of travel in the block being executed when the single–block command is executed
A stop state may continue over several blocks.
The stop is made as described later.

\[ A : \text{Amount of travel corresponding to deceleration from the current feedrate to 0} \]

(3) Stopping a movement if the stop may continue over several blocks
Acceleration/deceleration is performed over several blocks to decrease the feedrate to zero.

22.1.2 Automatic Feedrate Control Function

In AI High Precision Contour Control mode, the feedrate is automatically controlled by the reading–ahead of blocks.
The feedrate is determined using the following conditions. If the specified feedrate exceeds the determined feedrate, acceleration/ deceleration before interpolation is performed to achieve the determined feedrate.

(1) Feedrate changes on each axis at a corner and the permissible feedrate change that has been set
(2) Expected acceleration on each axis and the permissible acceleration that has been set
(3) Cutting load that is expected from the travel direction on the Z-axis

The machining error is decreased because of the deceleration by difference in feedrate.

The machining error is decreased because of the deceleration with the acceleration.

Fig. 22.1.2 (a)

To enable this function, set the desired values for the following parameters:

Parameter No. 8410:
Permissible feedrate difference used when the feedrate is to be determined from the feedrate difference at a corner

Parameter No. 8470:
Permissible acceleration when the feedrate is to be determined from the acceleration

For details, see the explanation of these parameters.

• Feedrate control conditions

In automatic feedrate control mode, the feedrate is controlled as described below:

(a) From the feedrate difference on each axis at a corner, the feedrate in the corner is determined, and deceleration is performed to achieve the feedrate at the corner.

(Example)

(b) From the acceleration on each axis at the corners at the start and end points of each block, the feedrate in the block is determined, and deceleration is performed so that the feedrate in the block is equal to or less than the determined feedrate.

(Example)
(c) During descent on the Z-axis, the cutting load increases, and override is applied according to the Z-axis descent angle.

Deceleration based on the feedrate difference at a corner

With look-ahead acceleration/deceleration before interpolation, the tangent feedrate is changed smoothly. Thus, no path error occurs due to acceleration/deceleration delay. With this acceleration/declaration, however, acceleration/deceleration is not performed for any feedrate change on any axis that may be made where the travel direction changes. By using the function for deceleration based on the feedrate difference at a corner, if a feedrate change occurs on an axis at a corner, the feedrate is determined so that any feedrate difference exceeding the permissible feedrate difference on that axis that has been set for parameter No. 8410 does not occur, and deceleration is automatically performed.
Program
N1 G01 G91 X100. F5000
N2 Y100.

The deceleration based on the feedrate difference is used.

Tangent feedrate

X-axis feedrate

The tangent feedrate is smooth, but the feedrate on each axis is not.

Y-axis feedrate

The feedrate difference becomes small, and the feedrate on each axis becomes smooth.

The method of deceleration based on the feedrate difference differs depending on the setting made for parameter FNW (bit 6 of No. 19500). If “0” is set, the largest feedrate that does not exceed the permissible feedrate difference set for parameter No. 8410 is assumed to be the deceleration feedrate. In this case, the deceleration feedrate differs if the travel direction differs, even if the shape is the same.
Deceleration to 500 mm/min

Deceleration to 354 mm/min

If “1” is set, the feedrate is determined not only with the condition that the permissible feedrate difference and permissible acceleration on each axis are not exceeded, but also that the deceleration feedrate is constant regardless of the travel direction if the shape is the same.

If 1 is set for this parameter, the deceleration feedrate determined with the feedrate difference or acceleration may be up to 30% lower than that determined if 0 is set.

Example of determining the feedrate with the acceleration on each axis

When consecutive small lines are used to form a curve, as in the example shown in the figure below, the feedrate differences on each axis at the individual corners are not very large. Thus, deceleration with the feedrate differences is not effective. Consecutive small feedrate differences, however, cause a large acceleration on each axis, as a whole.

In such a case, deceleration can be performed to reduce the impact on the machine and the machining error caused by too large an acceleration. The deceleration feedrate is determined to be the feedrate that does not cause the acceleration on each axis to exceed the permissible acceleration set for parameter No. 8470.

The deceleration feedrate is determined for each corner. The actual feedrate is the smaller of the deceleration feedrate determined at the start point of the block and that determined at the end point.

Example

In the following example, the acceleration (gradient of the broken line in the feedrate graph) at too large at corners N2 to N4 and N6 to N8 and, therefore, deceleration is performed.
The method of determining the feedrate with the acceleration differs depending on the setting of parameter FNW (bit 6 of No. 19500). If “0” is set, the highest feedrate that does not cause the permissible acceleration set for parameter No. 8470 to be exceeded is assumed to be the deceleration feedrate. In this case, the deceleration feedrate differs depending on the travel direction even if the shape is the same, as shown in the figure below.

(Example) If a circular shape with a radius of 10 mm is specified with small line blocks
Parameter FNW (bit 6 of No. 19500) = 0
Permissible acceleration = 1000 mm/s² (on all axes)

The feedrate is higher in these directions.
If “1” is set, the feedrate is determined with not only the condition that the permissible acceleration on each axis is not exceeded but also the condition that the deceleration feedrate is constant regardless of the travel direction if the shape is the same.

If 1 is set for this parameter, the deceleration feedrate determined with the feedrate difference or acceleration may be up to 30% lower than that determined if 0 is set.

The tangent feedrate is constant.

**NOTE**

In circular interpolation, the tangent feedrate is constant regardless of the setting of the parameter.

**Example of determining the feedrate with the cutting load**

This function is enabled when parameter ZAG (bit 4 of No. 8451) is set to 1.
Usually, the cutting resistance is higher when machining is performed with the bottom of the cutter, as shown in Fig. 22.1.2 (c), and when machining is performed with the side of the cutter, as shown in Fig. 22.1.2 (d). Deceleration is, therefore, required. In AI High Precision Countour Control, the tool travel direction on the Z-axis is used as a condition for calculating the machining feedrate.

The descent angle during descent on the Z-axis (angle formed by the XY plane and the tool center path) is as shown in Fig. 22.1.2 (d). The descent angle is divided into four areas, and the override values for the individual areas are set for the following parameters:

- Parameter No. 8456 for area 2
- Parameter No. 8457 for area 3
- Parameter No. 8458 for area 4

For area 1, however, no parameter is available, and an override of 100% is used at all times. The feedrate obtained according to other feedrate control is multiplied by the override value of the area to which descent angle belongs.

- Area 1: $0^\circ \leq \theta < 30^\circ$
- Area 2: $30^\circ \leq \theta < 45^\circ$
- Area 3: $45^\circ \leq \theta < 60^\circ$
- Area 4: $60^\circ \leq \theta \leq 90^\circ$
CAUTION
1 The function for determining the feedrate with the cutting feed is effective only when the tool is parallel with the Z-axis. Thus, it may not be possible to apply this function, depending on the structure of the machine used.
2 In the function for determining the feedrate with the cutting feed, the travel direction on the Z-axis is determined with the appropriate NC command. If, therefore, manual intervention is performed on the Z-axis with manual absolute on, or if a mirror image is applied on the Z-axis, the direction on the Z-axis cannot be determined. When using the function for determining the feedrate with the cutting load, do not use these functions.
3 When performing three–dimensional coordinate conversion, determine the descent angle on the Z-axis using the converted coordinate system.

Ignoring F code commands

In a block in which automatic feedrate control is enabled, all feed commands (F commands) can be ignored by setting parameter NOF (bit 7 of No. 8451). The term feed commands, as used here, refer to the following commands:

(1) Modal F commands before the block in which automatic feedrate control is enabled
(2) F commands and modal F commands in the block in which automatic feedrate control is enabled

When the F commands are ignored, it is assumed that the upper feedrate limit specified for parameter No. 8465 is specified.

Note, however, that any issued F commands and modal F commands are stored within the CNC.

Thus, in a block in which automatic feedrate control changes from the enabled state to the disabled state, the modal values of the F commands described in 1 and 2 described above are used as modal F commands, instead of the modal values of the F commands calculated by automatic feedrate control.

Override to a determined feedrate

The following gives the specifications of override to a feedrate determined by functions such as deceleration based on feedrate difference in look–ahead acceleration/deceleration before interpolation and deceleration based on acceleration rate in AI High Precision Countour Control.

– When bit 3 (OVR) of parameter No. 8459 = 0
  The conventional specifications apply.
  Override is invalid for deceleration functions such as deceleration based on feedrate difference and deceleration based on acceleration rate.

– When bit 3 (OVR) of parameter No. 8459 = 1
  Override is valid for deceleration functions such as deceleration based on feedrate difference and deceleration based on acceleration rate.
When bit 3 (OVR) of parameter No. 8459 is 1, the following feedrates can be overridden:

- Feedrate decelerated by deceleration based on feedrate difference in look-ahead acceleration/deceleration before interpolation
- Feedrate decelerated by deceleration based on acceleration rate in AI High Precision Contour Control.
- Feedrate decelerated by deceleration based on acceleration rate in circular interpolation
- Feedrate decelerated by acceleration clamp in involute interpolation
- Minimum feedrate for deceleration based on acceleration rate in AI High Precision Contour Control and circular interpolation
- Maximum feedrate of AI High Precision Contour Control.

Even when the feedrate is overridden, the resulting feedrate does not exceed the maximum cutting feedrate (parameter No. 1422 or No. 1430 or No. 1432).

**Another example of determining the feedrate**

If the calculated feedrate exceeds either the upper limit (parameter No. 8465) for automatic feedrate control that is set for the appropriate parameter or the feedrate specified with an F command, clamping is performed with the smaller of the upper limit feedrate and the feedrate specified with the F command.

If the feedrate calculated by the deceleration function based on the acceleration is smaller than the lower feedrate limit for the deceleration function based on the acceleration of AI High Precision Contour Control set for parameter No. 19511, the lower feedrate limit is used for the feedrate. If, however, the specified feedrate is smaller than the lower feedrate limit, the specified feedrate is used.

**Miscellaneous**

In AI high precision contour control mode or in AI nano high precision contour control mode, 3-dimensional coordinate conversion, coordinate system rotation, scaling, and rotary table dynamic fixture offset can be executed.

In the mode of each of the 3-dimensional coordinate conversion, coordinate system rotation, scaling, and rotary table dynamic fixture offset functions, AI high precision contour control mode or AI nano high precision contour control mode can be turned on and off with the appropriate parameter settings.

**22.1.3 Restrictions**

For the function which can be used and limitations in the AI High Precision Contour Control mode or in the AI NANO High Precision Contour Control mode, refer to the “Function List which can be used” and “Restrictions”.

- **Restriction–1**

  The following functions can be used but the state cannot be changed in the AI High Precision Contour Control mode or in the AI NANO High Precision Contour Control mode.

  - Inch/metric conversion (An alarm(P/S5000) is issued if the state is changed by G20 or G21)
• Mirror image (Do not change the state of the signal).
• F1 digit feed (Feedrate can not be changed by using the manual pulse generator.)

• **Restriction –2**

The AI High Precision Contour Control mode or the AI Nano high Precision Contour Control mode is automatically canceled once and the buffering is inhibited if the following function is used in the AI High Precision Contour Control mode or in the AI High Precision Contour Control mode.

- MDI operation
- Workpiece coordinate system selection (G54 to G59)
- Programmable parameter input (G10)
- Miscellaneous function
- 2nd. Auxiliary function
- 1 block plural M commands
- Spindle speed function
- Tool function
- Fixed cycle (G73,G74,G76,G80 to G89,G98,G99)
  (Set the parameter (No.5200#0=1) which an M code specifying the rigid tapping mode is not used if the rigid tapping is used)

• **Restriction –3**

The following commands can not be used in the AI High Precision Contour Control mode or AI NANO High Precision Contour Control mode. The alarm is issued if the function was used.

- Custom macro
- Exponential interpolation –G02.3,G03.3
- Dwell –G04
- High Speed Cutting Function relation –G05
  (G05P10000 and G05P0 are excluded)
- AI contour control –G05.1Q1,G5.1Q0
- Hypothetical axis interpolation –G07
- Advanced preview control –G08
  (Please use AI High Precision Contour Control)
- Polar coordinate interpolation –G12.1,G13.1
- Polar coordinate command –G15,G16
- Reference position return check –G27
- Reference point return –G28
- 2nd. Reference point return –G30
- 3rd/4th reference point return –G30
- Skip –G31
- Thread cutting –G33
- Automatic tool length measurement –G37
- Normal direction control –G40.1,G41.1,G42.1
- Cutter compensation B –G41,G42,G39
  (Cutter compensation C is available)
• 3-dimensional tool compensation – G41
• Wheel wear compensation – G41
• Tool offset – G45,G46,G47,G48
• Local coordinate system – G52
• Machine coordinate system – G53
• Single direction positioning – G60
• Automatic corner override – G62
• Tapping mode – G63
• Macro call – G65,G66,G67

(SubProgram call is available)

• Figure copying – G72.1,G72.2
• Simple electric gear box – G80,G81
• Functions for hobbing machine – G80,G81
• External operation function – G81
• Chopping function – G81.1
• Setting a workpiece coordinate system – G92
• Workpiece coordinate system preset – G92.1
• Feed per revolution – G95
• Constant surface speed control – G96,G97
• Infeed control – G160,G161

• Restriction – 4

The following functions can not be used in the AI High Precision Contour Control mode or AI NANO High Precision Contour Control mode.

• Flexible synchronous control
• Sequence number comparison and stop
  It is not possible to stop by the sequence number in the AI High Precision Contour Control mode or in the AI Nano High Precision Contour Control mode.
• Index table indexing
• Retrace function
  Do not use retrace function in the program which uses the AI High Precision Contour Control mode or the AI Nano High Precision Contour Control.
• Rotary axis control
• Gentle curve normal direction control
• Tool life management
  Tool life value is counted in the AI High Precision Contour Control mode or in the AI Nano AI High Precision Contour Control mode. However, do not use the command related to the tool life management function.
• Macro executor (Execution macro)
• Manual handle interruption

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• **Restriction –5**
  When the following function is used, a AI High Precision Contour Control and the AI Nano High Precision Contour Control cannot be used.
  • Angular axis control
  • Arbitrary angular axis control

• **Restriction –6**
  The limitation may be attached about the combination of the NC instructions occasionally.
  Refer the description of the each functions.

**NOTE**
1. If the permissible acceleration set for one axis is two or more times greater than that set for another, the feedrate may decrease temporarily at those corners where the travel direction changes abruptly.
2. If the machine lock signal is turned on during travel in look–ahead acceleration/deceleration before interpolation mode, the machine enters the machine lock state after the end of deceleration.
3. If there is a block with no travel or a one–shot G code command such as G04 in look–ahead acceleration/deceleration before interpolation mode, deceleration is performed for a stop in the preceding block.
4. If the dry run signal changes from “0” to “1” or from “1” to “0” during travel on an axis, acceleration/deceleration is performed to achieve the prescribed feedrate without deceleration to feedrate 0.
   The function for deceleration with the feedrate difference at a corner is effective even during dry run.

### 22.1.4
**The Function List which Can be Used**

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<thead>
<tr>
<th>Item</th>
<th>Specifications</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controlled axes</td>
<td>3 axes</td>
<td></td>
</tr>
<tr>
<td>Controlled paths</td>
<td>1–path</td>
<td></td>
</tr>
<tr>
<td>Simultaneously controlled axes</td>
<td>2 axes</td>
<td></td>
</tr>
<tr>
<td>Controlled axis expansion</td>
<td>Up to 8 axes</td>
<td></td>
</tr>
<tr>
<td>Simultaneously controlled axis expansion</td>
<td>Up to 6 axes</td>
<td></td>
</tr>
<tr>
<td>Item</td>
<td>Specifications</td>
<td>Note</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Axis control</strong></td>
<td></td>
<td><strong>Axis control by PMC</strong>&lt;br&gt;The axis which is used in the AI High Precision Contour Control mode or in the AI nano High Precision Contour Control mode cannot be used as the control axis of the PMC Axis Control in the AI High Precision Contour Control mode or in the AI nano High Precision Contour Control mode</td>
</tr>
<tr>
<td>Cs contour control</td>
<td></td>
<td>The nano interpolation and the Advanced preview feed–forward function are canceled once when the command for Cs axis in AI high precision contour control mode or AI nano high precision contour control mode</td>
</tr>
<tr>
<td>Axis name</td>
<td>3 basic axes: X,Y,Z; Additional axes: U,V,W,A,B, or C</td>
<td></td>
</tr>
<tr>
<td>Twin table control</td>
<td></td>
<td><strong>Twin table control</strong>&lt;br&gt;Synchronized operation/individual operation/a normal drive cannot be changed in the AI high precision contour control mode or in the AI nano high precision contour control mode. Please include all the twin table control axes to the maximum control axis number (parameter No.7510) of RISC.</td>
</tr>
<tr>
<td>Simple synchronous control</td>
<td></td>
<td><strong>Simple synchronous control</strong>&lt;br&gt;Synchronized operation/individual operation/a normal drive cannot be changed in the AI high precision contour control mode or in the AI nano high precision contour control mode. Please include all the simple synchronous control axes to the maximum control axis number (parameter No.7510) of RISC.</td>
</tr>
<tr>
<td>Least input increment</td>
<td>0.001mm,0.001deg,0.0001inch</td>
<td><strong>Least input increment</strong></td>
</tr>
<tr>
<td>Incremental System 1/10</td>
<td>0.0001mm,0.0001deg,0.00001inch</td>
<td><strong>Incremental System 1/10</strong></td>
</tr>
<tr>
<td>Inch/metric conversion</td>
<td></td>
<td><strong>Inch/metric conversion</strong>&lt;br&gt;Inch mode / metric mode cannot be changed in the AI high precision contour control mode or in the AI nano high precision contour control mode.</td>
</tr>
<tr>
<td>Interlock</td>
<td>All axes/each axis</td>
<td><strong>Interlock</strong></td>
</tr>
<tr>
<td>Machine lock</td>
<td>All axes/each axis</td>
<td><strong>Machine lock</strong></td>
</tr>
<tr>
<td>Emergency stop</td>
<td></td>
<td><strong>Emergency stop</strong></td>
</tr>
<tr>
<td>Stored stroke check 1</td>
<td></td>
<td><strong>Stored stroke check 1</strong>&lt;br&gt;The stroke limit cannot be set by the stroke limit external setting signal in the AI high precision contour control mode or in the AI nano high precision contour control mode. Overrun on the OT limit does not occur in the AI high precision contour control mode or in the AI nano high precision contour control mode.</td>
</tr>
</tbody>
</table>

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### Axis control

<table>
<thead>
<tr>
<th>Item</th>
<th>Specifications</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stored stroke check 2</td>
<td></td>
<td>The AI high precision contour control mode or the AI nano high precision contour control mode is automatically canceled once and the buffering is inhibited if G22 or G23 is used in the AI high Precision Contour Control mode, or in the AI high Precision Contour Control mode.</td>
</tr>
<tr>
<td>Mirror image</td>
<td></td>
<td>Do not change the state of the signal in the AI High Precision Contour Control mode or AI nano High Precision Contour Control mode.</td>
</tr>
<tr>
<td>Backlash compensation for each rapid traverse and cutting feed</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Operation

<table>
<thead>
<tr>
<th>Item</th>
<th>Specifications</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automatic operation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MDI operation</td>
<td></td>
<td>The AI high precision contour control mode or the AI nano high precision contour control mode is automatically canceled once and the buffering is inhibited if the MDI operation is used in the AI high Precision Contour Control mode or in the AI high Precision Contour Control mode. At this time, G05P10000 or G05P0 can not be used by the MDI operation.</td>
</tr>
<tr>
<td>Cycle start/Feed hold</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Program stop/Program end</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reset</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Program restart</td>
<td></td>
<td>Program restart function can not be used in NURBS interpolation, smooth interpolation, and cylindrical interpolation.</td>
</tr>
<tr>
<td>Dry run</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single block</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Interpolation functions

<table>
<thead>
<tr>
<th>Item</th>
<th>Specifications</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positioning</td>
<td>G00</td>
<td>The AI high precision contour control function or AI nano high precision contour control functions except the advanced preview feed–forward function, multi buffer function, and the nano interpolation become invalid.</td>
</tr>
<tr>
<td>Exact stop mode</td>
<td>G61</td>
<td></td>
</tr>
<tr>
<td>Exact stop</td>
<td>G09</td>
<td></td>
</tr>
<tr>
<td>Cutting mode</td>
<td>G64</td>
<td></td>
</tr>
</tbody>
</table>
### Interpolation functions

<table>
<thead>
<tr>
<th>Item</th>
<th>Specifications</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear interpolation</td>
<td>G01</td>
<td></td>
</tr>
<tr>
<td>Circular interpolation</td>
<td>G02,G03</td>
<td></td>
</tr>
<tr>
<td>Helical interpolation</td>
<td>(Circular interpolation) + (Linear interpolation for up to 2 axes)</td>
<td></td>
</tr>
<tr>
<td>Helical interpolation B</td>
<td>(Circular interpolation) + (Linear interpolation for up to 4 axes)</td>
<td></td>
</tr>
<tr>
<td>Involute interpolation</td>
<td>G02.2,G03.2</td>
<td></td>
</tr>
<tr>
<td>3–dimensional circular interpolation</td>
<td>G02.4,G03.4</td>
<td>The position is checked at the end point of the block which cancel 3 dimensional circular interpolation or at the end point of the previous block of the 3 dimensional circular interpolation if 3 dimensional circular interpolation is used except in AI high precision contour control mode or AI nano high precision contour control mode.</td>
</tr>
<tr>
<td>Smooth interpolation</td>
<td>G05.1</td>
<td>This function can be used in AI high precision contour control mode or AI nano high precision contour control mode.</td>
</tr>
<tr>
<td>NURBS interpolation</td>
<td>G06.2</td>
<td>This function can be used in AI high precision contour control mode or AI nano high precision contour control mode.</td>
</tr>
<tr>
<td>Cylindrical interpolation</td>
<td>G07.1</td>
<td>This function can be used in AI high precision contour control mode or AI nano high precision contour control mode.</td>
</tr>
<tr>
<td>Cylindrical interpolation cutting point control</td>
<td>G07.1</td>
<td>This function can be used in AI high precision contour control mode or AI nano high precision contour control mode.</td>
</tr>
<tr>
<td>Conical / spiral interpolation</td>
<td>G02,G03</td>
<td></td>
</tr>
</tbody>
</table>

### Feed functions

<table>
<thead>
<tr>
<th>Item</th>
<th>Specifications</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed per minute</td>
<td>G94</td>
<td></td>
</tr>
<tr>
<td>Cutting feedrate clamp</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linear acceleration/deceleration of cutting feed after interpolation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bell–type acceleration/deceleration of cutting feed after interpolation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feedrate override</td>
<td>0 to 254% (1% step)</td>
<td></td>
</tr>
<tr>
<td>2nd. Feedrate override</td>
<td>0 to 254% (1% step)</td>
<td></td>
</tr>
</tbody>
</table>
## Feed functions

<table>
<thead>
<tr>
<th>Item</th>
<th>Specifications</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1 digit feed</td>
<td></td>
<td>Using the manual pulse generator can not change Feedrate.</td>
</tr>
<tr>
<td>Inverse time feed</td>
<td>G93</td>
<td>External deceleration</td>
</tr>
<tr>
<td>External deceleration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Look ahead liner–type acceleration/ deceleration before interpolation.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Look ahead Bell–type acceleration/ deceleration before interpolation</td>
<td>Acceleration change time constant type</td>
<td></td>
</tr>
</tbody>
</table>

## Program input

<table>
<thead>
<tr>
<th>Item</th>
<th>Specifications</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tape code</td>
<td>Automatic recognition of EIA/ISO</td>
<td></td>
</tr>
<tr>
<td>Program format</td>
<td>Word address format</td>
<td></td>
</tr>
<tr>
<td>Control in/out</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Optional block skip</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Absolute/incremental programming</td>
<td>G90/G91</td>
<td></td>
</tr>
<tr>
<td>Input unit 10 time multiply</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plane selection</td>
<td>G17,G18,G19</td>
<td></td>
</tr>
<tr>
<td>Rotary axis roll over</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Workpiece coordinate system selection</td>
<td>G54 to G59</td>
<td>The AI high precision contour control mode or the AI nano high precision contour control mode is automatically canceled once and the buffering is inhibited if this function is used in the AI high Precision Contour Control mode or in the AI high Precision Contour Control mode.</td>
</tr>
<tr>
<td>Addition of workpiece coordinate system pair</td>
<td>48 sets / 300 sets</td>
<td>The AI high precision contour control mode or the AI nano high precision contour control mode is automatically canceled once and the buffering is inhibited if this function is used in the AI high Precision Contour Control mode or in the AI high Precision Contour Control mode.</td>
</tr>
<tr>
<td>Manual absolute ON/OFF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Programmable parameter input</td>
<td>G10</td>
<td>The AI high precision contour control mode or the AI nano high precision contour control mode is automatically canceled once and the buffering is inhibited if this function is used in the AI high Precision Contour Control mode or in the AI high Precision Contour Control mode.</td>
</tr>
<tr>
<td>Item</td>
<td>Specifications</td>
<td>Note</td>
</tr>
<tr>
<td>-----------------------------------------------------------</td>
<td>----------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>External memory and sub program calling function</td>
<td>M198</td>
<td></td>
</tr>
<tr>
<td>Subprogram call</td>
<td>M98</td>
<td></td>
</tr>
<tr>
<td>Circular interpolation by R programming</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scaling</td>
<td>G50,G51</td>
<td>The mode of AI high precision contour control or of AI nano high precision contour control is permitted to change ON and OFF in scaling</td>
</tr>
<tr>
<td></td>
<td></td>
<td>mode by setting the parameter. The alarm (P/S5012) occurs if the mode of AI high precision contour control or of AI nano high precision</td>
</tr>
<tr>
<td></td>
<td></td>
<td>contour control is changed in scaling mode (G51) when the parameter is not set. The scaling mirror image by a negative magnification can</td>
</tr>
<tr>
<td></td>
<td></td>
<td>not be done.</td>
</tr>
<tr>
<td>Coordinate system rotation</td>
<td>G68,G69</td>
<td>The mode of AI high precision contour control or of AI nano high precision contour control is permitted to change ON and OFF in coordinate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>system rotation mode by setting the parameter. The alarm (P/S5012) occurs if the mode of AI high precision contour control or of AI nano</td>
</tr>
<tr>
<td></td>
<td></td>
<td>high precision contour control is changed in coordinate system rotation mode (G51) when the parameter is not set.</td>
</tr>
<tr>
<td>3–dimensional coordinate system conversion</td>
<td>G68,G69</td>
<td>The mode of AI high precision contour control or of AI nano high precision contour control is permitted to change ON and OFF in 3–dimensional</td>
</tr>
<tr>
<td></td>
<td></td>
<td>coordinate system conversion mode by setting the parameter. The alarm (P/S5012) occurs if the mode of AI high precision contour control</td>
</tr>
<tr>
<td></td>
<td></td>
<td>or of AI nano high precision contour control is changed in 3–dimensional coordinate system conversion when the parameter is not set.</td>
</tr>
<tr>
<td>Miscellaneous/spindle functions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Miscellaneous function</td>
<td></td>
<td>The AI high precision contour control mode or the AI nano high precision contour control mode is automatically canceled once and the</td>
</tr>
<tr>
<td></td>
<td></td>
<td>buffering is inhibited if this function is used in the AI high Precision Contour Control mode or in the AI high Precision Contour Control</td>
</tr>
<tr>
<td></td>
<td></td>
<td>mode.</td>
</tr>
</tbody>
</table>
### Miscellaneous/spindle functions

<table>
<thead>
<tr>
<th>Item</th>
<th>Specifications</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>2nd. Auxiliary function</td>
<td>The AI high precision contour control mode or the AI nano high precision contour control mode is automatically canceled once and the buffering is inhibited if this function is used in the AI high Precision Contour Control mode or in the AI high Precision Contour Control mode.</td>
<td></td>
</tr>
<tr>
<td>1 block plural M commands</td>
<td>The AI high precision contour control mode or the AI nano high precision contour control mode is automatically canceled once and the buffering is inhibited if this function is used in the AI high Precision Contour Control mode or in the AI high Precision Contour Control mode.</td>
<td>It is possible to command up to 3.</td>
</tr>
<tr>
<td>Spindle speed function</td>
<td>The AI high precision contour control mode or the AI nano high precision contour control mode is automatically canceled once and the buffering is inhibited if this function is used in the AI high Precision Contour Control mode or in the AI high Precision Contour Control mode.</td>
<td></td>
</tr>
</tbody>
</table>

### Tool functions

<table>
<thead>
<tr>
<th>Item</th>
<th>Specifications</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tool function (T8-digit)</td>
<td>The AI high precision contour control mode or the AI nano high precision contour control mode is automatically canceled once and the buffering is inhibited if this function is used in the AI high Precision Contour Control mode or in the AI high Precision Contour Control mode.</td>
<td></td>
</tr>
<tr>
<td>Tool retract &amp; recover</td>
<td>G10.6</td>
<td>Issue the G10.6 command prior to the G05 P10000 command that causes the system to enter AI high precision contour control or AI nano contour control mode. The alarm (P/S 5000) occurs if it is issued in this mode.</td>
</tr>
<tr>
<td>Tool length compensation</td>
<td>G43</td>
<td></td>
</tr>
<tr>
<td>Cutter compensation C</td>
<td>G38,G39,G40,G41,G42</td>
<td>The buffering is inhibited when the command which automatically cancel AI high precision contour control mode or AI nano high precision contour control mode is used. So the tool offset vector is held.</td>
</tr>
<tr>
<td>Item</td>
<td>Specifications</td>
<td>Note</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>----------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>3–dimensional tool compensation</td>
<td>G41.2,G42.2 G41.3</td>
<td>The command which automatically cancel AI high precision contour control mode or AI nano high precision contour control mode can not be used. However M,S,T and B command can be used without the command that move some axes. In this case, the offset vector is held because the buffering is inhibited.</td>
</tr>
<tr>
<td>Tool axis direction tool length compensation</td>
<td>G43.1</td>
<td>The command which automatically cancel AI high precision contour control mode or AI nano high precision contour control mode can not be used. However M,S,T and B command can be used without the command that move some axes. In this case, the offset vector is held because the buffering is inhibited.</td>
</tr>
<tr>
<td>Tool center point control</td>
<td>G43.4,G43.5</td>
<td>The command which automatically cancel AI high precision contour control mode or AI nano high precision contour control mode can not be used. However M,S,T and B command can be used without the command that move some axes. In this case, the offset vector is held because the buffering is inhibited.</td>
</tr>
<tr>
<td>Rotary table dynamic fixture offset</td>
<td>G54.2</td>
<td>The mode of AI high precision contour control or of AI nano high precision contour control is permitted to change ON and OFF in rotary table dynamic fixture offset mode by setting the parameter. The alarm (P/S5012) occurs if the mode of AI high precision contour control or of AI nano high precision contour control is changed in rotary table dynamic fixture offset mode when the parameter is not set.</td>
</tr>
</tbody>
</table>
22.2 CYLINDRICAL INTERPOLATION CUTTING POINT CONTROL (G07.1)

General

The conventional cylindrical interpolation function controls the tool center so that the tool axis always moves along a specified path on the cylindrical surface, towards the rotation axis (cylindrical axis) of the workpiece. On the other hand, this function controls the tool so that the tangents to the tool and a contour figure cutting surface always pass through the rotation center of a workpiece.

As shown in Fig.22.2 (a), control is exercised along the offset axis (Y-axis) direction that is perpendicular to the tool, tool center axis, and workpiece rotation center axis. Therefore, contour figure on the cutting side can be assumed to be the same anytime without depending on the amount of the cutter compensation.

This function can be used in AI high precision contour control mode or in AI NANO high precision contour control mode.

---

Fig. 22.2 (a) Comparison with Conventional Interpolation
Format

<table>
<thead>
<tr>
<th>Command</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>G05 P10000</td>
<td>Sets Al High precision contour control mode.</td>
</tr>
<tr>
<td>G07.1 IPr</td>
<td>Sets cylindrical interpolation mode.</td>
</tr>
<tr>
<td>..G41(G42)..</td>
<td>Sets cutter compensation mode.</td>
</tr>
<tr>
<td>..G40..</td>
<td>Clear cutter compensation mode.</td>
</tr>
<tr>
<td>G07.1 IP0</td>
<td>Clears cylindrical interpolation mode.</td>
</tr>
<tr>
<td>G05 P0</td>
<td>Clears Al high precision contour control mode.</td>
</tr>
</tbody>
</table>

IP : One rotation axis address  
r : Cylinder radius of rotation axis  
Specify each of G07.1 IPr; and G07.1 IP0; singly in a block.

Explanations

- Cutting point compensation

(1) Cutting point compensation between blocks
   As shown in Fig. 22.2 (b), cutting point compensation is achieved by moving between blocks N1 and N2.
   1) Let C1 and C2 be the heads of the vectors normal to N1 and N2 from S1, which is the intersection of the tool center paths of blocks N1 and N2.
   2) After the tool moves to S1 according to the command of N1, the tool moves through V on the C-axis as a result of cutting point compensation, then through \(-V \times \frac{\pi}{180} \times r\) along the Y-axis.

![Cutting Point Compensation between Blocks](image)

(2) Cutting point compensation in a circular command block
   As shown in Fig. 22.2 (c), the movement required for cutting point compensation is made simultaneously with circular interpolation in block N1.
1) Let $C_0$ be the head of the vector normal to $N_1$ from $S_0$, which is the tool center position at the start point of circular block $N_1$. Let $C_1$ be the head of the similar vector at the end point.

2) As the tool moves from $S_0$ to $S_1$, a superimposed movement is made by the $C$–axis component of $(C_1 - C_2)$ ($V$ in the figure) on the $C$–axis, and a superimposed movement is made by $-V \times \frac{\pi}{180} \times r$ along the $Y$–axis. That is, the following expressions are valid. As movement is made through $L$ as shown in Fig. 22.2 (c), the superimposed movements are made on the $C$–axis and $Y$–axis as follows:

\[ \Delta C = \Delta V \]
\[ \Delta Y = - \frac{\pi}{180} (\Delta V) r \]
\[ \Delta V : \text{Cutting point compensation value} (\Delta V_2 - \Delta V_1) \text{ for movement of } \Delta L \]
\[ \Delta V_1 : C$–axis component of the vector normal to $N_1$ from the tool center of the start point of $\Delta L$ \]
\[ \Delta V_2 : C$–axis component of the vector normal to $N_1$ from the tool center of the end point of $\Delta L$ \]
\[ R : \text{Arc radius} \]

Fig. 22.2 (c) Cutting Point Compensation in a Circular Command Block

(3) When cutting point compensation is not applied between blocks
When, as shown in Fig. 22.2 (d) and Fig. 22.2 (e), the cutting point compensation value ($V$ in the figures) is less than the value set in parameter No. 6112, one of the operations below is performed. (The operation that is performed depends on the setting of bit 6 (CYS) of parameter No. 6004.

1) When bit 6 (CYS) of parameter No. 6004 is set to 1
Cutting point compensation is not applied between blocks $N_1$ and $N_2$, but is applied when block $N_2$ is executed.
2) When bit 6 (CYS) of parameter No. 6004 is set to 0
Cutting point compensation is not performed between blocks N1 and N2. Whether to apply cutting point compensation between block N2 and N3 is determined by taking the cutting point compensation value between blocks N2 and N3 (V1 in the figure) into consideration.
3) When the amount of travel (L1) of block N2 is less than the value set in parameter No. 6113, as shown in Fig. 22.2 (f), cutting point compensation is not applied between blocks N1 and N2. Instead, block N2 is executed with the cutting point compensation of the previous block. When the amount of travel (L2) of block N3 is greater than the value set in parameter No. 6113, cutting point compensation is applied between blocks N2 and N3.

![Diagram](image)

**Fig. 22.2 (f) When the Amount of Travel (L1) of Block N2 Is Less Than the Parameter Value**

4) When, as shown in Fig. 22.2 (g), the diameter of an arc (R in the figure) is less than the value set in parameter No. 6113, cutting point compensation is not applied simultaneously with circular interpolation.
**Feedrate during cutting point compensation**

(1) The tool moves at a specified feedrate while cutting point compensation is being applied between blocks.

(2) The actual speed indication and feedrate during circular interpolation are as described below.

Actual speed indication

The speed component of each axis after cutting point compensation at a point in time during circular interpolation is as follows:

- \( F_{z}' = F_z \) — Speed component of linear axis
- \( F_{c}' = F_c + (V_{ce} - V_{cs}) \) — Speed component of rotation axis
- \( F_{y}' = -(V_{ce} - V_{cs})\frac{\pi r}{180} \) — Speed component of offset axis

- \( F_z \): Speed component of a cylindrical interpolation linear axis before cutting point compensation
- \( F_c \): Speed component of cylindrical interpolation rotation axis before cutting point compensation
- \( V_{cs} \): Rotation axis component of a tool contact point vector (Vs in the figure) at the start point at a point in time
- \( V_{ce} \): Rotation axis component of tool contact point vector (Ve in the figure) at the end point at a point in time
- \( r \): Radius of the cylinder of a rotation axis

Accordingly, the actual speed indication during circular interpolation is greater than the specified value when \( |F_{c}'| > |F_c| \) (inner offset of the arc). Conversely, the actual speed indication during circular interpolation is less than the specified value when \( |F_{c}'| < |F_c| \) (outer offset of the arc).
**Usable G codes**

(1) In any of the following G code modes, cylindrical interpolation cutting point compensation can be specified:
- G17,G18,G19 : Plane selection
- G22 : Stored stroke check function on
- G64 : Cutting mode
- G90,G91 : Absolute command programming, incremental command programming
- G94 : Feed per minute

(2) Any of the following G codes can be specified in cylindrical interpolation cutting point compensation mode:
- G01,G02,G03 : Linear interpolation, circular interpolation
- G04 : Dwell
- G40,G41,G42 : Cutter compensation
- G40.1–G42. : Normal direction control
- G64 : Cutting mode
- G65–G67 : Macro call
- G90,G91 : Absolute command programming, incremental command programming

**Parameter**

Set to use this function as parameter CYA (No.19530#5)=1.

**Limitation**

**Overcutting during inner corner cutting**

Theoretically, when the inner area of a corner is cut using linear interpolation as shown in Fig. 22.2 (i), this function slightly overcuts the inner walls of the corner. This overcutting can be avoided by specifying a value of R that is slightly greater than the radius of the tool at the corner.
• Setting the minimum input increment for an offset axis (Y-axis)  
Set the same minimum input increment for an offset axis and linear axis when cylindrical interpolation is performed.

• Workpiece radius specification  
When specifying the radius of a workpiece, use the minimum input increment (with no decimal point) for the linear axis used in cylindrical interpolation.

• Roll over function of rotation axis  
When the rotation axis using the roll over function is specified as the rotation axis used for cylindrical interpolation, the roll over function is disabled in cylindrical interpolation mode. The roll over function is automatically enabled when cylindrical interpolation mode is released.

• Program restart  
During a program restart, G07.1 for cylindrical interpolation mode cannot be specified. PS/0175 occurs if G07.1 is specified.

Examples

• Example of cylindrical interpolation cutting point compensation  
The sample program below indicates the positional relationships between a workpiece and tool.

```
O0001(CYLINDRICAL INTERPOLATION1) ;
N01 G00 G90 Z100.0 C0 ;
N02 G01 G91 G19 Z0 C0 ;
N03 G07.1 C57299 ;
N04 G01 G42 G90 Z120.0 D01 F250. ;  -- -- (1)
N05 C20.0 ;  -- -- (2)
N06 G02 Z110.0 C60.0 R10.0 ;  -- -- (3)
N07 G01 Z100.0 ;  -- -- (4)
N08 G03 Z60.0 C70.0 R40.0 ;  -- -- (5)
:
M30 ;
```

Fig. 22.2 (i) Overcutting
Fig. 22.2 (j) Path of Sample Program for Cylindrical Interpolation Cutting Point Compensation

Fig. 22.2 (k) Positional Relationships between Workpiece and Tool of Sample Program

The cutting surfaces in the rotation axis direction in (3) and (4) are the same, even when the cutter compensation is changed.
### Alarm

<table>
<thead>
<tr>
<th>Number</th>
<th>Message</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>0015</td>
<td>TOO MANY AXES COMMANDED</td>
<td>A move command was specified for more axes than can be controlled by simultaneous axis control. Either add on the simultaneous axis control option, or divide the number of programmed move axes into two blocks.</td>
</tr>
<tr>
<td>0175</td>
<td>ILLEGAL G107 COMMAND</td>
<td>An axis which cannot perform cylindrical interpolation was specified. More than one axis was specified in a G07.1 block. An attempt was made to cancel cylindrical interpolation for an axis that was not in the cylindrical interpolation mode. For the cylindrical interpolation axis, set not “0” but one of 5, 6 or 7 (parallel axis specification) to parameter No. 1022 to instruct the arc with axis of rotation (ROT parameter No. 1006#1 is set to “1” and parameter No. 1260 is set) ON.</td>
</tr>
<tr>
<td>0176</td>
<td>IMPROPER G–CODE IN G107</td>
<td>A G code was specified that cannot be specified in the cylindrical interpolation mode. This alarm also is generated when an 01 group G code was in the G00 mode or code G00 was instructed. Cancel the cylindrical interpolation mode before instructing code G00.</td>
</tr>
</tbody>
</table>
On a five–axis machine having two rotation axes that turn a tool, tool length compensation can be performed momentarily even in the middle of a block.

This tool length compensation is classified into one of two types based on the programming method. In the explanation of this function, the two rotation axes are assumed to be the B– and C–axes.

(1) Type 1
The rotation axis position (B, C) is specified.
The CNC applies tool length compensation according to the compensation amount along the tool axis whose orientation is calculated from the specified rotation axis position. This means that compensation is performed by moving the three linear axes.

(2) Type 2
The tool axis orientation (I, J, K) is specified.
The CNC controls the two rotation axes so that the tool is oriented as specified, and performs tool length compensation in tool axis direction according to the compensation amount. This means that compensation is performed by moving the two rotation axes and three linear axes.

Tool center point control (type 1) differs from tool length compensation in tool axis direction as shown below:

**Fig. 22.3 (a) Difference between Tool Center Point Control and Tool Length Compensation in Tool Axis Direction**
NOTE
The length from the tool tip to tool pivot point must equal the sum of the tool length compensation amount and tool holder offset value.

Format

- Specifying tool center point control (type 1)

G43.4 H_;
H : Offset number

- Specifying tool center point control (type 2)

G43.5 I_ J_ K_ H_ Q_;
I, J, K : Tool axis orientation
H : Offset number
Q : Tool inclination angle (degrees)

NOTE
1 When I, J, and K are all omitted from a block, the compensation vector in the previous block is used.
2 When any of I, J, and K is omitted, the omitted I, J, or K is assumed to be 0.
3 Movement of the rotation axes is controlled by shortcut control so that the amount of movement does not exceed $180^\circ$.

- Canceling tool center point control

G49 ;

Description

- Specification of tool center point control

The tool compensation vector changes in the following cases:
Type 1 : The offset value is changed, or the rotation axis position (B, C) is specified.
Type 2 : The offset value is changed, or the tool axis orientation (I, J, K) is specified.

As the tool compensation vector changes, movement is performed along the X-, Y-, and Z-axes by an amount equal to the change. The time at which the tool compensation vector is calculated is as follows:
Tool center point control : Calculated momentarily even in the middle of a block.
Tool length compensation in tool axis direction: Calculated only at the end point of a block.
When only the rotation axis position is specified in tool center point control (type 1) mode, and when only I, J, and K are specified in tool center point control (type 2) mode, the tool tip center position remains unchanged before and after the specification. (Also, while the rotation axes are being moved, the tool tip center does not move.)

**Inclination of the tool**

For tool center point control (type 2), the inclination angle of the tool can be specified with address Q of G43.5. The inclination angle of the tool is the difference in the angle between the tool orientation specified by (I, J, K) and the tool orientation set for actual machining.

If the tool orientation specified by (I, J, K) matches the tool orientation set for actual machining, Q need not be specified.

Example: For machining with the tool tilted toward the machining direction by 2 degrees, specify the following:

G43.5 I_ J_ K_ H_ Q2.0

**Programmed point**

In programming, the position of the tool tip center is specified.
• **Linear interpolation (G01)**

  When linear interpolation (G01) is specified in tool center point control mode, the feedrate is controlled so that the tool tip center moves at a specified feedrate.

• **Specification of rotation axes**

  (1) Type 1
  
  When only the rotation axes are specified in tool center point control (type 1) mode, the feedrate of the rotation axes is set to the maximum cutting feedrate (parameter No. 1422 or No.1430 or No.1432).

  (2) Type 2
  
  In tool center point control (type 2) mode, the rotation axes cannot be specified. If the rotation axes are specified, alarm (5421) occurs.
• Positioning (G00)

**NOTE**
1 Set the following parameters:
   1. Bit 1 (LRP) of parameter No.1401 = 1: Linear-type rapid traverse
   2. Bit 5 (FRP) of parameter No.19501 = 1: Acceleration/deceleration before interpolation is used in rapid traverse
   3. Parameter No.1620: Time constant used for acceleration/deceleration for rapid traverse
   4. Parameter No.1621: Time constant T2 used for bell-shaped acceleration/deceleration for rapid traverse
2 If the above settings are not made, or if look-ahead acceleration/deceleration before interpolation is not valid, axis movement may be performed at a higher feedrate than the rapid traverse rate.

• Operation at start and cancellation

   (1) Type 1
   When tool center point control (type 1) starts (G43.4H_) and when it is canceled (G49), the CNC calculates the compensation vector only at the end of the block.

   (2) Type 2
   When tool center point control (type 2) starts (G43.5H_) and when it is canceled (G49), the CNC calculates the compensation vector only at the end of the block.

• Operation of tool center point control (type 1)

   The following items are the same as for tool length compensation in tool axis direction:
   - Machine configuration example and equation for rotation axis calculation
   - Tool holder offset
   - Specification of angular displacement in a parameter
   - Zero-point compensation for the rotation axes
   - Rotation axis offset

• Operation of tool center point control (type 2)

   The following item is the same as for tool length compensation in tool axis direction:
   - Tool holder offset

   Positioning(G00) and linear interpolation(G01) is made on all five axes simultaneously to the position \((x, y, z, b, c)\) calculated as shown below,
 Example of machine configuration and expression for rotation axis calculation

(1) When the rotation axes are the A– and C–axes, and the tool axis is the Z–axis

\[
x = X + l - \frac{I}{\sqrt{I^2 + J^2 + K^2}}
\]
\[
y = Y + l - \frac{J}{\sqrt{I^2 + J^2 + K^2}}
\]
\[
z = Z + l - \frac{K}{\sqrt{I^2 + J^2 + K^2}}
\]
\[b = \tan^{-1} \frac{\sqrt{I^2 + J^2}}{K}
\]
\[c = \tan^{-1} \frac{J}{I}
\]

\[
a = \tan^{-1} \frac{\sqrt{I^2 + J^2}}{K}
\]
\[
c = \tan^{-1} \frac{J}{I}
\]
(2) When the rotation axes are the B– and C–axes, and the tool axis is the Z–axis

\[ b = \tan^{-1}\left(\frac{E + F}{K}\right) \]

\[ c = \tan^{-1}\left(\frac{J}{I}\right) \]

(3) When the rotation axes are the A– and B–axes, and the tool axis is the X–axis

\[ a = \tan^{-1}\left(\frac{J}{K}\right) \]

\[ b = \tan^{-1}\left(\frac{\sqrt{F^2 + K^2}}{I}\right) \]
(4) When the rotation axes are the A– and B–axes, and the tool axis is the Z–axis (master axis: B–axis)

\[ a = \tan^{-1} \left( \frac{-f}{\sqrt{f^2 + K^2}} \right) \]

\[ b = \tan^{-1} \left( \frac{f}{K} \right) \]

(5) When the rotation axes are the A– and B–axes, and the tool axis is the Z–axis (master axis: A–axis)

\[ a = \tan^{-1} \left( \frac{-f}{\sqrt{f^2 + K^2}} \right) \]

\[ b = \tan^{-1} \left( \frac{f}{\sqrt{f^2 + K^2}} \right) \]

• **Tool life management**

  When tool life management is used, the tool length compensation amount of the tool used is used for tool center point control.
• Three–dimensional cutter compensation

Tool center point control and three–dimensional cutter compensation can be used at the same time.

Three–dimensional cutter compensation is applied to a specified tool tip point. Three–dimensional cutter compensation, however, is not performed momentarily in the middle of a block; it is performed only at the end of a block.

• Three–dimensional coordinate conversion

When tool center point control (type 2) is used during three–dimensional coordinate conversion, the tool axis orientation (I, J, K) is also subjected to three–dimensional coordinate conversion.

• Rotation axis rollover

NOTE
Whenever using tool center point control (type 2), set bit 2 (ROAx) of parameter No. 1008 to 1 to perform rotation axis rollover.

Restrictions

• Look–ahead acceleration/deceleration before interpolation

When using tool center point control, also use look–ahead acceleration/deceleration before interpolation. If look–ahead acceleration/deceleration before interpolation is not used, the feedrate may exceed the maximum cutting feedrate as a result of tool center point control, which will cause alarm P/S5422 to be issued.

Example:

In the above example, the feedrate is controlled so that the tool tip center moves at a specified feedrate. As a result, a higher feedrate than the specified feedrate is detected on the interpolation path. In such a case, if look–ahead acceleration/deceleration before interpolation is used, the feedrate is clamped so that the feedrate on the interpolation path does not exceed the maximum cutting feedrate. If look–ahead acceleration/deceleration before interpolation is not used, the feedrate on the interpolation path may become higher than the maximum cutting feedrate, resulting in alarm P/S5422 being issued.
When the following functions are used in tool center point control mode, the same operation as tool length compensation in tool axis direction results:

- Specification of an axis not related to tool center point control
- The following G functions of group 01:
  - Circular interpolation, helical interpolation (G02, G03)
  - Involute interpolation (G2.2, G3.2)
  - Three-dimensional circular interpolation (G2.4, G3.4)
- Inverse time feed (G93)

The following functions can be used but the state can not be changed in tool center point control mode.

- Inch/metric conversion (An alarm(P/S5000) is issued if the state is changed by G20 or G21)
- Mirror image (Do not change the state of the signal).
- Tool life management function

The tool length compensation use the amount of the tool specified by tool life management function. The command for the tool life management function have to command before tool axis direction tool length compensation mode.

- F1 digit feed (Feedrate can not be changed by using the manual pulse generator.)

The following commands can not be used in tool center point control mode. The alarm is issued if the function was used.

- Custom macro
- Exponential interpolation – G02.3, G03.3
- Dwell – G04
- High Speed Cutting Function relation – G05
  (G05P10000 and G05P0 are excluded)
- AI contour control – G05.1Q1, G5.1Q0
- Hypothetical axis interpolation – G07
- Cylindrical interpolation – G07.1
- Advanced preview control – G08
  (Please use AI High Precision Contour Control)
- Polar coordinate interpolation – G12.1, G13.1
- Polar coordinate command – G15, G16
- Reference position return check – G27
- Reference point return – G28
- 2nd. Reference point return – G30
- 3rd/4th reference point return – G30
- Skip – G31
- Thread cutting – G33
- Automatic tool length measurement – G37
- Normal direction control – G40.1, G41.1, G42.1
- Cutter compensation B – G41, G42, G39
  (Cutter compensation C is available)
3–dimensional tool compensation – G41
Wheel wear compensation – G41
Tool offset – G45, G46, G47, G48
Programmable mirror image – G50.1, G51.1
Local coordinate system – G52
Machine coordinate system – G53
Single direction positioning – G60
Automatic corner override – G62
Tapping mode – G63
Macro call – G65, G66, G67
(SubProgram call is available)
Figure copying – G72.1, G72.2
Canned cycle – G73–G70, G80, G81–G89, G98, G99
Simple electric gear box – G80, G81
Functions for hobbing machine – G80, G81
External operation function – G81
Chopping function – G81.1
Small hole peck drilling cycle – G83
Setting a workpiece coordinate system – G92
Workpiece coordinate system preset – G92.1
Feed per revolution – G95
Constant surface speed control – G96, G97
Infeed control – G160, G161
Workpiece coordinate system selection – G54 to G59, G54.1
M, S, T and B functions with motion command
Conical / spiral interpolation

In tool center point control mode, the functions listed below cannot be used.

If these functions are used, the compensation vector of the previous block is used as is.

– The following G functions of group 01:
  • Spline interpolation (G06.1)
  • Smooth interpolation (G05.1 Q2)
  • NURBS interpolation (G06.2)

**Unavailable functions**

In the mode for this function, the following functions cannot be used. The warning message is displayed on the screen when the following functions are used:

– MDI operation
In the mode for this function, the following functions cannot be used. The alarm (P/S5196) is issued when the following functions are used:

- Manual interruption operation
- Tool retract and recover

The following functions cannot be used in tool center point control mode.

- Flexible synchronous control
- Sequence number comparison and stop
  It is not possible to stop by the sequence number in tool center point control mode.
- Index table indexing
- Retrace function
  Do not use retrace function in the program which uses tool center point control mode.
- Rotary axis control
- Gentle curve normal direction control
- Tool life management
  Tool life value is counted in tool center point control mode. However, do not use the command related to the tool life management function.
- Macro executor (Execution macro)
- Manual handle interruption
- External deceleration (external deceleration is not effected)

- Other Restrictions

When the following function is used, tool center point control cannot be used.

- Angular axis control
- Arbitrary angular axis control

The limitation may be attached about the combination of the NC instructions occasionally.
Refer the description of the each functions.

### Alarms

<table>
<thead>
<tr>
<th>Number</th>
<th>Message</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>5425</td>
<td>ILLEGAL OFFSET VALUE</td>
<td>The offset number is illegal.</td>
</tr>
<tr>
<td>5420</td>
<td>ILLEGAL PARAMETER IN G43.4/G43.5</td>
<td>There is an illegal parameter relating to tool center point control.</td>
</tr>
<tr>
<td>5421</td>
<td>ILLEGAL COMMAND IN G43.4/G43.5</td>
<td>Rotation axes are specified in tool center point control (type 2).</td>
</tr>
<tr>
<td>5422</td>
<td>EXCESS VELOCITY IN G43.4/G43.5</td>
<td>As a result of tool center point control, the feedrate along an axis exceeds the maximum cutting feedrate.</td>
</tr>
</tbody>
</table>
When a 5-axis machine that has two axes for rotating the tool is used, tool length compensation can be performed in a specified tool axis direction on a rotation axis. When a rotation axis is specified in tool length compensation in tool axis direction mode, tool length compensation is applied in a specified tool axis direction on the rotation axis by the compensation value specified in the H code. That is, movement is made along the three linear axes (Xp, Yp, Zp).

Unless otherwise noted in the explanation of this function, the two rotation axes are assumed to be the B-axis and C-axis.

**Format**

- Command for tool length compensation in tool axis direction

  \[
  \text{G43.1 Hn ;}
  \]

  \(n\) : Offset number

- Command for cancellation of tool length compensation in tool axis direction

  \[
  \text{G49 ;}
  \]
Explanations

- **Command for tool length compensation in tool axis direction**

  The tool compensation vector changes as the offset value changes or movement is made on a rotation axis. When the tool compensation vector changes, movement is made according to the change value along the X-axis, Y-axis, and Z-axis.

  When the command specifies movement on a rotation axis only, the position of the tool tip is the same both before and after execution of the command. (During rotation axis movement, however, the tool tip moves.)

  Let \( V_x, V_y, V_z, L_c, a, b, \) and \( c \) be as follows:
  
  \[
  \begin{align*}
  V_x, V_y, V_z & : \text{Tool compensation vectors along the X-axis, Y-axis, and Z-axis} \\
  L_c & : \text{Offset value} \\
  a, b, c & : \text{Absolute coordinates on the A-axis, B-axis and C-axis}
  \end{align*}
  \]

  Then, the tool compensation vector on each axis in each machine configuration is indicated below.

  (1) A-axis and C-axis, with the tool axis on the Z-axis

  \[
  \begin{align*}
  V_x &= L_c \times \sin(a) \times \sin(c) \\
  V_y &= -L_c \times \sin(a) \times \cos(c) \\
  V_z &= L_c \times \cos(a)
  \end{align*}
  \]
(2) B–axis and C–axis, with the tool axis on the Z–axis

\[ V_x = L_c \cdot \sin(b) \cdot \cos(c) \]
\[ V_y = L_c \cdot \sin(b) \cdot \sin(c) \]
\[ V_z = L_c \cdot \cos(b) \]

(3) A–axis and B–axis, with the tool axis on the X–axis

\[ V_x = L_c \cdot \cos(b) \]
\[ V_y = L_c \cdot \sin(b) \cdot \sin(a) \]
\[ V_z = -L_c \cdot \sin(b) \cdot \cos(a) \]
(4) A–axis and B–axis, with the tool axis on the Z–axis, and the B–axis used as the master

\[ V_x = L_c \cdot \cos(a) \cdot \sin(b) \]
\[ V_y = -L_c \cdot \sin(a) \]
\[ V_z = L_c \cdot \cos(a) \cdot \cos(b) \]

(5) A–axis and B–axis, with the tool axis on the Z–axis, and the A–axis used as the master

\[ V_x = L_c \cdot \sin(b) \]
\[ V_y = -L_c \cdot \sin(a) \cdot \cos(b) \]
\[ V_z = L_c \cdot \cos(a) \cdot \cos(b) \]
• Tool holder offset

The machine-specific length from the rotation center of the tool rotation axes (A– and B–axes, A– and C–axes, and B– and C–axes) to the tool mounting position is referred to as the tool holder offset. Unlike a tool length offset value, a tool holder offset value is set in parameter No. 19666. When tool length compensation in tool axis direction is applied, the sum of the tool holder offset and tool length offset is handled as a tool length for compensation calculation.

![Fig. 22.4 (b) Tool Holder Offset](image)

• Parameter–based rotation angle specification

A tool compensation vector is found from the coordinates on the rotation axes for controlling the tool axis direction. However, the configuration of some machines is such that the tool axis is inclined using a fixed attachment. In such a case, the rotation angles of the rotation axes can be set using parameters.

Set bit 1 (RAP) of parameter No. 19650 to 1, and set the coordinates in parameter No. 19658.

This function compensates for a slight shift of the rotation axis origin caused, for example, by thermal displacement. Specify a compensation value in parameter No. 19660.

When the tool axis is on the Z–axis, and the rotation axes are the B–axis and C–axis, a compensation vector is calculated as follows:

\[
X_p = L_c \times \sin(B - Bz) \times \cos(C - Cz) \\
Y_p = L_c \times \sin(B - Bz) \times \sin(C - Cz) \\
Z_p = L_c \times \cos(B - Bz)
\]

\(X_p, Y_p, Z_p\) : Compensation pulse on each axis after origin shift compensation

\(L_c\) : Offset value

\(B, C\) : Machine position on B–axis and C–axis

\(Bz, Cz\) : Origin compensation value on B–axis and C–axis

• Rotation axis origin compensation

When the tool axis is on the Z–axis, and the rotation axes are the B–axis and C–axis, compensation vector calculation is performed as follows:

\[
X_p = L_c \times \sin(B - Bz) \times \cos(C - Cz) \\
Y_p = L_c \times \sin(B - Bz) \times \sin(C - Cz) \\
Z_p = L_c \times \cos(B - Bz)
\]

\(X_p, Y_p, Z_p\) : Compensation pulse on each axis after origin shift compensation

\(L_c\) : Offset value

\(B, C\) : Machine position on B–axis and C–axis

\(Bz, Cz\) : Origin compensation value on B–axis and C–axis

• Rotation axis offset

Set offsets relative to the rotation angles of the rotation axes in parameter No. 19659. The compensation vector calculation formula is the same as that used for rotation axis origin compensation, except that \(Bp\) and \(Cp\) are changed to rotation axis offsets.

When rotation axis origin compensation and rotation offsetting are set at the same time, both compensations are performed.

When the tool axis is on the Z–axis, and the rotation axes are the B–axis and C–axis, compensation vector calculation is performed as follows:
Xp = Lc * sin(B−(Bz+Bo)) * cos(C−(Cz+Co))
Yp = Lc * sin(B−(Bz+Bo)) * sin(C−(Cz+Co))
Zp = Lc * cos(B−(Bz+Bo))

Bz, Cz : B-axis and C-axis origin compensation values
Bo, Co : B-axis and C-axis rotation axis offset values

- **Control Point Compensation of Tool Length Compensation in Tool Axis Direction**

Normally, the control point of tool length compensation in tool axis direction is the point of intersection of the centers of two rotation axes. The machine coordinates also indicate this control point. This section explains the compensation performed when the centers of the two rotation axes do not intersect and also explains how to place the control point at a convenient position on the machine.

**Explanation**

- **Compensation of the rotation centers of two rotation axes**

Compensation when the rotation centers of two rotation axes do not match is performed. The length from the tool mounting position to the first rotation axis center is set as the tool holder offset value in parameter No. 19666. The vector from the first rotation axis center to the second rotation axis center is set as the rotation center compensation vector in parameter No. 19661. Since parameter No. 19661 is an axis type parameter, the compensation amount for three axes (X, Y, and Z) can be set in this parameter.

![Fig. 22.4 (c) Compensation of Rotation Centers of Two Rotation Axes](image-url)
According to the machine type, set the values listed in the following table:

**Table 22.4 (a) Setting the Tool Holder Offset and Rotation Center Compensation Vector**

<table>
<thead>
<tr>
<th>Machine type</th>
<th>Tool holder offset Parameter No. 19666</th>
<th>Rotation center compensation vector Parameter No. 19661</th>
</tr>
</thead>
<tbody>
<tr>
<td>(3) A– and B– axes. Tool axis is X– axis.</td>
<td>Length from tool mounting position to B–axis center</td>
<td>Vector from B–axis center to A–axis center</td>
</tr>
</tbody>
</table>

**NOTE**

When using the spindle center compensation described below, set the length from the tool mounting position to the spindle center as the tool holder offset.

- **Spindle center Compensation**

Compensation of the spindle center is performed. The amount of spindle center compensation is set in parameter No. 19662. Since parameter No. 19662 is an axis type parameter, the compensation amount for three axes (X, Y, and Z) can be set in this parameter.
Shifting the control point

Conventionally, the center of a rotation axis was used as the control point. The control point can now be shifted as shown in the figure below. Then, when the rotation axis is at the 0–degree position also in tool length compensation in tool axis direction (G43.1), the control point can be set to the same position as that for ordinary tool length compensation (G43). The control point here is indicated with machine coordinates. When linear interpolation is specified, for example, this control point moves linearly.
The method of shifting the control point can be selected using the following parameters:

**Table 22.4 (b) Methods of Shifting the Control Point**

<table>
<thead>
<tr>
<th>Bit 5 (SVC) of parameter No. 19665</th>
<th>Bit 4 (SPR) of parameter No. 19665</th>
<th>Shift of control point</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>–</td>
<td>As in the conventional case, the control point is not shifted.</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>The control point is shifted, and the shift vector is calculated automatically as follows: $- (\text{rotation center compensation vector (parameter No. 19661)}) + \text{spindle center compensation vector (parameter No. 19662)}) + \text{tool holder offset along tool axis (parameter No. 19666)})$</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>The control point is shifted, and the shift vector is the vector set in parameter No. 19667.</td>
</tr>
</tbody>
</table>

- **Equation for each machine type**

Vx, Vy, Vz: Tool length compensation vector
A, B, C: Absolute coordinates of A–, B–, and C–axes
To: Tool offset value
Ho: Tool holder offset value
Jx, Jy, Jz: Rotation center compensation vector
Cx, Cy, Cz: Spindle center compensation vector
Sx, Sy, Sz: Shift vector
Suppose the above. Then, the tool length compensation vector for each axis is calculated depending on the machine type, as follows:

1. A- and C-axes. The tool axis is the Z-axis.

\[ \begin{bmatrix} V_x \\ V_y \\ V_z \end{bmatrix} = \begin{bmatrix} \cos C & - \sin C & 0 \\ \sin C & \cos C & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos A - \sin A & 0 \\ 0 & \sin A & \cos A \end{bmatrix} \begin{bmatrix} Cx \\ Cy \\ To + Ho + Cz \end{bmatrix} + \begin{bmatrix} Jx \\ Jy \\ Jz \end{bmatrix} + \begin{bmatrix} Sx \\ Sy \\ Sz \end{bmatrix} \]

2. B- and C-axes. The tool axis is the Z-axis.

\[ \begin{bmatrix} V_x \\ V_y \\ V_z \end{bmatrix} = \begin{bmatrix} \cos C & - \sin C & 0 \\ \sin C & \cos C & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \cos B & 0 & \sin B \\ 0 & 1 & 0 \\ - \sin B & 0 & \cos B \end{bmatrix} \begin{bmatrix} Cx \\ Cy \\ To + Ho + Cz \end{bmatrix} + \begin{bmatrix} Jx \\ Jy \\ Jz \end{bmatrix} + \begin{bmatrix} Sx \\ Sy \\ Sz \end{bmatrix} \]

3. A- and B-axes. The tool axis is the X-axis.

\[ \begin{bmatrix} V_x \\ V_y \\ V_z \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos A - \sin A & 0 \\ 0 & \sin A & \cos A \end{bmatrix} \begin{bmatrix} \cos B & 0 & \sin B \\ 0 & 1 & 0 \\ - \sin B & 0 & \cos B \end{bmatrix} \begin{bmatrix} Cx \\ Cy \\ Cz \end{bmatrix} + \begin{bmatrix} Jx \\ Jy \\ Jz \end{bmatrix} + \begin{bmatrix} Sx \\ Sy \\ Sz \end{bmatrix} \]

4. A- and B-axes. The tool axis is the Z-axis, and the B-axis is the master.

\[ \begin{bmatrix} V_x \\ V_y \\ V_z \end{bmatrix} = \begin{bmatrix} \cos B & 0 & \sin B \\ 0 & 1 & 0 \\ - \sin B & 0 & \cos B \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos A - \sin A & 0 \\ 0 & \sin A & \cos A \end{bmatrix} \begin{bmatrix} Cx \\ Cy \\ To + Ho + Cz \end{bmatrix} + \begin{bmatrix} Jx \\ Jy \\ Jz \end{bmatrix} + \begin{bmatrix} Sx \\ Sy \\ Sz \end{bmatrix} \]

5. A- and B-axes. The tool axis is the Z-axis, and the A-axis is the master.

\[ \begin{bmatrix} V_x \\ V_y \\ V_z \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos A - \sin A & 0 \\ 0 & \sin A & \cos A \end{bmatrix} \begin{bmatrix} \cos B & 0 & \sin B \\ 0 & 1 & 0 \\ - \sin B & 0 & \cos B \end{bmatrix} \begin{bmatrix} Cx \\ Cy \\ Cz \end{bmatrix} + \begin{bmatrix} Jx \\ Jy \\ Jz \end{bmatrix} + \begin{bmatrix} Sx \\ Sy \\ Sz \end{bmatrix} \]

The shift vector (Sx, Sy, Sz) is calculated as follows:

A. When bit 5 (SVC) of parameter No.19665 = 0, the vector is set to 0.

B. When bit 5 (SVC) of parameter No.19665 = 1, and bit 4 (SPR) of parameter No. 19665 = 0:

When the machine type is other than (3)

\[ \begin{bmatrix} Sx \\ Sy \\ Sz \end{bmatrix} = - \begin{bmatrix} Cx + Jx \\ Cy + Jy \\ Cz + Jz + Ho \end{bmatrix} \]

When the machine type is (3)

\[ \begin{bmatrix} Sx \\ Sy \\ Sz \end{bmatrix} = - \begin{bmatrix} Cx + Jx + Ho \\ Cy + Jy \\ Cz + Jz \end{bmatrix} \]

C. When bit 5 (SVC) of parameter No.19665 = 1, and bit 4 (SPR) of parameter No. 19665 = 1, the vector specified in parameter No. 19667 is set.

**Restriction**

- **Limitation of Functions**

In the mode for this function, the following functions can be used, but the condition of each function cannot be changed

- Inch/metric conversion

  The alarm is issued when the condition is changed by G20 or G21 command.
– Mirror image
  The condition of DI signal cannot be changed.
– Tool life management function
  The tool length compensation use the amount of the tool specified by
tool life management function. The command for the tool life
management function have to command before tool axis direction tool
length compensation mode.
– One-digit F code feed
  The feedrate cannot be changed by using manual pulse generator.

• Commands that cannot be specified

In the mode for this function, the following commands cannot be used.
The alarm is issued when the following commands are ordered.

– Custom macro B
– Exponential interpolation – G02.3,G03.3
– Dwell – G04
– Function concerning high-speed machining
  (exclude G05P10000 and 05P0)
– AI precision control – G05.1Q1,G5.1Q0
– Hypothetical axis interpolation – G07
– Cylindrical interpolation – G07.1
– Advanced preview control – G08
  (Please use AI HPCC function)
– Polar coordinate interpolation – G12.1,G13.1
– Polar coordinate command – G15,G16
– Reference position return check – G27
– Reference position return – G28
– 2nd Reference position return – G30
– 3rd/4th Reference position return – G30
– Skip – G31
– Threading – G33
– Automatic tool length measurement – G37
– Normal direction control – G40.1,G41.1,G42.1
– Cutter compensation B – G41,G42,G39
  (Cutter compensation C is available)
– 3 dimensional cutter compensation – G41
– Wheel wear compensaton – G41
– Tool offset – G45,G46,G47,G48
– Programmable mirror image – G50.1,G51.1
– Local coordinate system – G52
– Machine coordinate system – G53
– Single direction positioning – G60
– Automatic corner override – G62
– Tapping mode – G63
– Macro call – G65,G66,G67
  (Sub program call is available)
– Figure copy – G72.1, G72.2
– Canned cycles – G73–G79, G80, G81–G89, G98, G99
– Electric gear box – G80, G81
– Function for hobbing machine – G80, G81
– External motion function – G81
– Chopping – G81.1
– Small–hole peck drilling cycle – G83
– Changing workpiece coordinate system – G92
– workpiece coordinate system preset – G92.1
– Feed per revolution – G95
– Constant surface speed control – G96, G97
– Infeed control – G160, G161
– NURBS interpolation – G06.2
– Workpiece coordinate system – G54, G54.1, G55, G56, G57, G58, G59
– M, S, T and B functions with motion command

**Function that cannot be specified**

In the mode for this function, the following functions cannot be used. The warning message is displayed on the screen when the following functions are used:
– MDI intervention

In the mode for this function, the following functions cannot be used. The alarm(P/S5196) is issued when the following functions are used:
– Manual interruption operation
– Tool retract and recover

And, in the mode for this function, the following functions cannot be used:
– Flexible synchronous control
– Sequence number comparison and stop
  (The program is not stop at the specified sequence block in tool axis direction tool length compensation mode.)
– Index table indexing
– Retrace function
  Retrace function cannot be used by the program which uses tool axis direction tool length compensation.
– Rotary axis control
– Gentle normal direction control
– The command for the tool life management function
  (Tool life time is able to be counted in this mode, but the command for the tool life management function cannot be used.)
– Macro executor (Execution macro)
– Manual handle interruption operation
– External deceleration
  External deceleration is not available in this mode.

• Others

  tool axis direction tool length compensation function cannot be used with
  the following function.
  – Angular axis control
  – Arbitrary angular axis control

  The limitation attaches about the combination of other NC instructions
  occasionally.
  Please refer to the manual of the each function.

Alarms

<table>
<thead>
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<th>Number</th>
<th>Message</th>
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<tbody>
<tr>
<td>5196</td>
<td>ILLEGAL AXIS OPERATION</td>
<td>A function which cannot be used during HPCC function or 5-axis control function is being executed was commanded.</td>
</tr>
<tr>
<td>5435</td>
<td>PARAMETER OUT OF RANGE (TLAC)</td>
<td>Illegal parameter setting. (Set value is out of range.)</td>
</tr>
<tr>
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22.5
3–DIMENSIONAL CUTTER COMPENSATION

The 3–dimensional cutter compensation function is used with machines that can control the direction of tool axis movement by using rotation axes (such as the B– and C–axes). This function performs cutter compensation by calculating a tool vector from the positions of the rotation axes, then calculating a compensation vector in a plane (compensation plane) that is perpendicular to the tool vector.

There are two types of cutter compensation: Tool side compensation and leading edge compensation. Which is used depends on the type of machining.

22.5.1 Tool Side Compensation

Tool side compensation is a type of cutter compensation that performs 3–dimensional compensation on a plane (compensation plane) perpendicular to a tool direction vector.

Format

- Tool side compensation(left)

  \[
  \text{G41.2 X}_\_ \_ Y\_\_ Z\_\_ D\_ \; ;
  \]
  
  If type C of cancellation operation is selected at start–up, never specify a move command such as X.Y.Z in the G41.2 block.

- Tool side compensation(right)

  \[
  \text{G42.2 X}_\_\_ Y\_\_ Z\_\_ D\_ \; ;
  \]
  
  If type C of cancellation operation is selected at start–up, never specify a move command such as X.Y.Z in the G42.2 block.

- Tool side offset cancel

  \[
  \text{G40 X}_\_\_ Y\_\_ Z\_ \; ;
  \]
Explanations

- Operation at compensation start–up and cancellation

(1) Type A
Type A operation is similar to cutter compensation as shown below.

![Operation in linear interpolation](image1)

![Operation in circular interpolation](image2)

Fig. 22.5.1 (b) Operation at compensation start–up and cancellation (Type A)

(2) Type B
Type B operation is similar to cutter compensation as shown below.
(3) Type C
As shown in the following figures, when G41.2, G42.2, or G40 is specified, a block is inserted which moves the tool perpendicularly to the movement direction specified in the next block by the distance of the tool radius.

Fig. 22.5.1 (c) Operation at compensation start–up and cancellation (Type B)

Fig. 22.5.1 (d) Operation at compensation start–up and cancellation (Type C)
**NOTE**

For type C operation, the following conditions must be satisfied when tool side compensation is started up or canceled:

1. The block containing G40, G41.2, or G42.2 must be executed in the G00 or G01 mode.
2. The block containing G40, G41.2, or G42.2 must have no move command.
3. The block after the block containing G41.2 or G42.2 must contain a G00, G01, G02, or G03 move command.

---

**Operation in the compensation mode**

Changing of offset directions and offset values, holding of vectors, interference checks, and so on are performed in the same way as for cutter compensation. G39 (corner rounding) cannot be specified. So, note the following:

(1) When the tool center path goes outside the programmed tool path at a corner, a linear movement block, instead of an arc movement block, is inserted to move the tool around the corner. When the tool center path goes inside the programmed tool path, no block is inserted.

![Diagram](image)

**Fig. 22.5.1 (e) Operation in the compensation mode (1)–1, 2**

In the above examples, the term “inside” means that the tool center path is positioned inside the programmed tool path at a corner, and “outside” means that the tool center path is positioned outside the programmed tool path. In Example (1)–3, the relationship between the tool center path and the programmed tool path is the same as in Example (1)–1; the tool center path is positioned outside the programmed tool path. Example (1)–4 has the same relationship as Example (1)–2, where the tool center path is positioned inside the programmed tool path.
(2) When the tool moves at a corner, the feedrate of the previous block is used if the corner is positioned before a single–block stop point; if the corner is after a single–block stop point, the feedrate of the next block is used.

In the above example, the single block stop point of N2 is Q2’, so that the feedrates along paths P’–Q1’ and Q1’–Q2’ are the same, namely, F100.

(3) When a command is specified to make the tool retrace the path specified in the previous block, the tool path can match the locus of the previous block by changing the G code to change the offset direction. If the G code is left unchanged, the operation shown in Example (3)–2 results:

```
Program(2)–1
N1 G90 G4 Xp Yp Zp Bp Cp D1 ;
N2 G01 Xq Yq Zq F100 ;
N3 Xr Yr Zr F200 ;
```
(4) Even when the tool movement changes linear to circular (helical), circular (helical) to linear, or circular (helical) to circular (helical), the start, end, and center points of a circular (helical) movement are projected on the compensation plane that is perpendicular to the tool axis, a compensation vector is calculated for the plane, then the vector is added to the originally specified position to obtain the command position. Then the tool is moved linearly or circularly (helically) to the obtained command position. In this case, the tool moves circularly (helically) in the currently selected plane. The tool does not move circularly (helically) in the compensation plane. Therefore, when the tool compensation is for circular movement, the compensation plane must be the XY, YZ, or ZX plane.
In above figure, cutter compensation vector VD at point Q is calculated as follows:

(1) Calculating the tool vector (VT)

(2) Calculating the coordinate conversion matrix (M)

Coordinate systems are defined as follows:

- Coordinate system C1: \{O; X, Y, Z\}
  - Cartesian coordinate system whose fundamental vectors are the following unit vectors along the X-, Y-, and Z-axes:
    - (1, 0, 0)
    - (0, 1, 0)
    - (0, 0, 1)

- Coordinate system C2: \{O; e2, e3, e1\}
  - Cartesian coordinate system whose fundamental vectors are the following unit vectors:
    - e2
    - e3
    - e1

where, e2, e3, and e1 are defined as follows:

- \(e_1 = V_T\)
- \(e_2 = b_2 / \|b_2\|, b_2 = a_2 - (a_2, e_1)\cdot e_1\)
- \(e_3 = b_3 / \|b_3\|, b_3 = a_3 - (a_3, e_1)\cdot e_1 - (a_3, e_2)\cdot e_2\)

a2 is an arbitrary vector linearly independent of e1, and a3 is an arbitrary vector linearly independent of e2 and e1.

The coordinate conversion matrix M from coordinate system C1 to C2, and the coordinate conversion matrix \(M^{-1}\) from coordinate system C2 to C1 are expressed as:

\[
M = \begin{bmatrix}
  e_2 \\
  e_3 \\
  e_1
\end{bmatrix}, \quad M^{-1} = (e_2 \ e_3 \ e_1)\]
(3) Converting coordinates from coordinate system C1 to coordinate system C2
The coordinates of the start and end points P and Q of a block and coordinates of the end point R of the next block in coordinate system C1 are converted to coordinates P', Q', and R' in coordinate system C2, respectively, by using the following expressions:

\[ P' = MP \]
\[ Q' = MQ \]
\[ R' = MR \]

(4) Calculating the intersection vector (V_D') in the compensation plane \( \{O; e_2, e_3\} \)
In the coordinates in coordinate system C2 obtained in (3), two components (the e1 component, the component of the tool direction, is excluded) are used to calculate intersection vector V_D' in the compensation plane.

![Fig. 22.5.1 (k) Compensation vector calculation](image)

The e1 component of V_D' is assumed to be always 0. The calculation is similar to the calculation of cutter compensation C. Although one vector is obtained in this example, up to four vectors may be calculated.

If the difference between the e2 and e3 components (in the compensation plane) between two points is smaller than the value set in parameter No. 6114 in intersection vector calculation, the block is assumed to specify no movement. In this case, intersection calculation is performed using the coordinates of one block ahead.

(5) Converting the intersection vector from coordinate system C2 to coordinate system C1
From the following expression, vector V_D' in coordinate system C2 is converted to vector V_D in coordinate system C1:

\[ V_D = M^{-1}V_D' \]

Vector VD is the compensation vector in the original XYZ coordinate system.
(1) When a rotation axis and linear axis are specified at the same time
When a rotation axis and linear axis are specified in the same block in the G41.2 or G42.2 mode (the compensation plane changes frequently), the cutter compensation vector is calculated using the coordinates of the rotation axis at each point at which the vector is obtained.

<Example>

G90 G00 X0 Y0 Z0 B0 C0 ;
G01 F1000 ;
N1 G42.2 Xp Yp Zp Bp Cp D1 ;
N2 Xq Yq Zq Bq Cq ;
N3 Xr Yr Zr Br Cr ;
N4 Xs Ys Zs Bs Cs ;
:

Vector calculation at the end point (Q) of block N2
- The tool vector (VT) and coordinate conversion matrix (M) are calculated using the coordinates (Bq, Cq) of the rotation axis at point Q.
- The cutter compensation vector is calculated using the resultant coordinates into which three points, P, Q, and R, are converted by matrix M.

Fig. 22.5.1 (l) When a Rotation Axis and Linear Axis Are Specified at the Same Time

(2) When a rotation axis is specified alone
When a rotation axis is specified alone in the G41.2 or G42.2 mode (the compensation plane changes), the cutter compensation vector is calculated as follows:

<Example>

G90 G00 X0 Y0 Z0 B0 C0 ;
G01 F1000 ;
N1 G42.2 Xp Yp Zp D1 ;
N2 Xq Yq Zq ;
N3 Br Cr ;
N4 Xs Ys Zs ;
:
Vector calculation at the end point (Q) of block N2
- The tool vector (VT) and coordinate conversion matrix (MN2) are calculated using the coordinates (B = 0, C = 0) of the rotation axis at point Q.
- The cutter compensation vector (VN2) is calculated using the resultant coordinates into which three points, P, Q, and S, are converted by matrix MN2.

Vector calculation at the end point of block N3
- The coordinate conversion matrix (MN3) is calculated using the coordinates (Br, Cr) of the rotation axis at point R.
- The cutter compensation vector (VN3) is calculated from the following expression:

\[ VN3 = MN3^{-1}(MN2 - VN2) \]

Fig. 22.5.1 (m) When a rotation axis is specified alone

- **Interference check made when the compensation plane is changed**

An interference check is made when the compensation plane (plane perpendicular to a tool direction vector) is changed.

<Example>

If the program below is executed, a PS0272 alarm (overcutting due to offsetting) is issued from N4.

```
O100 F3000
N1 G90 G00 X0 Y0 Z0 A-46 C180
N2 G41.2 D1
N3 G01 X100
N4 Y-200 Z-200
N5 A45
N6 Y-400 Z0
N7 X0
N8 Y-200 Z-200
N9 A-46
N10 Y0 Z0
N11 G40
M30
```
Fig. 22.5.1 (n) Conceptual Diagram

Fig. 22.5.1 (o) Tool Direction Vector

Fig. 22.5.1 (p) Compensation Vector at the End Point (Point B) of N4 (on Compensation Plane)
The move direction of $A'B'$ is opposite to that of $B'C'$, so that two compensation vectors, $V_1$ and $V_2$, are produced at point $B'$ (end point of N4). There is a possibility of overcutting in this case, so an alarm (PS0272) is issued from N4.

(1) Conditions for issuing the interference alarm
Suppose that the tool direction vector changes considerably from one block to another due to a move command for a rotation axis. In this case, an interference alarm is assumed because compensation vectors are regarded as being generated in the wrong directions when the path angle difference on the compensation plane is large, even though the angle difference of the directions of compensation vectors to be generated by those blocks is small.

Here, the compensation plane is perpendicular to the tool direction ($V_a$ in Fig. 14.14.1(q)) of the first of the two blocks. Specifically, the conditions below are used for issuing the alarm.

- $U_a : Vector \overrightarrow{AB}$
- $U_b : Vector \overrightarrow{BC}$
- $V_a : Tool direction vector between A and B$
- $V_b : Tool direction vector between B and C$
- $W_a : V_a \times U_a$
- $W_b : V_b \times U_b$

(Here, $\times$ represents an outer product operator.)

![Fig. 22.5.1 (q) Conceptual Diagram](image-url)
When all the following conditions are satisfied, an alarm (PS0272) issued.

(a) The tool direction vector changes remarkably.
\[ \alpha : \text{Angle for determination set in parameter No. 6261 (The default is } 45^\circ \). \]
\[ (V_a,V_b) \leq \cos(\alpha) \text{(Here, } (V_a,V_b) \text{ means an inner product.)} \]

(b) The difference between the directions of the compensation vectors to be generated is small.
\[ W_a : \text{Direction of a compensation vector to be generated by the AB block.} \]
\[ W_b : \text{Direction of a compensation vector to be generated by the BC block.} \]
\[ W_a = V_a \times U_a \]
\[ W_b = V_b \times U_b \]
\[ (W_a,W_b) \geq 0 \]

(c) The path angle difference on the compensation plane is large.
\[ (R_a,R_b) < 0 \]

(2) Suppressing the issue of the alarm with a Q command
By inserting a Q command into a block that issued the alarm, the issue of the alarm can be suppressed.

(a) Q1 command
By inserting a Q1 command, a vertical vector is generated.
Example) N4 Y–200 Z–200 Q1
At point B', a vector (V) perpendicular to A'B' is generated.

**Fig. 22.5.1 (s) Q1 Command**

A vertical vector can also be generated by specifying G41.2 or G42.1 in the next block as indicated in the example below.

Example) N6 G41.2 Y–400 Z0

(b) Q2 command

With a program specifying a linear–to–linear connection, up to two compensation vectors are generated. In this case, the second vector is deleted by inserting a Q2 command. The Q2 command has no effect on circular interpolation.

Example) N4 Y–200 Z–200 Q2

The second vector (V2) is deleted, and only V1 is used as a compensation vector.

**Fig. 22.5.1 (t) Q2 Command**

(c) Q3 command

By inserting a Q3 command, the issue of the alarm can be suppressed.

Example) N4 Y–200 Z–200 Q3

The two vectors (V1 and V2) are not deleted.

**Fig. 22.5.1 (u) Q3 Command**


22.5.2 Leading Edge Offset

Leading edge offset is a type of cutter compensation that is used when a workpiece is machined with the edge of a tool. A tool is automatically shifted by a specified cutter compensation value on the line where a plane formed by a tool direction vector and tool movement direction intersects a plane perpendicular to the tool axis direction.

![Fig. 22.5.2 (a) Reading edge offset](image)

**Format**

- **Leading edge offset**

  G41.3 D_;

- **Leading edge offset cancel**

  G40;

**NOTE**

1. G41.3 can be specified only in the G00 or G01 mode. In a block containing G41.3 or G40, only the addresses D, O, and N can be specified.
2. The block after a block containing a G41.3 command must contain a move command. In that block, however, tool movement in the same direction as the tool axis direction or the opposite direction cannot be specified.
3. No continuous–state G code that belongs to the same group as G00 and G01 can be specified in the G41.3 mode.

**Explanations**

- **Operation at compensation start–up and cancellation**

  Unlike tool side compensation the operation performed at leading edge compensation start–up and cancellation does not vary. When G41.3 is specified, the tool is moved by the amount of compensation (V_C) in the plane formed by the movement vector (V_M) of the block after a G41.3 block and the tool vector (V_T) obtained at the time of G41.3 specification. The tool movement is perpendicular to the tool vector. When G40 is specified, the tool is moved to cancel V_C. The following illustrates how the compensation is performed.
(1) When the tool vector is inclined in the direction the tool moves

![Diagram](image1)

Fig. 22.5.2 (b) When the tool vector is inclined in the direction the tool moves

(2) When the tool vector is inclined in the direction opposite to the direction the tool moves

![Diagram](image2)

Fig. 22.5.2 (c) When the tool vector is inclined in the direction opposite to the direction the tool moves

**Operation in the compensation mode**

The tool center moves so that a compensation vector ($V_C$) perpendicular to the tool vector ($V_T$) is created in the plane formed by the tool vector ($V_T$) at the end point of each block and the movement vector ($V_M$) of the next block.

![Diagram](image3)

Fig. 22.5.2 (d) Operation in the compensation mode

If a G code or M code that suppresses buffering is specified in the compensation mode, however, the compensation vector created immediately before the specification is maintained.

When a block involving no movement (including a block containing a move command for a rotation axis only) is specified, the movement vector of the block after the block involving no movement is used to create a compensation vector as shown below.
If block 3 involves no movement, the compensation vector of block 2 ($V_{C2}$) is created so that it is perpendicular to $V_{T2}$ and lies in the plane formed by the movement vector ($V_{M4}$) of block 4 and the tool vector ($V_{T2}$) at the end point of block 2.

**NOTE**

If two or more successive blocks involve no movement, the previously created compensation vector is maintained. However, such specification should be avoided.

### Block immediately before the offset cancel command (G40)

In the block immediately before the compensation cancel command (G40), a compensation vector is created from the movement vector of that block and the tool vector at the end point of the block as shown below:

The compensation vector ($V_{C2}$) of block 2 is created so that it is perpendicular to $V_{T2}$ and lies in the plane formed by the tool vector ($V_{T2}$) at the end point of block 2 and the movement vector ($V_{M2}$) of block 2.

### Method of compensation vector calculation

In leading edge compensation, the compensation vector is calculated as follows:

1. **Tool vector**
2. **Movement vector**
   
   The movement vector ($V_{Mn+1}$) of block $n+1$ is obtained from the following expression:

   $V_{Mn+1} = \begin{bmatrix} X_{n+1} - X_n \\ Y_{n+1} - Y_n \\ Z_{n+1} - Z_n \end{bmatrix}$

   $X_n$: Absolute coordinate value of X axis at end point of block n
   $Y_n$: Absolute coordinate value of Y axis at end point of block n
   $Z_n$: Absolute coordinate value of Z axis at end point of block n

3. **Compensation vector**
   
   The direction of the compensation vector ($V_{Cn}$) of block $n$ is defined as follows:
   
   (a) $(V_{Mn+1}, V_{Tn}) > 0$ (0deg < θ < 90deg.)
The compensation vector \( \mathbf{V}_{\text{Cn}} \) of block \( n \) is calculated from \( \mathbf{V}_{\text{Tn}} \) and \( \mathbf{V}_{\text{Mn+1}} \) as described below.

\[
R = \text{Offset value}
\]

\[
\mathbf{V} = \begin{bmatrix} V_{\text{TX}} \\ V_{\text{TY}} \\ V_{\text{TZ}} \end{bmatrix}
\]

\[
\mathbf{V}_{\text{Mn+1}} = \begin{bmatrix} V_{\text{MX}} \\ V_{\text{MY}} \\ V_{\text{MZ}} \end{bmatrix}
\]

\[
\mathbf{V} = \begin{bmatrix} V_{\text{TX}} \\ V_{\text{TY}} \\ V_{\text{TZ}} \end{bmatrix} = (\mathbf{V}_{\text{Mn+1}} \times \mathbf{V}_{\text{Tn}}) \times \mathbf{V}_{\text{Tn}}
\]

\[
V_{\text{TX}} (V_{\text{Mn+1}} V_{\text{TX}} - V_{\text{MX}} V_{\text{TZ}}) - V_{\text{TY}} (V_{\text{Mn+1}} V_{\text{TY}} - V_{\text{MY}} V_{\text{TZ}}) - V_{\text{TZ}} (V_{\text{Mn+1}} V_{\text{TZ}} - V_{\text{MZ}} V_{\text{TX}})
\]

Then,

(a) When \( (\mathbf{V}_{\text{Mn+1}}, \mathbf{V}_{\text{Tn}}) > 0 \) (0deg. < \( \theta \) < 90deg.)

\[
\mathbf{V}_{\text{Cn}} = \frac{R}{\sqrt{V_{\text{TX}}^2 + V_{\text{TY}}^2 + V_{\text{TZ}}^2}} \begin{bmatrix} V_{\text{TX}} \\ V_{\text{TY}} \\ V_{\text{TZ}} \end{bmatrix}
\]

(b) When \( (\mathbf{V}_{\text{Mn+1}}, \mathbf{V}_{\text{Tn}}) < 0 \) (90deg. < \( \theta \) < 180deg.)

\[
\mathbf{V}_{\text{Cn}} = \frac{-R}{\sqrt{V_{\text{TX}}^2 + V_{\text{TY}}^2 + V_{\text{TZ}}^2}} \begin{bmatrix} V_{\text{TX}} \\ V_{\text{TY}} \\ V_{\text{TZ}} \end{bmatrix}
\]
When the included angle $\theta$ between $V_{Mn+1}$ and $V_{Tn}$ is regarded as 0deg., 180deg., or 90deg., the compensation vector is created in a different way. So, when creating an NC program, note the following points:

1. Setting a variation range for regarding $\theta$ as 0deg., 180deg., or 90deg. When the included angle ($\theta$) between the tool vector ($V_T$) and the movement vector ($V_M$) becomes approximately 0deg., 180deg., or 90deg., the system regards $\theta$ as 0deg., 180deg., or 90deg., then creates a compensation vector which is different from the normal compensation vector. The variation range used for regarding $\theta$ as 0deg., 180deg., and 90deg. is or in parameter 6115. For example, suppose that the angle set in parameter 6115 is $\Delta \theta$.

(a) If $0 \leq \theta \leq \Delta \theta$, $\theta$ is regarded as 0deg.

(b) If $(180 - \Delta \theta) \leq \theta \leq 180$, $\theta$ is regarded as 180deg.

(c) If $(90 - \Delta \theta) \leq \theta \leq (90 + \Delta \theta)$, $\theta$ is regarded as 90deg.

2. Compensation vector when $\theta$ is regarded as 0deg. or 180deg. If $\theta$ is regarded as 0deg. or 180deg. when G41.3 is specified to start leading edge compensation, alarm PS998 is issued. This means that the tool vector of the current block and the movement vector of the
next block must not point in the same direction or in opposite
directions at start-up.
The previously created compensation vector is maintained other than
at start-up at all times.
If the included angles between $V_T2$ and $V_M3$, $V_T3$ and $V_M4$, and $V_T4$
and $V_M5$ are regarded as 05, the compensation
vector $V_C1$ of block 1 is maintained as the compensation vectors $V_C2$,
$V_C3$, and $V_C4$, of blocks 2, 3, and 4, respectively.

![Diagram](image)

**Fig. 22.5.2 (l) When $\theta=0$deg. Is Determined**

If the included angles between $V_T2$ and $V_M3$, $V_T3$ and $V_M4$, and $V_T4$
and $V_M5$ are regarded as 180deg., the compensation vector $V_C1$ of
block 1 is maintained as the compensation vectors $V_C2$, $V_C3$, and $V_C4$
of blocks 2, 3, and 4, respectively.

![Diagram](image)

**Fig. 22.5.2 (m) When $\theta=180$deg. Is Determined**

(3) Compensation vector when $\theta$ is regarded as 90deg.
If the previous compensation vector ($V_{Cn-1}$) points in the opposite
direction ($V_{Mn} \times V_{Tn-1}$) $\times V_{Tn-1}$ direction) to $V_{Mn}$ with respect to
$V_{Tn-1}$, the current compensation vector ($V_{Cn}$) is created so it points
in the ($V_{Mn+1} \times V_{Tn}$) $\times V_{Tn}$ direction.

![Diagram](image)

**Fig. 22.5.2 (n) When $\theta=90$deg. Is Determined (1)**

If the previous compensation vector ($V_{Cn-1}$) points in the same
direction ($-(V_{Mn} \times V_{Tn-1}) \times V_{Tn-1}$ direction) as $V_{Mn}$ with respect to
$V_{Tn-1}$, the current compensation vector ($V_{Cn}$) is created so it points in the
$-(V_{Mn+1} \times V_{Tn}) \times V_{Tn}$ direction.
22.5.3 Restrictions

- **G41.2, G42.2, and G41.3 modes**
  G41.2, G42.2, G41.3, and G40 are continuous-state G codes that belong to the same group. Therefore, the G41.2, G42.2, and G41.3 modes cannot exist at the same time.

- **Canned cycle command**
  Specify a canned cycle command in the compensation cancel mode (G40).

- **Command that must not be specified in two or more successive blocks**
  In the compensation mode, never successively specify two or more blocks that involve no movement. Blocks involving no movement include:
  - M05; M code output
  - S21; S code output
  - G04X1000; Dwell
  - G22X100000; Machining area setting
  - G10P01R100; Offset value setting
  - (G17)Z2000; Movement not in the offset plane (movement in the tool axis direction)
  - G90; O10; N20: Block containing no move command
  - Blocks regarded as involving no movement according to parameter 6114 (for tool side compensation only)

- **Reset**
  Resetting the system in a compensation mode (G41.2, G42.2, or G41.3) always results in the cancellation mode (G40).

- **Limitation of Functions**
  In the mode for this function, the following functions can be used, but the condition of each function cannot be changed
  - Inch/metric conversion
    The alarm is issued when the condition is changed by G20 or G21 command.
  - Mirror image
    The condition of DI signal cannot be changed.
  - Tool life management function
    The tool length compensation use the amount of the tool specified by tool life management function. The command for the tool life management function have to command before the 3 dimensional cutter compensation mode.
• Commands that cannot be specified

- One-digit F code feed
  The feedrate cannot be changed by using manual pulse generator.

In the mode for this function, the following commands cannot be used. The alarm is issued when the following commands are ordered:
- Custom macro B
- Exponential interpolation – G02.3, G03.3
- Dwell – G04
- Function concerning high-speed machining – G05
  (exclude G05P10000 and 05P0)
- AI precision control – G05.1Q1, G5.1Q0
- Hypothetical axis interpolation – G07
- Cylindrical interpolation – G07.1
- Advanced preview control – G08
  (Please use AI HPCC function)
- Polar coordinate interpolation – G12.1, G13.1
- Polar coordinate command – G15, G16
- Reference position return check – G27
- Reference position return – G28
- 2nd Reference position return – G30
- 3rd/4th Reference position return – G30
- Skip – G31
- Threading – G33
- Automatic tool length measurement – G37
- Normal direction control – G40.1, G41.1, G42.1
- Cutter compensation B, C – G41, G42, G39
- 3 dimensional cutter compensation – G41
- Wheel wear compensation – G41
- Tool offset – G45, G46, G47, G48
- Programmable mirror image – G50.1, G51.1
- Local coordinate system – G52
- Machine coordinate system – G53
- Single direction positioning – G60
- Automatic corner override – G62
- Tapping mode – G63
- Macro call – G65, G66, G67
  (Sub program call is available)
- Figure copy – G72.1, G72.2
- Canned cycles – G73–G79, G80, G81–G89, G98, G99
- Electric gear box – G80, G81
- Function for hobbing machine – G80, G81
- External motion function – G81
- Chopping – G81.1
– Small-hole peck drilling cycle – G83
– Changing workpiece coordinate system – G92
– Workpiece coordinate system preset – G92.1
– Feed per revolution – G95
– Constant surface speed control – G96, G97
– Infeed control – G160, G161
– NURBS interpolation – G06.2
– Workpiece coordinate system – G54, G54.1, G55, G56, G57, G58, G59
– M, S, T, and B functions with motion command

**Function that cannot be specified**

In the mode for this function, the following functions cannot be used. The warning message is displayed on the screen when the following functions are used:

– MDI intervention

In the mode for this function, the following functions cannot be used. The alarm (P/S5196) is issued when the following functions are used:

– Manual interruption operation
– Tool retract and recover
And, in the mode for this function, the following functions cannot be used:

– Flexible synchronous control
– Sequence number comparison and stop
  (The program is not stop at the specified sequence block in 3 dimensional cutter compensation mode.)
– Index table indexing
– Retrace function
  Retrace function cannot be used by the program which uses 3 dimensional cutter compensation.
– Rotary axis control
– Gentle normal direction control
– The command for the tool life management function
  (Tool life time is able to be counted in this mode, but the command for the tool life management function cannot be used.)
– Macro executor (Execution macro)
– Manual handle interruption operation
– External deceleration
  External deceleration is not available in this mode.

**Others**

3 dimensional cutter compensation function cannot be used with the following function.

– Angular axis control
– Arbitrary angular axis control

The limitation attaches about the combination of other NC instructions occasionally. Please refer to the manual of the each function.
## Alarms

<table>
<thead>
<tr>
<th>Number</th>
<th>Message</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>0037</td>
<td>CRC:PLANE CHANGE</td>
<td>An attempt was made to change the plane in the cutter compensation mode. To change the plane, cancel the cutter compensation mode.</td>
</tr>
</tbody>
</table>
| 0041   | CRC:INTERFERENCE  | The depth of the cut is too great during cutter compensation. Check the program. The criteria for judging interference are as follows:  
(1) The direction of movement of the programmed block differs from the direction of movement of the corresponding tool center path block by 90° or more or 270° or less. The check in this case can be disabled by setting CNC parameter No. 6001#1 to “1”.  
(2) In the case of an arc, the difference in angle between the start and end points of the programmed block differs by 180° or more with the difference in angle between the start and end points of the corresponding tool center path block. |
| 0033   | CRC:NO INTERSECTIO| There is not point of intersection of the compensated tool center path during cutter compensation.                                                                |
| 5196   | ILLEGAL AXIS OPERA| A function which cannot be used during HPCC function or 5-axis control function is being executed was commanded.                                                    |
| 5405   | ILLEGAL PARAMETER | The parameter settings (parameter Nos. 19610 to 19619) for determining the relationship between the axis of rotation and the rotation plane are incorrect.            |
| 5406   | G41.3/G40 FORMAT   | (1) A move instruction was specified in a block in which the G41.3 or G40 code is specified.  
(2) A G or M code which suppresses buffering was specified in the block in which the G41.3 code was specified. |
| 5407   | ILLEGAL COMMAND   | (1) A G code other than G00 or G01 in group 01 was specified in the G41.3 mode.  
(2) An offset (G code in group 07) was specified in the G41.3 mode.  
(3) The block following the block in which G41.3 (startup) was specified did not contain a move command. |
<table>
<thead>
<tr>
<th>Number</th>
<th>Message</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>5408</td>
<td>G41.3 ILLEGAL START_UP</td>
<td>(1) The G41.3 G code (startup) was specified in a group 01 mode for other than G00 and G01.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2) The angle formed by the tool direction vector and the movement direction vector was 0° or 180° degrees at startup.</td>
</tr>
<tr>
<td>5409</td>
<td>ILLEGAL PARAMETER IN G41.3</td>
<td>The parameter settings (parameter Nos. 19610 to 19619) for determining the relationship between the axis of rotation and the rotation plane are incorrect.</td>
</tr>
</tbody>
</table>
22.6
3–DIMENSIONAL CIRCULAR INTERPOLATION

General

Specifying an intermediate and end point on an arc enables circular interpolation in a 3–dimensional space.

Format

The command format is as follows:

G02.4X1 Y1 Z1 α1 β1 ; First block (mid–point of the arc)
X1 Y1 Z1 α1 β1 ; Second block (end point of the arc)

Or,

G03.4X1 Y1 Z1 α1 β1 ; First block (mid–point of the arc)
X1 Y1 Z1 α1 β1 ; Second block (end point of the arc)
α,β : Arbitrary axes other than the 3–dimensional circular interpolation axis (up to two axes)

Explanations

• G code group

G02.4 and G03.4 are modal G codes of group 01. They therefore remain effective until another G code in group 01 is specified.

• Start point, mid–point, and end point

An arc in a 3–dimensional space is uniquely defined with its start point (current position) and a specified intermediate point and end point, as shown below. Two command blocks are used to define this arc. The first command block specifies the tool path between the start point and intermediate point. The second command block specifies the tool path between the intermediate point and end point.
If the modal code is changed by specifying a code such as G01 with the end point not specified, the arc cannot be obtained, and alarm PS5432 is issued. During MDI operation, alarm PS5432 is also issued if a cycle start is applied with only the mid–point specified.

### Movement along axes other than the 3–dimensional circular interpolation axis

In addition to the 3–dimensional circular interpolation axis (X/Y/Z), up to two arbitrary axes (α/β) can be specified at a time. If α/β are omitted from the first block (mid–point specification) and are specified only in the second block (end point specification), the tool moves to the specified point along the α/β axes during movement from the mid–point of the arc to the end point. If α/β are omitted from the second block (end point specification) and are specified only in the first block (mid–point specification), the tool moves to the specified point along the α/β axes during movement from the start point of the arc to the mid–point.

### Incremental commands

With an incremental command, the position of the mid–point relative to the start point must be specified in the first block, and the position of the end point relative to the mid–point must be specified in the second block.

### Direction of rotation

The direction of rotation cannot be specified. The movement is the same regardless of whether G02.4 or G03.4 is specified.

### Single block

When operation is performed using a single block, one cycle start causes movement from the start point to the end point. A single–block stop is not performed between the first block (mid–point specification) and the second block (end point specification).

### Start point assumed if 3–dimensional circular interpolations are specified consecutively

If 3–dimensional circular interpolations are specified consecutively, the end point in one interpolation is assumed to be the start point in the next interpolation.

### Velocity command

Specify a tangential velocity along an arc in the three–dimensional space.

### Deceleration

In a mode other than AI high–precision contour control mode or AI nano–based high–precision contour control mode, deceleration is applied at the end point of the block immediately before the block that commands three–dimensional circular interpolation or the end point of that block. Then in–position check is performed.
Limitation

- Cases in which linear interpolation is performed
  - If the start point, mid-point, and end-point are on the same line, linear interpolation is performed.
  - If the start point coincides with the mid-point, the mid-point coincides with the end point, or the end point coincides with the start point, linear interpolation is performed up to the end point.
  - If the start point, mid-point, and end-point are on the same line and the end point lies between the start point and the mid-point, the tool first moves with linear interpolation from the start point to the mid-point, then returns from the mid-point to the end point with linear interpolation. Thus, the tool always passes through the specified point.

- Whole circles
  A whole circle (360° arc) cannot be specified. (This corresponds to the case in which linear interpolation is performed, as described earlier.)

- Compensation functions
  Before using this function, cancel the compensation functions of group 07, such as cutter radius compensation.

- Manual absolute
  While this function is in use, manual intervention is not possible with the manual absolute switch set to the ON position. If intervention is performed, alarm PS0713 is issued when operation restarts.

- Background graphic
  This function cannot be used with background graphic drawing.

- Limitation of Functions
  In the mode for this function, the following functions can be used, but the condition of each function cannot be changed
  - Inch/metric conversion
    The alarm is issued when the condition is changed by G20 or G21 command.
  - Mirror image
    The condition of DI signal cannot be changed.
  - Tool life management function
    The tool length compensation use the amount of the tool specified by tool life management function. The command for the tool life management function have to command before the 3 dimensional cutter compensation mode.
  - One-digit F code feed
    The feedrate cannot be changed by using manual pulse generator.
In the mode for this function, the following commands cannot be used. The alarm is issued when the following commands are ordered:

- Custom macro B
- Exponential interpolation – G02.3, G03.3
- Dwell – G04
- Function concerning high-speed machining
  (exclude G05P10000 and 05P0)
- AI precision control – G05.1Q1, G5.1Q0
- Hypothetical axis interpolation – G07
- Cylindrical interpolation – G07.1
- Advanced preview control – G08
  (Please use AI HPCC function)
- Polar coordinate interpolation – G12.1, G13.1
- Polar coordinate command – G15, G16
- Reference position return check – G27
- Reference position return – G28
- 2nd Reference position return – G30
- 3rd/4th Reference position return – G30
- Skip – G31
- Threading – G33
- Automatic tool length measurement – G37
- Normal direction control – G40.1, G41.1, G42.1
- Cutter compensation B, C – G41, G42, G39
- 3 dimensional cutter compensation – G41
- Wheel wear compensation – G41
- Tool offset – G45, G46, G47, G48
- Programmable mirror image – G50.1, G51.1
- Local coordinate system – G52
- Machine coordinate system – G53
- Single direction positioning – G60
- Automatic corner override – G62
- Tapping mode – G63
- Macro call – G65, G66, G67
  (Sub program call is available)
- Figure copy – G72.1, G72.2
- Canned cycles – G73–G79, G80, G81–G89, G98, G99
- Electric gear box – G80, G81
- Function for hobbing machine – G80, G81
- External motion function – G81
- Chopping – G81.1
- Small-hole peck drilling cycle – G83
- Changing workpiece coordinate system – G92
– workpiece coordinate system preset –G92.1
– Feed per revolution –G95
– Constant surface speed control –G96,G97
– Infeed control –G160,G161
– NURBS interpolation –G06.2
– Workpiece coordinate system –G54,G54.1,G55,G56,G57,G58,G59
– Three–dimensional coordinate conversion –G68
– Coordinate system rotation –G68
– Scaling –G50, G51
– Programmable mirror image –G50.1, G51.1
– Exact stop mode –G61
– Cutter compensation –G40, G41, G42
– Three–dimensional cutter compensation –G40, G41.2, G41.3, G42.2
– Data setting –G10
– Exact stop –G09
– Miscellaneous function
– Second auxiliary function
– Spindle function
– Tool function

**Function that cannot be specified**

In the mode for this function, the following functions cannot be used. The warning message is displayed on the screen when the following functions are used:

– MDI intervention

In the mode for this function, the following functions cannot be used. The alarm(P/S5196) is issued when the following functions are used:

– Manual interruption operation
– Tool retract and recover

And, in the mode for this function, the following functions cannot be used:

– Flexible synchronous control
– Sequence number comparison and stop
  (The program is not stop at the specified sequence block in 3-dimensional cutter compensation mode.)
– Index table indexing
– Retrace function
  Retrace function cannot be used by the program which uses 3-dimensional cutter compensation.
– Rotary axis control
– Gentle normal direction control
– The command for the tool life management function
  (Tool life time is able to be counted in this mode, but the command for the tool life management function cannot be used.)
- Macro executor (Execution macro)
- Manual handle interruption operation
- External deceleration
  - External deceleration is not available in this mode.
- Arbitrary chanfering/Cornner rounding

**Others**

3 dimensional cutter compensation function cannot be used with the following function.
- Angular axis control
- Arbitrary angular axis control

The limitation attaches about the combination of other NC instructions occasionally.
Please refer to the manual of the each function.

---

### Alarm

<table>
<thead>
<tr>
<th>Number</th>
<th>Message</th>
<th>Contents</th>
</tr>
</thead>
</table>
| 0710   | ILLEGAL COMMAND IN 3–D CIR                       | In a model state in which a 3–dimensional circular interpolation (G02.4 or G03.4) cannot be commanded, an attempt for such interpolation was made. An invalid code was commanded while in three–dimensional circular interpolation mode. This happens when:
- An M, S, T, or B code was commanded while a command that cancels three–dimensional circular interpolation was being executed (such a cancel command is another G code in group 01).
- The specified command was not one that cancels three–dimensional circular interpolation and includes G05P10000 or G05P0. |
| 0712   | G02.4/G03.4 FORMAT ERROR                         | Three–dimensional circular interpolation (G02.4 or G03.4) was commanded incorrectly.                                                                                                                                                                           |
| 0713   | MANUAL INTERVENTION IN G02.4/G03.4 (ABS ON)      | While 3–dimensional circular interpolation mode (G02.4 or G03.4) is in progress, manual operation was performed with the manual absolute switch turned on.                                                                                                     |
III. OPERATION
1. GENERAL
1.1 MANUAL OPERATION

Explanations

• Manual reference position return (See Section III–3.1)

The CNC machine tool has a position used to determine the machine position. This position is called the reference position, where the tool is replaced or the coordinate are set. Ordinarily, after the power is turned on, the tool is moved to the reference position. Manual reference position return is to move the tool to the reference position using switches and pushbuttons located on the operator’s panel.

The tool can be moved to the reference position also with program commands. This operation is called automatic reference position return (See Section II–6).
• The tool movement by manual operation

Using machine operator’s panel switches, pushbuttons, or the manual handle, the tool can be moved along each axis.

![Diagram](image)

**Fig. 1.1 (b) The tool movement by manual operation**

The tool can be moved in the following ways:

(i) Jog feed (See Section III–3.2)
   - The tool moves continuously while a pushbutton remains pressed.

(ii) Incremental feed (See Section III–3.3)
   - The tool moves by the predetermined distance each time a button is pressed.

(iii) Manual handle feed (See Section III–3.4)
   - By rotating the manual handle, the tool moves by the distance corresponding to the degree of handle rotation.
1.2 TOOL MOVEMENT BY PROGRAMMING—AUTOMATIC OPERATION

Automatic operation is to operate the machine according to the created program. It includes memory, MDI and DNC operations. (See Section III–4).

Explanations

• Memory operation

After the program is once registered in memory of CNC, the machine can be run according to the program instructions. This operation is called memory operation.

• MDI operation

After the program is entered, as an command group, from the MDI keyboard, the machine can be run according to the program. This operation is called MDI operation.

• DNC operation

In this mode of operation, the program is not registered in the CNC memory. It is read from the external input/output devices instead. This is called DNC operation. This mode is useful when the program is too large to fit the CNC memory.
1.3 AUTOMATIC OPERATION

Explanations

- Program selection
  Select the program used for the workpiece. Ordinarily, one program is prepared for one workpiece. If two or more programs are in memory, select the program to be used, by searching the program number (Section III–9.3).

![Fig. 1.3 (a) Program Selection for Automatic Operation](image)

- Start and stop
  Pressing the cycle start pushbutton causes automatic operation to start. By pressing the feed hold or reset pushbutton, automatic operation pauses or stops. By specifying the program stop or program termination command in the program, the running will stop during automatic operation. When one process machining is completed, automatic operation stops. (See Section III–4)

![Fig. 1.3 (b) Start and Stop for Automatic Operation](image)
• **Handle interruption**

While automatic operation is being executed, tool movement can overlap automatic operation by rotating the manual handle. (See Section III–4.8)

![Diagram showing handle interruption for automatic operation.](image)

**Fig. 1.3 (c) Handle Interruption for Automatic Operation**
Before machining is started, the automatic running check can be executed. It checks whether the created program can operate the machine as desired. This check can be accomplished by running the machine actually or viewing the position display change (without running the machine) (See Section III–5).

1.4.1 Check by Running the Machine

**Dry run**

Remove the workpiece, check only movement of the tool. Select the tool movement rate using the dial on the operator’s panel. (See Section III–5.4)

**Feedrate override**

Check the program by changing the feedrate specified in the program. (See Section III–5.2)
• Single block

When the cycle start pushbutton is pressed, the tool executes one operation then stops. By pressing the cycle start again, the tool executes the next operation then stops. The program is checked in this manner. (See Section III–5.5)

![Fig. 1.4.1 (c) Single Block](image)

1.4.2
How to View the Position Display Change without Running the Machine

Explanations
• Machine lock

![Fig. 1.4.2 Machine Lock](image)

• Auxiliary function lock

When automatic running is placed into the auxiliary function lock mode during the machine lock mode (See Sections III–5.1), all auxiliary functions (spindle rotation, tool replacement, coolant on/off, etc.) (See Section III–5.1) are disabled.
1.5 EDITING A PART PROGRAM

After a created program is once registered in memory, it can be corrected or modified from the MDI panel (See Section III–9). This operation can be executed using the part program storage/edit function.

Fig. 1.5 (a) Part Program Editing
1.6 DISPLAYING AND SETTING DATA

The operator can display or change a value stored in CNC internal memory by key operation on the MDI screen (See III–11).

![Diagram of MDI screen with CNC memory and data setting display]

**Explanations**

- **Offset value**

![Diagram of MDI screen with CNC memory showing offset values]

The tool has the tool dimension (length, diameter). When a workpiece is machined, the tool movement value depends on the tool dimensions. By setting tool dimension data in CNC memory beforehand, automatically generates tool routes that permit any tool to cut the workpiece specified by the program. Tool dimension data is called the offset value (See Section III–11.4.1).
• Displaying and setting operator’s setting data

Apart from parameters, there is data that is set by the operator in operation. This data causes machine characteristics to change.

For example, the following data can be set:

- Inch/Metric switching
- Selection of I/O devices
- Mirror image cutting on/off

The above data is called setting data (See Section III–11.4.3).

![Diagram showing machine shape, tool paths, and offset values](image)

**Fig. 1.6 (c) Offset Value**

![Diagram showing CNC memory flow](image)

**Fig. 1.6 (d) Displaying and Setting Operator’s setting data**
• Displaying and setting parameters

The CNC functions have versatility in order to take action in characteristics of various machines.
For example, CNC can specify the following:
• Rapid traverse rate of each axis
• Whether increment system is based on metric system or inch system.
• How to set command multiply/detect multiply (CMR/DMR)
Data to make the above specification is called parameters (See Section III–11.5.1).
Parameters differ depending on machine tool.

![Diagram showing the relationship between CNC memory, data setting, and machine operation]

• Data protection key

A key called the data protection key can be defined. It is used to prevent part programs, offset values, parameters, and setting data from being registered, modified, or deleted erroneously (See Section III–11).

![Diagram showing the protection key's role in data security]
1.7  DISPLAY

1.7.1 Program Display

The contents of the currently active program are displayed. In addition, the programs scheduled next and the program list are displayed. (See Section III–11.2.1)

```
PROGRAM  O1100  N00005

N1  G90  G17  G00  G41  D07  X250.0  Y550.0 ;
N2  G01  Y900.0  F150 ;
N3  X450.0 ;
N4  G03  X500.0  Y1150.0  R650.0 ;
N5  G02  X900.0  R-250.0 ;
N6  G03  X950.0  Y900.0  R650.0 ;
N7  G01  X1150.0 ;
N8  Y550.0 ;
N9  X700.0  Y650.0 ;
N10  X250.0  Y550.0 ;
N11  G00  G40  X0  Y0 ;

> _
MEM STOP  .....  .....  13 : 18 : 14

[ PRGRM ] [ CHECK ] [ CURRNT ] [ NEXT ] [ OPRT ]
```

The cursor indicates the currently executed location

```
PROGRAM  O1100  N00003

SYSTEM EDITION  B0A1 – 03
PROGRAM NO. USED  ’ 10  FREE ’  53
MEMORY AREA USED  ’ 960  FREE ’  5280

PROGRAM LIBRARY LIST
O0001  O0002  O0010  O0020  O0040  O0050
O0100  O0200  O1000  O1100

> _
EDIT  .....  .....  .....  13 : 18 : 14

[ PRGRM ] [ LIB ] [ ] [ ] [ JPRTK ]
```
1.7.2 Current Position Display

The current position of the tool is displayed with the coordinate values. The distance from the current position to the target position can also be displayed. (See Section III–11.1.1 to 11.1.3)

![Diagram of workpiece coordinate system]

1.7.3 Alarm Display

When a trouble occurs during operation, error code and alarm message are displayed on the screen. (See Section III–7.1)

See APPENDIX G for the list of error codes and their meanings.
1.7.4 Parts Count Display, Run Time Display

When this option is selected, two types of run time and number of parts are displayed on the screen. (See Section III–11.4.5)

When this option is selected, two types of run time and number of parts are displayed on the screen. (See Section III–11.4.5)

**ACTUAL POSITION (ABSOLUTE)**

| X   | 150.000 |
| Y   | 300.000 |
| Z   | 100.000 |

**PART COUNT** 18

**RUN TIME** 0H16M  **CYCLE TIME** 0H 1M 0S

**MEM STRT** . . .  **FIN** 20 : 22 : 23

**ABS**  [ ]  **REL**  [ ]  **ALL**  [ ]  [ ]  (OPRT)

1.7.5 Graphic Display

Programmed tool movement can be displayed on the following planes: (See Section III–12)

1) XY plane
2) YZ plane
3) XZ plane
4) Three dimensional display

(1) Display on the XY plane
(2) Display on the YZ plane
(3) Display on the XZ plane
(4) Three dimensional display (isometric)

*Fig. 1.7.5 (a) Graphic display*
1.8 DATA INPUT/OUTPUT

Programs, offset values, parameters, etc. input in CNC memory can be output to paper tape, cassette, or a floppy disk for saving. After once output to a medium, the data can be input into CNC memory.

Fig. 1.8 (a) Data Output
The available operational devices include the setting and display unit attached to the CNC, the machine operator’s panel, and external input/output devices such as a Handy File and etc.
2.1 SETTING AND DISPLAY UNITS

The setting and display units are shown in Subsections 2.1.1 to 2.1.5 of Part III.

7.2”/8.4” LCD–Mounted type CNC Control Unit . . . . . . III–2.1.1
9.5”/10.4” LCD–Mounted type CNC Control Unit . . . . . . III–2.1.2
Stand–Alone Type Small MDI Unit . . . . . . . . . . . . . . III–2.1.3
Stand–Alone Type Standard MDI Unit . . . . . . . . . . . . . III–2.1.4
Stand–Alone Type 61 Full Key MDI Unit . . . . . . . . . III–2.1.5
2.1.1
7.2”/8.4” LCD–Mounted
Type CNC Control Unit

2.1.2
9.5”/10.4” LCD–Mounted
Type CNC Control Unit
2.1.3
Stand–Alone Type
Small MDI Unit

![MDI Unit Diagram]

- Function keys
- Address/numeric keys
- Shift key
- Cancel (CAN) key
- Input key
- Edit keys
- Help key
- Reset key
- Cursor keys
- Page change keys
2.1.4
Stand–Alone Type
Standard MDI Unit

![Diagram of MDI Unit with keys labeled:]
- Help key
- Reset key
- Address/numeric keys
- Edit keys
- Cancel (CAN) key
- Input key
- Shift key
- Page change keys
- Cursor keys
- Function keys

- Q, N, G, P, 7, 8, 9
- A, T, U, Y, Z
- I, J, K, R
- M, S, T, L
- F, D, H, B
- /, EOF, CAN, INPUT
- PAGE, PAGE, POS, PROG, OFFSET, SETTING, CUSTOM
2.1.5
Stand–Alone Type 61
Full Key MDI Unit
### 2.2 EXPLANATION OF THE KEYBOARD

<table>
<thead>
<tr>
<th>Number</th>
<th>Name</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>RESET key</td>
<td>Press this key to reset the CNC, to cancel an alarm, etc.</td>
</tr>
<tr>
<td>2</td>
<td>HELP key</td>
<td>Press this button to use the help function when uncertain about the operation of an MDI key (help function). In case of 160i/180i/160is/180is, this key is assigned to “Esc” key of the personal computer.</td>
</tr>
<tr>
<td>3</td>
<td>Soft keys</td>
<td>The soft keys have various functions, according to the Applications. The soft key functions are displayed at the bottom of the screen.</td>
</tr>
<tr>
<td>4</td>
<td>Address and numeric keys</td>
<td>Press these keys to input alphabetic, numeric, and other characters.</td>
</tr>
<tr>
<td>5</td>
<td>SHIFT key</td>
<td>Some keys have two characters on their keytop. Pressing the &lt;SHIFT&gt; key switches the characters. Special character Ê is displayed on the screen when a character indicated at the bottom right corner on the keytop can be entered.</td>
</tr>
<tr>
<td>6</td>
<td>INPUT key</td>
<td>When an address or a numerical key is pressed, the data is input to the buffer, and it is displayed on the screen. To copy the data in the key input buffer to the offset register, etc., press the INPUT key. This key is equivalent to the [INPUT] key of the soft keys, and either can be pressed to produce the same result.</td>
</tr>
<tr>
<td>7</td>
<td>Cancel key</td>
<td>Press this key to delete the last character or symbol input to the key input buffer.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>When the key input buffer displays &gt;N001X100Z and the cancel key is pressed, Z is canceled and &gt;N001X100 is displayed.</td>
</tr>
<tr>
<td>8</td>
<td>Program edit keys</td>
<td>Press these keys when editing the program.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(In case of 160i/180i/160is/180is, this key is assigned to “Tab” key of the personal computer.)</td>
</tr>
<tr>
<td></td>
<td>ALTER</td>
<td>Alteration</td>
</tr>
<tr>
<td></td>
<td>INSERT</td>
<td>Insertion</td>
</tr>
<tr>
<td></td>
<td>DELETE</td>
<td>Deletion</td>
</tr>
<tr>
<td>9</td>
<td>Function keys</td>
<td>Press these keys to switch display screens for each function.</td>
</tr>
<tr>
<td></td>
<td>POS</td>
<td>See III – 2.3 for details of the function keys.</td>
</tr>
<tr>
<td></td>
<td>PROG</td>
<td>…</td>
</tr>
</tbody>
</table>
Table 2.2 Explanation of the MDI keyboard

<table>
<thead>
<tr>
<th>Number</th>
<th>Name</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Cursor move keys</td>
<td>There are four different cursor move keys.</td>
</tr>
<tr>
<td></td>
<td>![Cursor Move Keys]</td>
<td>: This key is used to move the cursor to the right or in the forward direction. The cursor is moved in short units in the forward direction.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>: This key is used to move the cursor to the left or in the reverse direction. The cursor is moved in short units in the reverse direction.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>: This key is used to move the cursor in a downward or forward direction. The cursor is moved in large units in the forward direction.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>: This key is used to move the cursor in an upward or reverse direction. The cursor is moved in large units in the reverse direction.</td>
</tr>
<tr>
<td>11</td>
<td>Page change keys</td>
<td>Two kinds of page change keys are described below.</td>
</tr>
<tr>
<td></td>
<td>![Page Change Keys]</td>
<td>: This key is used to changeover the page on the screen in the forward direction.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>: This key is used to changeover the page on the screen in the reverse direction.</td>
</tr>
</tbody>
</table>

Explanations

- **Key operation with 2–path control**

In the 2–path control, be sure to select the tool post for which data is specified, using the path selection switch on the machine operator’s panel. Then, perform keyboard operation, such as displaying or specifying various data items, and editing a program.
2.3 FUNCTION KEYS AND SOFT KEYS

The function keys are used to select the type of screen (function) to be displayed. When a soft key (section select soft key) is pressed immediately after a function key, the screen (section) corresponding to the selected function can be selected.

2.3.1 General Screen Operations

1. Press a function key on the MDI panel. The chapter selection soft keys that belong to the selected function appear.

2. Press one of the chapter selection soft keys. The screen for the selected chapter appears. If the soft key for a target chapter is not displayed, press the continuous menu key (next–menu key). In some cases, additional chapters can be selected within a chapter.

3. When the target chapter screen is displayed, press the operation selection key to display data to be manipulated.

4. To redisplay the chapter selection soft keys, press the return menu key.

The general screen display procedure is explained above. However, the actual display procedure varies from one screen to another. For details, see the description of individual operations.
Function keys are provided to select the type of screen to be displayed. The following function keys are provided on the MDI panel:

- **POS** Press this key to display the **position screen**.
- **PROG** Press this key to display the **program screen**.
- **OFFSET SETTING** Press this key to display the **offset/setting screen**.
- **SYSTEM** Press this key to display the **system screen**.
- **MESSAGE** Press this key to display the **message screen**.
- **GRAPH** Press this key to display the **graphics screen**.
- **CUSTOM** Press this key to display the **custom screen (conversational macro screen)**.
  
  In case of 160i/180i/160is/180is, this key is assigned to “Ctrl” key of the personal computer.

  In case of 160i/180i/160is/180is, this key is assigned to “Alt” key of the personal computer.
2.3.3 Soft Keys

To display a more detailed screen, press a function key followed by a soft key. Soft keys are also used for actual operations. The following illustrates how soft key displays are changed by pressing each function key.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="screen" /></td>
<td>Indicates screens</td>
</tr>
<tr>
<td><img src="image" alt="screen" /></td>
<td>Indicates a screen that can be displayed by pressing a function key (*1)</td>
</tr>
<tr>
<td><img src="image" alt="soft key" /></td>
<td>Indicates a soft key (*2)</td>
</tr>
<tr>
<td><img src="image" alt="input" /></td>
<td>Indicates input from the MDI panel.</td>
</tr>
<tr>
<td><img src="image" alt="green soft key" /></td>
<td>Indicates a soft key displayed in green.</td>
</tr>
<tr>
<td><img src="image" alt="continuous menu key" /></td>
<td>Indicates the continuous menu key (rightmost soft key) (*3).</td>
</tr>
</tbody>
</table>

*1 Press function keys to switch between screens that are used frequently.

*2 Some soft keys are not displayed depending on the option configuration.

*3 In some cases, the continuous menu key is omitted when the 12 soft keys display unit is used.
POSITION SCREEN  Soft key transition triggered by the function key  POS

Absolute coordinate display

ABS  [OPRT]  [PTSPRE]  [EXEC]
        [RUNPRE]  [EXEC]
        [WORK]  [ALLEXE] (Axis name)  [EXEC]

Relative coordinate display

REL  [OPRT]  (Axis or numeral)  [PRESET]
      [ORIGIN]  [ALLEXE]
      [PTSPRE]  [EXEC]
      [RUNPRE]  [EXEC]

Current position display

[ALL]  [OPRT]  (Axis or numeral)  [PRESET]
       [ORIGIN]  [ALLEXE]
       [PTSPRE]  [EXEC]
       [RUNPRE]  [EXEC]

Handle interruption

[HNDL]  [OPRT]  [PTSPRE]  [EXEC]
        [RUNPRE]  [EXEC]

Monitor screen

[MONI]  [OPRT]  [PTSPRE]  [EXEC]
        [RUNPRE]  [EXEC]
PROGRAM SCREEN

Soft key transition triggered by the function key in the MEM mode

Program display screen

[PRGRM] - [(OPRT)]

See “When the soft key [BG–EDT] is pressed”

[O number] - [O SRH]

[REWIND]

[BG–EDT]

[N number] - [N SRH]

[REWIND]

[REWIND]

[P TYPE]

[Q TYPE]

[F SRH] - [CAN]

[CAN]

(N number) - [EXEC]

Program check display screen

[CHECK] - [ABS] - [(OPRT)]

See “When the soft key [BG–EDT] is pressed”

[BG–EDT]

[O number] - [O SRH]

[REWIND]

[REWIND]

[P TYPE]

[Q TYPE]

[F SRH] - [CAN]

[CAN]

(N number) - [EXEC]

Current block display screen

[CURRNT] - [(OPRT)] - [BG–EDT]

See “When the soft key [BG–EDT] is pressed”

Next block display screen

[NEXT] - [(OPRT)] - [BG–EDT]

See “When the soft key [BG–EDT] is pressed”

Program restart display screen

[RSTR] - [(OPRT)] - [BG–EDT]

See “When the soft key [BG–EDT] is pressed”

(2)(Continued on the next page)
(2) [FL.SDL] [PRGRM]  Return to (1) (Program display)

File directory display screen
(DIR) [OPRT] [SELECT] (number) [F SET] [EXEC]

Schedule operation display screen
[SCHDUL] [OPRT] [CLEAR] [CAN] [EXEC] (Schedule data) [INPUT]
2. OPERATIONAL DEVICES

PROGRAM SCREEN

Soft key transition triggered by the function key in the EDIT mode

[PRGRM] – [OPRT]

- See "When the soft key [BG–EDT] is pressed"

[BG–EDT] (O number) [O SRH]

[SRFL] (Address) [SRHT]

[REWIND]

[F SRH] (N number) [EXEC]

[CAN] [READ] [CHAIN] (The cursor moves to the end of a program.)

[STOP] (O number) [EXEC]

[CAN] [PUNCH] [STOP] (O number) [EXEC]

[CAN] [DELETE] [CAN] (N number) [EXEC]

[EX–EDT] [COPY] (O number) [EXEC]

[CRSR−] [CRSR] [BTTM] [ALL]

[MOVE] [CRSR−] (O number) [EXEC]

[CRSR] [BTTM] [ALL]

[MERGE] [CRSR] (O number) [EXEC]

[BTTM]

[CHANGE] (Address) [BEFORE]

(Address) [AFTER] [SKIP]

[T–EXEC] [EXEC]

(1) (Continued on the next page)
When a G number is omitted, the standard screen appears.
PROGRAM SCREEN

Soft key transition triggered by the function key in the MDI mode

Program display

[PRGRM]—[(OPRT)]—[BG—EDT] ⇔ See “When the soft key [BG—EDT] is pressed”

Program input screen

[MDI]—[(OPRT)]—[BG—EDT] ⇔ See “When the soft key [BG—EDT] is pressed”

Current block display screen

[CURRNT]—[(OPRT)]—[BG—EDT] ⇔ See “When the soft key [BG—EDT] is pressed”

Next block display screen

[NEXT]—[(OPRT)]—[BG—EDT] ⇔ See “When the soft key [BG—EDT] is pressed”

Program restart display screen

[RSTR]—[(OPRT)]—[BG—EDT] ⇔ See “When the soft key [BG—EDT] is pressed”
2. OPERATIONAL DEVICES

OPERATION

B–63534EN/02

[PROGRAM SCREEN] Soft key transition triggered by the function key in the HNDL, JOG, or REF mode

PROG

Program display


Current block display screen


Next block display screen


Program restart display screen


[PROGRAM SCREEN] Soft key transition triggered by the function key in the TJOG or THDL mode

PROG

Program display


(O number) — [SRH ↓]

(O number) — [SRH ↑]

(Address) — [SRH↑]

(Address) — [SRHT]

[REWIND]

Program directory display


(O number) — [O SRH]  \(\Rightarrow\) Return to the program
PROGRAM SCREEN

Soft key transition triggered by the function key \text{\texttt{PROG}}
(When the soft key \text{\texttt{BG–EDT}} is pressed in all modes)

(1)(Continued on the next page)
Program directory display

[LIB] (OPRT) [BG-EDT] (O number) [O SRH] ➞ Return to the program

[READ]

[CHAIN]

[STOP]

[CAN]

[O number] [EXEC]

[PUNCH]

[CHAIN]

[STOP]

[CAN]

[O number] [EXEC]

Graphic Conversational Programming

[C.A.P.] [PRGRM] ➞ Return to the program

[G.MENU]

(G number) [BLOCK] (Data) [INPUT]

When a G number is omitted, the standard screen appears.

[(OPRT)] [INPUT]

Floppy directory display

[FLOPPY] [PRGRM] ➞ Return to the program

[DIR] (OPRT)

[F SRH]

[number] [F SET]

[CAN]

[EXEC]

[READ]

[number] [F SET]

[CAN]

[EXEC]

[O number] [O SET]

[STOP]

[CAN]

[EXEC]

[PUNCH]

[number] [F SET]

[CAN]

[EXEC]

[DELETE]

[number] [F SET]

[CAN]

[EXEC]
2. OPERATIONAL DEVICES
SYSTEM SCREEN

Soft key transition triggered by the function key [SYSTEM]

Parameter screen

[PARAM] (OPRT) [NUM (Numeral)] [ON:1] [OFF:0] [NO SRH]

[READ] [CAN] [EXEC] [PUNCH] [CAN] [EXEC]

Diagnosis screen

[DGNOS] (OPRT) [NUM (Number)] [NO SRH]

PMC screen

[PMC]

System configuration screen

[System]

ID information screen : αi servo information screen

[System] [SV-INF]

ID information screen : αi spindle information screen

[System] [SP-INF]

Note) Search for the start of the file using the PRGRM screen for read/punch.
Note) Search for the start of the file using the PRGRM screen for read/punch.
### MESSAGE SCREEN
Soft key transition triggered by the function key **MESSAGE**
- **MESSAGE**
  - Alarm display screen
  - [ALARM]
  - Message display screen
  - [MSG]
  - Alarm history screen
  - [HISTORY] — [OPRT] — [CLEAR]

### HELP SCREEN
Soft key transition triggered by the function key **HELP**
- **HELP**
  - Alarm detail screen
    - [ALAM] — [OPRT] — [SELECT]
  - Operation method screen
    - [OPR] — [OPRT] — [SELECT]
  - Parameter table screen
    - [PARA]
GRAPHIC SCREEN

Soft key transition triggered by the function key

Tool path graphics

GRAPH

- [PARAM]
- [EXEC] → (OPRT)

- [AUTO]
- [STSRT]
- [STOP]
- [REWIND]
- [CLEAR]

- [ZOOM] → (OPRT)
- [EXEC]

- [←]
- [→]
- [↑]
- [↓]

- [POS]

Solid graphics

GRAPH

- [PARAM]
- [BLANK] → (OPRT)

- [ANEW]
- [+ROT]
- [-ROT]
- [+TILT]
- [-TILT]

- [EXEC] → (OPRT)

- [A.ST]
- [F.ST]
- [STOP]
- [REWIND]

- [REVIEW] → (OPRT)

- [ANEW]
- [+ROT]
- [-ROT]
- [+TILT]
- [-TILT]

- [PARAM]
- [3–PLN] → (OPRT)

- [→]
- [←]
- [↑]
- [↓]

- [POS]
When an address and a numerical key are pressed, the character corresponding to that key is input once into the key input buffer. The contents of the key input buffer is displayed at the bottom of the CRT screen.

In order to indicate that it is key input data, a “>” symbol is displayed immediately in front of it. A “_” is displayed at the end of the key input data indicating the input position of the next character.

Key input buffer display

To input the lower character of the keys that have two characters inscribed on them, first press the [SHIFT] key and then the key in question.

When the [SHIFT] key is pressed, “_” indicating the next character input position changes to “~”. Now lowercase characters can be entered (shift state).

When a character is input in shift status the shift status is canceled. Furthermore, if the [SHIFT] key is pressed in shift status, the shift status is canceled.

It is possible to input up to 32 characters at a time in the key input buffer. Press the [CAN] key to cancel a character or symbol input in the key input buffer.

(Example)

When the key input buffer displays

> N001X100Z_

and the cancel [CAN] key is pressed, Z is canceled and

> N001X100_

is displayed.
2.3.5 Warning Messages

After a character or number has been input from the MDI panel, a data check is executed when the [Input] key or a soft key is pressed. In the case of incorrect input data or the wrong operation a flashing warning message will be displayed on the status display line.

![Diagram](image_url)

Table 2.3.5 Warning Messages

<table>
<thead>
<tr>
<th>Warning message</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>FORMAT ERROR</td>
<td>The format is incorrect.</td>
</tr>
<tr>
<td>WRITE PROTECT</td>
<td>Key input is invalid because of data protect key or the parameter is not write enabled.</td>
</tr>
<tr>
<td>DATA IS OUT OF RANGE</td>
<td>The input value exceeds the permitted range.</td>
</tr>
<tr>
<td>TOO MANY DIGITS</td>
<td>The input value exceeds the permitted number of digits.</td>
</tr>
<tr>
<td>WRONG MODE</td>
<td>Parameter input is not possible in any mode other than MDI mode.</td>
</tr>
<tr>
<td>EDIT REJECTED</td>
<td>It is not possible to edit in the current CNC status.</td>
</tr>
</tbody>
</table>
2.3.6 Soft Key Configuration

There are 12 soft keys in the 10.4" LCD/MDI or 9.5" LCD/MDI. As illustrated below, the 5 soft keys on the right and those on the right and left edges operate in the same way as the 7.2" LCD or 8.4" LCD, whereas the 5 keys on the left hand side are expansion keys dedicated to the 10.4" LCD or 9.5" LCD.

![Diagram of LCD soft key configuration]

Whenever a position display appears in the left half of the screen after a function key other than POS is pressed, the soft keys on the left half of the soft key display area are displayed as follows:

![Diagram of soft key display]

The soft key corresponding to the position display is indicated in reverse video.

This manual may refer to 10.4" and 9.5" LCD display units as 12 soft key types, and 7.2" and 8.4" LCD display units as 7 soft key types.
2.4 EXTERNAL I/O DEVICES

External input/output devices such as FANUC Handy File and so forth are available. For details on the devices, refer to the manuals listed below.

Table 2.4 (a) External I/O device

<table>
<thead>
<tr>
<th>Device name</th>
<th>Usage</th>
<th>Max. storage capacity</th>
<th>Reference manual</th>
</tr>
</thead>
<tbody>
<tr>
<td>FANUC Handy File</td>
<td>Easy-to-use, multi function input/output device. It is designed for FA equipment and uses floppy disks.</td>
<td>3600m</td>
<td>B–61834E</td>
</tr>
</tbody>
</table>

The following data can be input/output to or from external input/output devices:
1. Programs
2. Offset data
3. Parameters
4. Custom macro common variables
For how to input or output data and input data from or output it to a memory card, see III–8.
Before an external input/output device can be used, parameters must be set as follows.

This CNC has a total of three channels of reader/puncher and remote buffer interfaces. It also has a memory card interface. The input/output device to be used is specified by setting the channel (interface) connected to that device in setting parameter I/O CHANNEL.

The specified data, such as a baud rate and the number of stop bits, of an input/output device connected to a specific channel must be set in parameters for that channel in advance. (These settings are not required for the memory card interface.)

For channel 1, two combinations of parameters to specify the input/output device data are provided.

The following shows the interrelation between the reader/puncher interface parameters for the channels.
2.4.1 FANUC Handy File

The Handy File is an easy-to-use, multi function floppy disk input/output device designed for FA equipment. By operating the Handy File directly or remotely from a unit connected to the Handy File, programs can be transferred and edited.

The Handy File uses 3.5-inch floppy disks, which do not have the problems of paper tape (i.e., noisy during input/output, easily broken, and bulky).

One or more programs (up to 1.44M bytes, which is equivalent to the memory capacity of 3600-m paper tape) can be stored on one floppy disk.
2.5
POWER ON/OFF

2.5.1
Turning on the Power

Procedure of turning on the power

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check that the appearance of the CNC machine tool is normal. (For example, check that front door and rear door are closed.)</td>
</tr>
<tr>
<td>2</td>
<td>Turn on the power according to the manual issued by the machine tool builder.</td>
</tr>
<tr>
<td>3</td>
<td>After the power is turned on, check that the position screen is displayed. An alarm screen is displayed if an alarm occurs upon power–on. If the screen shown in Section III–2.5.2 is displayed, a system failure may have occurred.</td>
</tr>
<tr>
<td>4</td>
<td>Check that the fan motor is rotating.</td>
</tr>
</tbody>
</table>

**WARNING**

Until the positional or alarm screen is displayed at the power on, do not touch them. Some keys are used for the maintenance or special operation purpose. When they are pressed, unexpected operation may be caused.
2.5.2 Screen Displayed at Power–on

If a hardware failure or installation error occurs, the system displays one of the following three types of screens then stops. Information such as the type of printed circuit board installed in each slot is indicated. This information and the LED states are useful for failure recovery.

Slot status display

For more information about the types of printed circuit boards and module functions, refer to the maintenance manual (B–63525EN).
Screen indicating module setting status

B0H1 – 01

**SLOT 01 (3046): END**

**SLOT 02 (3050):**

- **END:** Setting completed
- **Blank:** Setting not completed

Module ID
Slot number

Display of software configuration

B0H1 – 01

**CNC control software**

**SERVO:** 90B0–01
**SUB:** xxxx–xx
**OMM:** yyyy–yy
**PMC:** zzzz–zz

Digital servo ROM
Sub CPU (remote buffer)
Order–mademacro/macro compiler
PMC

The software configuration can be displayed on the system configuration screen also. Refer to the MAINTENANCE MANUAL (B–63525EN) for the system configuration screen.

2.5.3 Power Disconnection

**Power Disconnection**

**Procedure**

1. Check that the LED indicating the cycle start is off on the operator’s panel.
2. Check that all movable parts of the CNC machine tool is stopping.
3. If an external input/output device such as the Handy File is connected to the CNC, turn off the external input/output device.
4. Continue to press the POWER OFF pushbutton for about 5 seconds.
5. Refer to the machine tool builder’s manual for turning off the power to the machine.
MANUAL OPERATION are six kinds as follows :
3.1 Manual reference position return
3.2 Jog feed
3.3 Incremental feed
3.4 Manual handle feed
3.5 Manual absolute on and off
3.6 Tool axis direction handle feed/Tool axis direction handle feed B
3.7 Manual linear/circular interpolation
3.8 Manual rigid tapping
3.9 Manual numeric command
3.1 MANUAL REFERENCE POSITION RETURN

The tool is returned to the reference position as follows:

The tool is moved in the direction specified in parameter ZMI (bit 5 of No. 1006) for each axis with the reference position return switch on the machine operator’s panel. The tool moves to the deceleration point at the rapid traverse rate, then moves to the reference position at the FL speed. The rapid traverse rate and FL speed are specified in parameters (No. 1420, 1421, and 1425).

Fourstep rapid traverse override is effective during rapid traverse. When the tool has returned to the reference position, the reference position return completion LED goes on. The tool generally moves along only a single axis, but can move along three axes simultaneously when specified so in parameter JAX(bit 0 of No.1002).

---

**Procedure for Manual Reference Position Return**

1. Press the reference position return switch, one of the mode selection switches.

2. To decrease the feedrate, press a rapid traverse override switch. When the tool has returned to the reference position, the reference position return completion LED goes on.

3. Press the feed axis and direction selection switch corresponding to the axis and direction for reference position return. Continue pressing the switch until the tool returns to the reference position. The tool can be moved along three axes simultaneously when specified so in an appropriate parameter setting. The tool moves to the deceleration point at the rapid traverse rate, then moves to the reference position at the FL speed set in a parameter.

4. Perform the same operations for other axes, if necessary. The above is an example. Refer to the appropriate manual provided by the machine tool builder for the actual operations.
Explanations

- **Automatically setting the coordinate system**
  Bit 0 (ZPR) of parameter No. 1201 is used for automatically setting the coordinate system. When ZPR is set, the coordinate system is automatically determined when manual reference position return is performed.
  When \( \alpha, \beta \) and \( \gamma \) are set in parameter 1250, the workpiece coordinate system is determined so that reference point on the tool holder or the position of the tip of the reference tool is \( X = \alpha, Y = \beta, Z = \gamma \) when reference position return is performed. This has the same effect as specifying the following command for reference position return:
  \[ G92X_{\alpha}Y_{\beta}Z_{\gamma}; \]
  However, when options of the workpiece coordinate system is selected, it is not able to use.

Restrictions

- **Moving the tool again**
  Once the REFERENCE POSITION RETURN COMPLETION LED lights at the completion of reference position return, the tool does not move unless the REFERENCE POSITION RETURN switch is turned off.

- **Reference position return completion LED**
  The REFERENCE POSITION RETURN COMPLETION LED is extinguished by either of the following operations:
  - Moving from the reference position.
  - Entering an emergency stop state.

- **The distance to return to reference position**
  For the distance (Not in the deceleration condition) to return the tool to the reference position, refer to the manual issued by the machine tool builder.
3.2 JOG FEED

In the jog mode, pressing a feed axis and direction selection switch on the machine operator’s panel continuously moves the tool along the selected axis in the selected direction.

The jog feedrate is specified in a parameter (No.1423)

The jog feedrate can be adjusted with the jog feedrate override dial. Pressing the rapid traverse switch moves the tool at the rapid traverse feedrate (No. 1424) regardless of the position of the jog feedrate override dial. This function is called the manual rapid traverse.

Manual operation is allowed for one axis at a time. 3 axes can be selected at a time by parameter JAX (No.1002#0).

While a switch is pressed, the tool moves in the direction specified by the switch.

Procedure for JOG feed

1. Press the jog switch, one of the mode selection switches.
2. Press the feed axis and direction selection switch corresponding to the axis and direction the tool is to be moved. While the switch is pressed, the tool moves at the feedrate specified in a parameter (No. 1423). The tool stops when the switch is released.
3. The jog feedrate can be adjusted with the jog feedrate override dial.
4. Pressing the rapid traverse switch while pressing a feed axis and direction selection switch moves the tool at the rapid traverse rate while the rapid traverse switch is pressed. Rapid traverse override by the rapid traverse override switches is effective during rapid traverse.

The above is an example. Refer to the appropriate manual provided by the machine tool builder for the actual operations.
Limitations

- **Acceleration/deceleration for rapid traverse**
  Feedrate, time constant and method of automatic acceleration/deceleration for manual rapid traverse are the same as G00 in programmed command.

- **Change of modes**
  Changing the mode to the jog mode while pressing a feed axis and direction selection switch does not enable jog feed. To enable jog feed, enter the jog mode first, then press a feed axis and direction selection switch.

- **Rapid traverse prior to reference position return**
  If reference position return is not performed after power–on, pushing RAPID TRAVERSE button does not actuate the rapid traverse but the remains at the JOG feedrate. This function can be disabled by setting parameter RPD (No.1401#01).
In the incremental (INC) mode, pressing a feed axis and direction selection switch on the machine operator’s panel moves the tool one step along the selected axis in the selected direction. The minimum distance the tool is moved is the least input increment. Each step can be 10, 100, or 1000 times the least input increment. This mode is effective when a manual pulse generator is not connected.

Procedure for Incremental Feed

1. Press the INC switch, one of the mode selection switches.
2. Select the distance to be moved for each step with the magnification dial.
3. Press the feed axis and direction selection switch corresponding to the axis and direction the tool is to be moved. Each time a switch is pressed, the tool moves one step. The feedrate is the same as the jog feedrate.
4. Pressing the rapid traverse switch while pressing a feed axis and direction selection switch moves the tool at the rapid traverse rate. Rapid traverse override by the rapid traverse override switch is effective during rapid traverse.

The above is an example. Refer to the appropriate manual provided by the machine tool builder for the actual operations.
In the handle mode, the tool can be minutely moved by rotating the manual pulse generator on the machine operator’s panel. Select the axis along which the tool is to be moved with the handle feed axis selection switches.

The minimum distance the tool is moved when the manual pulse generator is rotated by one graduation is equal to the least input increment. Or the distance the tool is moved when the manual pulse generator is rotated by one graduation can be magnified by 10 times or by one of the two magnifications specified by parameters (No. 7113 and 7114).

**Procedure for Manual Handle Feed**

1. Press the HANDLE switch, one of the mode selection switches.
2. Select the axis along which the tool is to be moved by pressing a handle feed axis selection switch.
3. Select the magnification for the distance the tool is to be moved by pressing a handle feed magnification switch. The minimum distance the tool is moved when the manual pulse generator is rotated by one graduation is equal to the least input increment.
4. Move the tool along the selected axis by rotating the handle. Rotating the handle 360 degrees moves the tool the distance equivalent to 100 graduations.

The above is an example. Refer to the appropriate manual provided by the machine tool builder for the actual operations.
Explanations

- **Availability of manual pulse generator in Jog mode (JHD)**
  
  Parameter JHD (bit 0 of No. 7100) enables or disables the manual handle feed in the JOG mode. When the parameter JHD (bit 0 of No. 7100) is set 1, both manual handle feed and incremental feed are enabled.

- **Availability of manual pulse generator in TEACH IN JOG mode (THD)**
  
  Parameter THD (bit 1 of No. 7100) enables or disables the manual handle feed in the TEACH IN JOG mode.

- **A command to the MPG exceeding rapid traverse rate (HPF)**
  
  Parameter HPF (bit 4 of No. 7100) or (No. 7117) specifies as follows:
  
  - **Parameter HPF (bit 4 of No. 7100)**
    
    **Set value 0:** The feedrate is clamped at the rapid traverse rate and generated pulses exceeding the rapid traverse rate are ignored. (The distance the tool is moved may not match the graduations on the manual pulse generator.)
    
    **Set value 1:** The feedrate is clamped at the rapid traverse rate and generated pulses exceeding the rapid traverse rate are not ignored but accumulated in the CNC. (No longer rotating the handle does not immediately stop the tool. The tool is moved by the pulses accumulated in the CNC before it stops.)

  - **Parameter HPF (No. 7117) (It is available when parameter HPF is 0.)**
    
    **Set value 0:** The feedrate is clamped at the rapid traverse rate and generated pulses exceeding the rapid traverse rate are ignored. (The distance the tool is moved may not match the graduations on the manual pulse generator.)
    
    **Other than 0:** The feedrate is clamped at the rapid traverse rate and generated pulses exceeding the rapid traverse rate are not ignored but accumulated in the CNC until the limit specified in parameter No. 7117 is reached. (No longer rotating the handle does not immediately stop the tool. The tool is moved by the pulses accumulated in the CNC before it stops.)

- **Movement direction of an axis to the rotation of MPG (HNGx)**
  
  Parameter HNGx (No. 7102 #0) switches the direction of MPG in which the tool moves along an axis, corresponding to the direction in which the handle of the manual pulse generator is rotated.
Restrictions

- **Number of MPGs**

  Up to three manual pulse generators can be connected, one for each axis. The three manual pulse generators can be simultaneously operated.

  **WARNING**
  Rotating the handle quickly with a large magnification such as x100 moves the tool too fast. The feedrate is clamped at the rapid traverse feedrate.

  **NOTE**
  Rotate the manual pulse generator at a rate of five rotations per second or lower. If the manual pulse generator is rotated at a rate higher than five rotations per second, the tool may not stop immediately after the handle is no longer rotated or the distance the tool moves may not match the graduations on the manual pulse generator.
Whether the distance the tool is moved by manual operation is added to the coordinates can be selected by turning the manual absolute switch on or off on the machine operator’s panel. When the switch is turned on, the distance the tool is moved by manual operation is added to the coordinates. When the switch is turned off, the distance the tool is moved by manual operation is not added to the coordinates.

![Diagram showing coordinates with the switch ON](Fig. 3.5 (a) Coordinates with the switch ON)

The coordinates do not change.

![Diagram showing coordinates with the switch OFF](Fig. 3.5 (b) Coordinates with the switch OFF)
The following describes the relation between manual operation and coordinates when the manual absolute switch is turned on or off, using a program example.

```
G01 G90 X100.0 Y150.0 F010 ; 1
X200.0 Y150.0 ; 2
X300.0 Y200.0 ; 3
```

The subsequent figures use the following notation:

- Movement of the tool when the switch is on
- Movement of the tool when the switch is off

The coordinates after manual operation include the distance the tool is moved by the manual operation. When the switch is off, therefore, subtract the distance the tool is moved by the manual operation.

- **Manual operation after the end of block**
  Coordinates when block 2 has been executed after manual operation (X-axis +20.0, Y-axis +100.0) at the end of movement of block.

- **Manual operation after a feed hold**
  Coordinates when the feed hold button is pressed while block 2 is being executed, manual operation (Y-axis +75.0) is performed, and the cycle start button is pressed and released.
• When reset after a manual operation following a feed hold

Coordinates when the feed hold button is pressed while block \( C0019 \) is being executed, manual operation (Y-axis +75.0) is performed, the control unit is reset with the RESET button, and block \( C0019 \) is read again.

```
(150.0 , 200.0)
(200.0, 225.0)
(100.0 , 100.0)
(150.0 , 125.0)
(150.0 , 200.0)
(300.0 , 200.0)
(300.0 , 275.0)
```

• When a movement command in the next block is only one axis

When there is only one axis in the following command, only the commanded axis returns.

```
N1G01X100.0Y100.0F500;
N2X200.0;
N3Y150.0;
```

• When the next move block is an incremental

When the following commands are incremental commands, operation is the same as when the switch is OFF.

• Manual operation during cutter compensation

When the switch is OFF

After manual operation is performed with the switch OFF during cutter compensation, automatic operation is restarted then the tool moves parallel to the movement that would have been performed if manual movement had not been performed. The amount of separation equals to the amount that was performed manually.
When the switch is ON during cutter compensation
Operation of the machine upon return to automatic operation after manual intervention with the switch is ON during execution with an absolute command program in the cutter compensation mode will be described. The vector created from the remaining part of the current block and the beginning of the next block is shifted in parallel. A new vector is created based on the next block, the block following the next block and the amount of manual movement. This also applies when manual operation is performed during cornering.

Manual operation performed in other than cornering
Assume that the feed hold was applied at point $P_H$ while moving from $P_A$ to $P_B$ of programmed path $P_A$, $P_B$, and $P_C$ and that the tool was manually moved to $P_H'$. The block end point $P_B$ moves to the point $P_B'$ by the amount of manual movement, and vectors $V_{B1}$ and $V_{B2}$ at $P_B$ also move to $V_{B1'}$ and $V_{B2'}$. Vectors $V_{C1}$ and $V_{C2}$ between the next two blocks $P_B - P_C$ and $P_C - P_D$ are discarded and new vectors $V_{C1'}$ and $V_{C2'}$ ($V_{C2'} = V_{C2}$ in this example) are produced from the relation between $P_B' - P_C$ and $P_C - P_D$. However, since $V_{B2'}$ is not a newly calculated vector, correct offset is not performed at block $P_B' - P_C$. Offset is correctly performed after $P_C$. 

![Diagram showing cutter path before and after manual operation.](image)
Manual operation during cornering
This is an example when manual operation is performed during cornering. \(V_{A2}', V_{B1}',\) and \(V_{B2}'\) are vectors moved in parallel with \(V_{A2}, V_{B1}\) and \(V_{B2}\) by the amount of manual movement. The new vectors are calculated from \(V_{C1}\) and \(V_{C2}\). Then correct cutter compensation is performed for the blocks following \(P_c\).

**Manual operation after single block stop**
Manual operation was performed when execution of a block was terminated by single block stop. Vectors \(V_{B1}\) and \(V_{B2}\) are shifted by the amount of manual operation. Subsequent processing is the same as case a described above. An MDI operation can also be intervened as well as manual operation. The movement is the same as that by manual operation.
3.6 TOOL AXIS DIRECTION HANDLE FEED/TOOL AXIS DIRECTION HANDLE FEED B

Tool axis direction handle feed moves the tool over a specified distance by handle feed in the direction of the tool axis tilted by the rotation of the rotary axis.

Tool axis direction handle feed B has the function of tool axis direction handle feed, and also has the tool axis normal direction handle feed which is handle feed at right angles to the tool axis.

These functions are used, for example, with 5-axis engraving machines.

3.6.1 Tool Axis Direction Handle Feed

When the tool axis direction handle mode is selected and the manual pulse generator is rotated, the tool is moved by the specified travel distance in the direction of the tool axis tilted by the rotation of the rotary axis.

Tool Axis Normal Direction Handle Feed

Procedure

1. Select the HANDLE switch from the mode selection switches.

2. Select the tool axis direction handle feed switch.

3. Select the tool axis direction handle feed mode axis as the handle feed axis for the first manual pulse coder (parameter No. 7121).

4. When the handle is turned, the tool moves in the tool axis direction by the corresponding distance.

When both the tool axis direction handle feed mode and tool axis right-angle direction handle feed mode are selected, neither mode is set, but the ordinary handle mode is set.

The procedure above is only an example. Refer to the relevant manual published by the machine tool builder for other possible operations.
Assume that the rotary axes for basic axes X, Y, and Z are A, B, and C, respectively. Assume also that the Z-axis represents the tool axis. Depending on the axis configuration of the machine, four types of tool axis directions are available. Specify the direction with parameter No. 7120.

### Axis configuration

1. **A–C axis type**
   - \[ X_p = \frac{H_p}{\sin (a)} \times \sin (c) \]
   - \[ Y_p = -\frac{H_p}{\sin (a)} \times \cos (c) \]
   - \[ Z_p = \frac{H_p}{\cos (a)} \]

2. **B–C axis type**
   - \[ Z (tool axis) \]

3. **A–B axis (A–axis master) type**
   - \[ Z (tool axis) \]

4. **A–B axis (B–axis master) type**
   - \[ Z (tool axis) \]

### Pulse distribution to basic axes

The figure below shows handle pulse (Hp) distribution to the X–axis, Y–axis, and Z–axis for each of the four directions.
(2) B–C axis type
\[ X_p = H_p \times \sin(b) \times \cos(c) \]
\[ Y_p = H_p \times \sin(b) \times \sin(c) \]
\[ Z_p = H_p \times \cos(b) \]

(3) A–B axis (A axis master) type
\[ X_p = H_p \times \sin(b) \]
\[ Y_p = -H_p \times \cos(b) \times \sin(a) \]
\[ Z_p = H_p \times \cos(b) \times \cos(a) \]

(4) A–B axis (B axis master) type
\[ X_p = H_p \times \cos(a) \times \sin(b) \]
\[ Y_p = -H_p \times \sin(a) \]
\[ Z_p = H_p \times \cos(a) \times \cos(b) \]
In the figures above, a, b, and c represent the positions (angles) of the A–axis, B–axis, and C–axis from the machine zero point; those values present when the tool axis direction handle feed mode is set or a reset occurs are used. To change the feed direction, reenter the tool axis direction handle feed mode, or press the reset key.

For tool axis direction determination, the coordinates (rotation angles) of rotary axes can be set using bits 3 and 4 (3D1X and 3D2X) of parameter No. 7104, and parameter Nos. 7144 and 7145.

- **Setting basic axes and rotary axes**
  Basic axes X, Y, and Z are determined by parameter No. 1022 (plane selection). Rotary axes A, B, and C are determined by parameter No. 1020 (axis name).

- **Tool axis direction**
  The direction of the tool X axis is determined by setting bit 0 (TLX) of parameter No. 7104.

- **Setting for 4–axis machines**
  This function is usually used with 5–axis machines. However, 4–axis machines (One axis is for rotation) can be used by setting bit 2 (CXC) of parameter No. 7104 to 1.

**Restrictions**

- **Axis configuration**
  If either of the two axes selected in type specification based on the axis configuration is nonexistent as an axis, P/S alarm No. 5015 is issued.

### 3.6.2 Tool Axis Normal Direction Handle Feed

When the tool axis normal direction handle mode is selected and the manual pulse generator is rotated, the tool is moved by the specified travel distance in the direction normal to the tool axis tilted by the rotation of the rotary axis.
Tool Axis Direction Handle Feed

Procedure

1. Select the HANDLE switch from the mode selection switches.

2. Select the tool axis normal direction handle feed switch.

3. Select the tool axis direction handle feed mode axis as the handle feed axis for the first manual pulse coder (parameter No. 7141, No. 7142).

4. When the handle is turned, the tool moves in normal direction to the tool axis direction by the corresponding distance.

   When both the tool axis direction handle feed mode and tool axis right-angle direction handle feed mode are selected, neither mode is set, but the ordinary handle mode is set.

   The procedure above is only an example. Refer to the relevant manual published by the machine tool builder for other possible operations.

Explanations

- Axis configuration

Assume that the rotary axes for basic axes X, Y, and Z are A, B, and C, respectively. Assume also that the Z-axis represents the tool axis. Depending on the axis configuration of the machine, two types of tool axis directions in which X-axis direction and Y-axis direction are available. Specify the direction with parameter No. 7120.
• Pulse distribution to basic axes

The figure below shows handle pulse (Hp) distribution to the X–axis, Y–axis, and Z–axis for each of the four directions.

(1) A–C axis type (X–axis direction)
\[ X_p = Hp \times \cos(C) \]
\[ Y_p = Hp \times \sin(C) \]
\[ Z_p = 0 \]

The XY plane is drawn because A– and C–axes are specified and because rotation about the A–axis, which is on the X–axis, does not cause the tool to rotate about the X–axis at the tool tip. Suppose that the Z–axis on this side of the XY plane is positive.

(2) A–C axis type (Y–axis direction)
\[ X_p = -Hp \times \cos(A) \times \sin(C) \]
\[ Y_p = Hp \times \cos(A) \times \cos(C) \]
\[ Z_p = Hp \times \sin(A) \]
(3) B–C axis type (X–axis direction)

\[ \begin{align*}
X_p &= \frac{H_p \times \cos(B) \times \cos(C)}{C_0}\cos(B) \\
Y_p &= \frac{H_p \times \cos(B) \times \sin(C)}{C_0}\sin(B) \\
Z_p &= -\frac{H_p \times \sin(B)}{C_0}
\end{align*} \]

(4) B–C axis type (Y–axis direction)

\[ \begin{align*}
X_p &= -\frac{H_p \times \sin(C)}{C_0} \\
Y_p &= \frac{H_p \times \cos(C)}{C_0} \\
Z_p &= 0
\end{align*} \]

The XY plane is drawn because B– and C–axes are specified and because rotation about the B–axis, which is on the Y–axis, does not cause the tool to rotate about the Y–axis at the tool tip. Suppose that the Z–axis on this side of the XY plane is positive.

In the figures above, a, b, and c represent the positions (angles) of the A–axis, B–axis, and C–axis from the machine zero point; those values present when the tool axis direction handle feed mode is set or a reset occurs are used. To change the feed direction, reenter the tool axis direction handle feed mode, or press the reset key.

For tool axis direction determination, the coordinates (rotation angles) of rotary axes can be set using bits 3 and 4 (3D1X and 3D2X) of parameter No. 7104, and parameter Nos. 7144 and 7145.
• **Setting basic axes and rotary axes**  
Basic axes X, Y, and Z are determined by parameter No. 1022 (plane selection). Rotary axes A, B, and C are determined by parameter No. 1020 (axis name).

• **Tool axis direction**  
The direction of the tool X axis is determined by setting bit 0 (TLX) of parameter No. 7104.

• **Setting for 4–axis machines**  
This function is usually used with 5–axis machines. However, 4–axis machines (One axis is for rotation) can be used by setting bit 2 (CXC) of parameter No. 7104 to 1.

**Restrictions**

• **Axis configuration**  
If either of the two axes selected in type specification based on the axis configuration is nonexistent as an axis, P/S alarm No. 5015 is issued. Moreover, the A–C axis type or B–C axis type must be selected as the axis configuration type.
In manual handle feed or jog feed, the following types of feed operations are enabled in addition to the conventional feed operation along a specified single axis (X-axis, Y-axis, Z-axis, and so forth) based on simultaneous 1-axis control:

- Feed along a tilted straight line in the XY plane (linear feed) based on simultaneous 2-axis control
- Feed along a circle in the XY plane (circular feed) based on simultaneous 2-axis control

**NOTE**
The X-axis and Y-axis must be the first controlled axis and second controlled axis, respectively.

**Procedure for Manual Linear/Circular Interpolation**

1. To perform manual handle feed, select manual handle feed mode. To perform jog feed, select jog feed mode.

2. To perform manual handle feed, select a feed axis (for simultaneous 1-axis feed along the X-axis, Y-axis, or Z-axis, or for simultaneous linear or circular 2-axis feed along a specified straight line or circle in the XY plane) subject to manual handle feed operation. Use the handle feed axis select switch for this selection. To perform jog feed, select a feed axis and direction with the feed axis direction select switch. While a feed axis and its direction are specified, the tool moves in the specified axis direction or along a straight line or circle at the jog feedrate specified in parameter No. 1423.

3. For manual handle feed

The tool is moved along a specified axis by turning the respective manual handle. The feedrate depends on the speed at which the manual handle is turned. A distance to be traveled by the tool when the manual handle is turned by one pulse can be selected using the manual handle feed travel distance magnification switch.
For jog feed

The feedrate can be overridden using the manual feedrate override dial.

The procedure above is just an example. For actual operations, refer to the relevant manual provided by the machine tool builder.

**Explanations**

- **Definition of a straight line/circle**
  
  For feed along an axis, no straight line/circle definition is required. For linear feed or circular feed, a straight line or circle must be defined beforehand. (For circular feed, for example, data such as a radius and the center of a circle must be set.) For details, refer to the relevant manual provided by the machine tool builder.

- **Manual handle feed**

  In manual handle feed, the tool can be moved along a specified axis (X-axis, Y-axis, Z-axis, ..., or the 8th axis), or can be moved along a tilted straight line (linear feed) or a circle (circular feed).

  (1) Feed along a specified axis (simultaneous 1-axis control)

  By turning a manual handle, the tool can be moved along the desired axis (such as X-axis, Y-axis, and Z-axis) on a simultaneous 1-axis control basis. (This mode of feed is the conventional type of manual handle feed.)

![Diagram of Feed along a specified axis](image-url)
(2) Linear feed (simultaneous 2–axis control)

By turning a manual handle, the tool can be moved along the straight line parallel to a specified straight line on a simultaneous 2–axis control basis. This manual handle is referred to as the guidance handle. Moreover, by turning another manual handle, the tool can be moved at right angles to a specified straight line on a simultaneous 2–axis control basis. This manual handle is referred to as the approach handle. When the guidance handle or approach handle is turned clockwise or counterclockwise, the tool travels forward or backward along the respective path.

![Linear feed diagram]

(3) Circular feed (simultaneous 2–axis control)

By turning a manual handle, the tool can be moved from the current position along the concentric circle that has the same center as a specified circle on a simultaneous 2–axis control basis. This manual handle is referred to as the guidance handle. Moreover, by turning another manual handle, the tool can be moved along the normal to a specified circle on a simultaneous 2–axis control basis. This manual handle is referred to as the approach handle. When the guidance handle or approach handle is turned clockwise or counterclockwise, the tool travels forward or backward along the respective path.

![Circular feed diagram]

**Feedrate**
• **Feedrate for manual handle feed**

The feedrate depends on the speed at which a manual handle is turned. A distance to be traveled by the tool (along a tangent in the case of linear or circular feed) when a manual handle is turned by one pulse can be selected using the manual handle feed travel distance magnification switch.

• **Manual handle selection**

The Series 16/18 has three manual pulse generator interfaces to allow up to three manual handles to be connected. For information about how to use the manual handles connected to the interfaces (whether to use each manual handle as a handle for feed along an axis, as a guidance handle, or as an approach handle), refer to the relevant manual provided by the machine tool builder.

• **Direction of movement using manual handles**

The user can specify the direction of the tool moved along a straight line or circle (for example, whether to make a clockwise or counterclockwise movement along a circle) when the guidance handle or approach handle is turned clockwise or counterclockwise. For details, refer to the relevant manual provided by the machine tool builder.

• **Jog feed (JOG)**

In jog feed, the tool can be moved along a specified axis (X-axis, Y-axis, Z-axis, ..., or the 8th axis), or can be moved along a tilted straight line (linear feed) or a circle (circular feed).

1. **Feed along a specified axis (simultaneous 1-axis control)**

   While a feed axis and its direction are specified with the feed axis direction select switch, the tool moves in the specified axis direction at the feedrate specified in parameter No. 1423. The feedrate can be overridden using the manual feedrate override dial.

2. **Linear feed (simultaneous 2-axis control)**

   By defining a straight line beforehand, the tool can be moved as follows:
   
   • While a feed axis and its direction are selected using the feed axis direction select switch, the tool moves along a straight line parallel to the specified straight line on a simultaneous 2-axis control basis.
   
   • While a feed axis and its direction are selected using the feed axis direction select switch, the tool moves at right angles to the specified straight line on a simultaneous 2-axis control basis.

   The feedrate in the tangential direction is specified in parameter No. 1410. The feedrate can be overridden using the manual feedrate override dial.

3. **Circular feed (simultaneous 2-axis control)**

   By defining a circle beforehand, the tool can be moved as follows:
   
   • While a feed axis and its direction are selected using the feed axis direction select switch, the tool moves from the current position along the concentric circle that has the same center as the specified circle.
   
   • While a feed axis and its direction are selected using the feed axis direction select switch, the tool moves along the normal to the specified circle.

   The feedrate in the tangential direction is specified in parameter No. 1410. The feedrate can be overridden using the manual feedrate override dial.
• **Manual handle feed in JOG mode**

Even in JOG mode, manual handle feed can be enabled using bit 0 (JHD) of parameter No. 7100. In this case, however, manual handle feed is enabled only when the tool is not moved along any axis by jog feed.

**Limitations**

• **Mirror image**

Never use the mirror image function when performing manual operation. (Perform manual operation when the mirror image switch is off, and mirror image setting is off.)
3.8 MANUAL RIGID TAPPING

For execution of rigid tapping, set rigid mode, then switch to handle mode and move the tapping axis with a manual handle. For more information about rigid tapping, see Section II–13.2 and refer to the relevant manual provided by the machine tool builder.

Procedure for Manual Rigid Tapping

Procedure

1. Stop the spindle and servo axes, then set MDI mode by pressing the MDI switch among the mode selection switches.

2. Enter and execute the following program:
   
   M29 S1000 ;
   G91 G84 Z0 F1000 ;

   The program above is required to determine a screw lead and set rigid tapping mode. In this program, a tapping axis must always be specified. Specify a value that does not operate the tapping axis.

   **WARNING**

   In this MDI programming, never specify commands to position the tool at a drilling position and at point R. Otherwise, the tool moves along an axis.

3. When the entered program is executed, rigid tapping mode is set.

4. After rigid mode is set upon completion of MDI program execution, switch to the handle mode by pressing the handle switch among the mode selection switches.

   **CAUTION**

   At this time, never press the reset key. Otherwise, rigid mode is canceled.

5. To perform rigid tapping, select a tapping axis with the handle feed axis select switch, and move the tapping axis with the manual handle.
Explanations

- **Manual rigid tapping**
  Manual rigid tapping is enabled by setting bit 0 (HRG) of parameter No. 5203 to 1.

- **Cancellation of rigid mode**
  To cancel rigid mode, specify G80 as same the normal rigid tapping. When the reset key is pressed, rigid mode is canceled, but the canned cycle is not canceled.

  When the rigid mode switch is to be set to off for rigid mode cancellation (when bit 2 (CRG) of parameter No. 5200 is set to 0), the G80 command ends after the rigid mode switch is set to off.

- **Spindle rotation direction**
  The rotation direction of the spindle is determined by a specified tapping cycle G code and the setting of bit 1 (HRM) of parameter No. 5203. For example, when the HRM parameter is set to 0 in G84 mode, the spindle makes forward rotations as the tapping axis moves in the minus direction. (When the tapping axis moves in the plus direction, the spindle makes reverse rotations.)

- **Arbitrary tapping axis**
  By setting bit 0 (FXY) of parameter No. 5101 to 1, an arbitrary tapping axis can be selected. In this case, specify a G code for plane selection and tapping axis address when rigid mode is set in MDI mode.

- **Specification of M29 and G84 in the same block**
  In an MDI program for setting rigid mode, G84 can be used as a rigid tapping G code, or M29 and G84 can be specified in the same block.

- **Specification of manual handle feed faster than the rapid traverse rate**
  Set bit 0 (HPF) of parameter No. 7100 to 0 so that when manual handle feed is specified which is faster than the rapid traverse rate, the handle pulses beyond the rapid traverse rate are ignored.

Limitations

- **Excessive error check**
  In manual rigid tapping, only an excessive error during movement is checked.

- **Tool axis direction handle feed**
  Tool axis direction handle feed is disabled.

- **Extraction override**
  In manual rigid tapping, the extraction override function is disabled, and the use of an acceleration/deceleration time constant for extraction is disabled.

- **Number of repeats**
  In MDI programming, never specify K0 and L0, which are used to specify that the number of repeats is 0 and to disable the execution of a G84 block. If K0 or L0 is specified, rigid mode cannot be set.

- **Positioning of the tool to a drilling position**
  When positioning the tool to a drilling position, select the X–axis or Y–axis with the axis select switch in handle mode. Never use the method of positioning to a drilling position in MDI mode or MEM mode. The method can operate the tapping axis.
3.9 MANUAL NUMERIC COMMAND

The manual numeric command function allows data programmed through the MDI to be executed in jog mode. Whenever the system is ready for jog feed, a manual numeric command can be executed. The following eight functions are supported:

1. Positioning (G00)
2. Linear interpolation (G01)
3. Automatic reference position return (G28)
4. 2nd/3rd/4th reference position return (G30)
5. M codes (miscellaneous functions)
6. S codes (spindle functions)
7. T codes (tool functions)
8. B codes (second auxiliary functions)

By setting the following parameters, the commands for axial motion and the M, S, T, and B functions can be disabled:

1. Positioning (G00): .............. Bit 0 (JAXx) of parameter No. 7002
2. Linear interpolation (G01): .............. Bit 1 (JSF) of parameter No. 7002
3. Automatic reference position return (G28): .............. Bit 2 (JSF) of parameter No. 7002
4. 2nd/3rd/4th reference position return (G30): .............. Bit 3 (JBF) of parameter No. 7002
5. M codes (miscellaneous functions): .............. Bit 0 (JMF) of parameter No. 7002

Procedure

1. Press the jog switch (one of the mode selection switches).
2. Press function key PRG.
3. Press soft key [JOG] on the screen. The following manual numeric command screen is displayed.

Example 1: When the maximum number of controlled axes is six

```
PROGRAM (JOG)          00010 N00020
G00 P (ABSOLUTE)       (DISTANCE TO GO)
X  X  0.000  X  0.000
Y  Y  0.000  Y  0.000
Z  Z  0.000  Z  0.000
U  U  0.000  U  0.000
V  V  0.000  V  0.000
W  W  0.000  W  0.000
M  S  T  B  >_

JOG  *****  ***  ***  00 : 00 : 00
   [PRGRM] [JOG] [CURRT] [NEXT] [OPRT]
```
Example 2: When the maximum number of controlled axes is 7 or 8

<table>
<thead>
<tr>
<th>PROGRAM (JOG)</th>
<th>O0010 N00020</th>
</tr>
</thead>
<tbody>
<tr>
<td>G00 P (ABSOLUTE) (DISTANCE TO GO)</td>
<td></td>
</tr>
<tr>
<td>X 0.000 X 0.000</td>
<td>X 0.000</td>
</tr>
<tr>
<td>Y 0.000 Y 0.000</td>
<td>Y 0.000</td>
</tr>
<tr>
<td>Z 0.000 Z 0.000</td>
<td>Z 0.000</td>
</tr>
<tr>
<td>U 0.000 U 0.000</td>
<td>U 0.000</td>
</tr>
<tr>
<td>V 0.000 V 0.000</td>
<td>V 0.000</td>
</tr>
<tr>
<td>W 0.000 W 0.000</td>
<td>W 0.000</td>
</tr>
<tr>
<td>A 0.000 A 0.000</td>
<td>A 0.000</td>
</tr>
<tr>
<td>C 0.000 C 0.000</td>
<td>C 0.000</td>
</tr>
<tr>
<td>M T S B &gt;_</td>
<td></td>
</tr>
</tbody>
</table>

JOG **** *** *** 00:00:00

4 Enter the required commands by using address keys and numeric keys on the MDI panel, then press soft key [INPUT] or the INPUT key to set the entered data.

<table>
<thead>
<tr>
<th>PROGRAM (JOG)</th>
<th>O0010 N00020</th>
</tr>
</thead>
<tbody>
<tr>
<td>G00 P (ABSOLUTE) (DISTANCE TO GO)</td>
<td></td>
</tr>
<tr>
<td>X 10.000 X 0.000</td>
<td>X 0.000</td>
</tr>
<tr>
<td>Y 0.000 Y 0.000</td>
<td>Y 0.000</td>
</tr>
<tr>
<td>Z 0.000 Z 0.000</td>
<td>Z 0.000</td>
</tr>
<tr>
<td>U 0.000 U 0.000</td>
<td>U 0.000</td>
</tr>
<tr>
<td>V 0.000 V 0.000</td>
<td>V 0.000</td>
</tr>
<tr>
<td>W 0.000 W 0.000</td>
<td>W 0.000</td>
</tr>
<tr>
<td>M S T B &gt;Z120.5_</td>
<td></td>
</tr>
</tbody>
</table>

JOG **** *** *** 00:00:00

The following data can be set:

1. G00: Positioning
2. G01: Linear interpolation
4. G30: 2nd/3rd/4th reference position return
5. M codes: Miscellaneous functions
6. S codes: Spindle functions
7. T codes: Tool functions
8. B codes: Second auxiliary functions

The set data is maintained even when the screen or mode is changed.
3. MANUAL OPERATION

NOTE
When an alarm state exists, data cannot be set.

5 Press the cycle start switch on the machine operator’s panel to start command execution. The status is indicated as "MSTR." (When the 9" screen is being used, the actual feedrate "ACT.F" and spindle speed "SACT" appear on the key input line.) The automatic operation signal, STL, can be turned on by setting bit 2 (JST) of parameter No. 7001.

```
ACT.F 1000 SACT 0
JOG MSTR *** MTN 00 : 00 : 00
```

NOTE
If the cycle start switch is pressed while an alarm state exists, a "START IMPOSSIBLE" warning is generated, and the entered data cannot be executed.

6 Upon the completion of execution, the "MSTR" status indication is cleared from the screen, and automatic operation signal STL is turned off. The set data is cleared entirely. G codes are set to G00 or G01 according to the setting of bit 0 (G01) of parameter No. 3402.

Explanations

• Positioning

An amount of travel is given as a numeric value, preceded by an address such as X, Y, or Z. This is always regarded as being an incremental command, regardless of whether G90 or G91 is specified. The tool moves along each axis independently at the rapid traverse rate. Linear interpolation type positioning (where the tool path is linear) can also be performed by setting bit 1 (LRP) of parameter No. 1401.

<table>
<thead>
<tr>
<th>Manual rapid traverse selection switch</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Feedrate (parameter)</strong></td>
</tr>
<tr>
<td>Off</td>
</tr>
<tr>
<td>Jog feedrate for each axis (No. 1423)</td>
</tr>
<tr>
<td>On</td>
</tr>
<tr>
<td>Rapid traverse rate for each axis</td>
</tr>
<tr>
<td>(No. 1420)</td>
</tr>
<tr>
<td><strong>Automatic acceleration/deceleration (parameter)</strong></td>
</tr>
<tr>
<td>Off</td>
</tr>
<tr>
<td>Exponential acceleration/deceleration in jog feed for each axis (No. 1624)</td>
</tr>
<tr>
<td>On</td>
</tr>
<tr>
<td>Linear acceleration/deceleration in rapid traverse for each axis (No. 1620)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Override</th>
</tr>
</thead>
<tbody>
<tr>
<td>Off</td>
</tr>
<tr>
<td>Manual feed override</td>
</tr>
<tr>
<td>On</td>
</tr>
<tr>
<td>Rapid traverse override</td>
</tr>
</tbody>
</table>
NOTE
When the manual rapid traverse selection switch is set to the OFF position, the jog feedrate for each axis is clamped such that a parameter–set feedrate, determined by bit 1 (LRP) of parameter No. 1401 as shown below, is not exceeded.

<table>
<thead>
<tr>
<th>LRP</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Manual rapid traverse rate for each axis (parameter No. 1424)</td>
</tr>
<tr>
<td>1</td>
<td>Rapid traverse rate for each axis (parameter No. 1420)</td>
</tr>
</tbody>
</table>

- **Linear interpolation (G01)**

An amount of travel is given as a numeric value, preceded by an address such as X, Y, or Z. This is always regarded as being an incremental command, regardless of whether G90 or G91 is specified. Axial movements are always performed in incremental mode even during scaling or polar coordinate interpolation. In addition, movement is always performed in feed per minute mode regardless of the specification of G94 or G95.

<table>
<thead>
<tr>
<th>Feedrate (parameter)</th>
<th>Dry run feedrate (No. 1410)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automatic acceleration/deceleration (parameter)</td>
<td>Exponential acceleration/deceleration in cutting feed for each axis (No. 1622)</td>
</tr>
<tr>
<td>Override</td>
<td>Manual feed override</td>
</tr>
</tbody>
</table>

NOTE
Since the feedrate is always set to the dry run feedrate, regardless of the setting of the dry run switch, the feedrate cannot be specified using F. The feedrate is clamped such that the maximum cutting feedrate, set in parameter No. 1422, is not exceeded.

- **Automatic reference position return (G28)**

The tool returns directly to the reference position without passing through any intermediate points, regardless of the specified amount of travel. For axes for which no move command is specified, however, a return operation is not performed.

<table>
<thead>
<tr>
<th>Feedrate (parameter)</th>
<th>Rapid traverse rate (No. 1420)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automatic acceleration/deceleration (parameter)</td>
<td>Linear acceleration/deceleration in rapid traverse for each axis (No. 1620)</td>
</tr>
<tr>
<td>Override</td>
<td>Rapid traverse override</td>
</tr>
</tbody>
</table>
• **2nd, 3rd, or 4th reference position return (G30)**

The tool returns directly to the 2nd, 3rd, or 4th reference position without passing through any intermediate points, regardless of the specified amount of travel. To select a reference position, specify P2, P3, or P4 in address P. If address P is omitted, a return to the second reference position is performed.

<table>
<thead>
<tr>
<th>Feedrate (parameter)</th>
<th>Rapid traverse rate for each axis (No. 1420)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automatic acceleration/deceleration (parameter)</td>
<td>Linear acceleration/deceleration in rapid traverse for each axis (No. 1620)</td>
</tr>
<tr>
<td>Override</td>
<td>Rapid traverse override</td>
</tr>
</tbody>
</table>

**NOTE**

The function for 3rd/4th reference position return is optional.

- When the option is not selected
  Return to the 2nd reference position is performed, regardless of the specification of address P.
- When the option is selected
  If neither P2, P3, nor P4 is specified in address P, a “START IMPOSSIBLE” warning is generated, and the entered data cannot be executed.

• **M codes (miscellaneous functions)**

After address M, specify a numeric value of no more than the number of digits specified by parameter No. 3030. When M98 or M99 is specified, it is executed but not output to the PMC.

**NOTE**

Neither subprogram calls nor custom macro calls can be performed using M codes.

• **S codes (spindle functions)**

After address S, specify a numeric value of no more than the number of digits specified by parameter No. 3031.

**NOTE**

Subprogram calls cannot be performed using S codes.

• **T codes (tool functions)**

After address T, specify a numeric value of no more than the number of digits specified by parameter No. 3032.

**NOTE**

Subprogram calls cannot be performed using T codes.
• B codes (second auxiliary functions)

After address B, specify a numeric value of no more than the number of digits specified by parameter No. 3033.

NOTE
1 B codes can be renamed "U," "V," "W," "A," or "C" by setting parameter No. 3460. If the new name is the same as an axis name address, "B" is used. When "B" is used, and axis name "B" exists, "B" is used as the axis address. In this case, no second auxiliary function can be specified.
2 Subprogram calls cannot be performed using B codes.

• Data input

(1) When addresses and numeric values of a command are typed, then soft key [INPUT] is pressed, the entered data is set. In this case, the input unit is either the least input increment or calculator–type input format, according to the setting of bit 0 (DPI) of parameter No. 3401.

The [INPUT] key on the MDI panel can be used instead of soft key [INPUT].

(2) Commands can be typed successively.

(3) Key entry is disabled during execution.

If soft key [INPUT] or the [INPUT] key on the MDI panel is pressed during execution, an "EXECUTION/MODE SWITCHING IN PROGRESS" warning is output.

(4) If input data contains an error, the following warnings may appear:

<table>
<thead>
<tr>
<th>Warning</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>FORMAT ERROR</td>
<td>- A G code other than G00, G01, and G28 has been entered.</td>
</tr>
<tr>
<td></td>
<td>- An address other than those displayed on the manual numeric command screen has been entered.</td>
</tr>
<tr>
<td>TOO MANY DIGITS</td>
<td>A value that exceeds the following limitations has been entered.</td>
</tr>
<tr>
<td></td>
<td>- Address G: 2 digits</td>
</tr>
<tr>
<td></td>
<td>- Address P: 1 digit</td>
</tr>
<tr>
<td></td>
<td>- Axis address: 8 digits</td>
</tr>
<tr>
<td></td>
<td>- M, S, T, B: The parameter–set number of digits</td>
</tr>
</tbody>
</table>

NOTE
Even when the memory protection key is set, key input can nevertheless be performed.
• Erasing data

(1) When soft key [CLEAR] is pressed, followed by soft key [EXEC], all the set data is cleared. In this case, however, the G codes are set to G00 or G01, depending on the setting of bit 0 (G01) of parameter No. 3402. Data can also be cleared by pressing the \[reset\] key on the MDI panel.

(2) If soft key [CLEAR] is pressed during execution, an "EXECUTION/MODE SWITCHING IN PROGRESS" warning is output.

• Halting execution

If one of the following occurs during execution, execution is halted, and the data is cleared in the same way as when soft key [CLEAR] is pressed. The remaining distance to be traveled is canceled.

(1) When a feed hold is applied

(2) When the mode is changed to other than jog feed mode

(3) When an alarm is generated

(4) When a reset or emergency stop is applied

The M, S, T, and B functions remain effective even upon the occurrence of the above events, with the exception of (4).

• Modal information

Modal G codes and addresses used in automatic operation or MDI operation are not affected by the execution of commands specified using the manual numeric command function.

• Jog feed

When the tool is moved along an axis using a feed axis and direction selection switch on the manual numeric command screen, the remaining amount of travel is always shown as "0".

Limitations

• Constant surface speed control

S codes cannot be specified in constant surface speed control mode.

• M, S, T, and B functions

While automatic operation is halted, manual numeric commands can be executed. In the following cases, however, a "START IMPOSSIBLE" warning is output, and command execution is disabled.

(1) When an M, S, T, or B function is already being executed, a manual numeric command containing an M, S, T, or B function cannot be executed.

(2) When an M, S, T, or B function is already being executed, and that function alone is specified or a block specifying that function also contains another function (such as a move command or dwell function) which has already been completed, a manual numeric command cannot be executed.

• Jog feed

When a manual numeric command is specified while the tool is being moved along an axis by using a feed axis and direction selection switch, the axial movement is interrupted, and the manual numeric command is executed. Therefore, the tool cannot be moved along an axis by using a feed axis and direction selection switch during execution of a manual numeric command.

• Mirror image

A mirror image cannot be produced for the direction of a specified axial movement.
The manual numeric command screen appears even when the mode is changed to REF mode. If, however, an attempt is made to set and execute data, a "WRONG MODE" warning is output and the attempt fails.

Commands cannot be specified for an axis along which operation is being performed during indexing or chopping. If such an axis is specified for execution, a "START IMPOSSIBLE" warning is output.
Programmed operation of a CNC machine tool is referred to as automatic operation. This chapter explains the following types of automatic operation:

- **MEMORY OPERATION**
  Operation by executing a program registered in CNC memory

- **MDI OPERATION**
  Operation by executing a program entered from the MDI panel

- **DNC OPERATION**
  Operation while reading a program from an input/output device

- **SIMULTANEOUS INPUT/OUTPUT**
  Program execution and memory registration can be performed simultaneously.

- **PROGRAM RESTART**
  Restarting a program for automatic operation from an intermediate point

- **SCHEDULING FUNCTION**
  Scheduled operation by executing programs (files) registered in an external input/output device (Handy File, Floppy Cassette, or FA Card)

- **SUBPROGRAM CALL FUNCTION**
  Function for calling and executing subprograms (files) registered in an external input/output device (Handy File, Floppy Cassette, or FA Card) during memory operation

- **MANUAL HANDLE INTERRUPTION**
  Function for performing manual feed during movement executed by automatic operation

- **MIRROR IMAGE**
  Function for enabling mirror–image movement along an axis during automatic operation

- **TOOL WITHDRAWAL AND RETURN**
  Function for withdrawing the tool from a workpiece and for returning the tool to restart machining

- **RETRACE FUNCTION**
  Function for moving the tool in the reverse direction to retrace the path followed, and for moving the tool in the forward direction again along the retraced path.

- **MANUAL INTERVENTION AND RETURN**
  Function restarting automatic operation by returning the tool to the position where manual intervention was started during automatic operation

- **RETREAT AND RETRY FUNCTIONS**
  This function enables machining to be restarted from the start block.

- **MEMORY CARD–BASED DNC OPERATION**
  Automatic operation by a program written to a memory card
4.1 MEMORY OPERATION

Programs are registered in memory in advance. When one of these programs is selected and the cycle start switch on the machine operator’s panel is pressed, automatic operation starts, and the cycle start LED goes on.

When the feed hold switch on the machine operator’s panel is pressed during automatic operation, automatic operation is stopped temporarily. When the cycle start switch is pressed again, automatic operation is restarted.

When the \text{RESET} key on the MDI panel is pressed, automatic operation terminates and the reset state is entered.

For the two-path control, the programs for the two tool posts can be executed simultaneously so the two tool posts can operate independently at the same time.

The following procedure is given as an example. For actual operation, refer to the manual supplied by the machine tool builder.

Procedure for Memory Operation

\begin{itemize}
  \item [1] Press the \text{MEMORY} mode selection switch.
  \item [2] Select a program from the registered programs. To do this, follow the steps below.
    \begin{itemize}
      \item [2-1] Press \text{PROG} to display the program screen.
      \item [2-2] Press address \text{O}.
      \item [2-3] Enter a program number using the numeric keys.
      \item [2-4] Press the \text{[O SRH]} soft key.
    \end{itemize}
  \item [3] For the two-path control, select the tool post to be operated with the tool post selection switch on the machine operator’s panel.
  \item [4] Press the cycle start switch on the machine operator’s panel. Automatic operation starts, and the cycle start LED goes on. When automatic operation terminates, the cycle start LED goes off.
  \item [5] To stop or cancel memory operation midway through, follow the steps below.
    \begin{itemize}
      \item [a] Stopping memory operation
        Press the feed hold switch on the machine operator’s panel. The feed hold LED goes on and the cycle start LED goes off. The machine responds as follows:
        \begin{itemize}
          \item [(i)] When the machine was moving, feed operation decelerates and stops.
          \item [(ii)] When dwell was being performed, dwell is stopped.
          \item [(iii)] When M, S, or T was being executed, the operation is stopped after M, S, or T is finished.
        \end{itemize}
        When the cycle start switch on the machine operator’s panel is pressed while the feed hold LED is on, machine operation restarts.
    \end{itemize}
\end{itemize}
b. Terminating memory operation

Press the \[\text{RESET}\] key on the MDI panel.

Automatic operation is terminated and the reset state is entered. When a reset is applied during movement, movement decelerates then stops.

**Explanation**

**Memory operation**

After memory operation is started, the following are executed:

1. A one–block command is read from the specified program.
2. The block command is decoded.
3. The command execution is started.
4. The command in the next block is read.
5. Buffering is executed. That is, the command is decoded to allow immediate execution.
6. Immediately after the preceding block is executed, execution of the next block can be started. This is because buffering has been executed.
7. Hereafter, memory operation can be executed by repeating the steps (4) to (6)

**Stopping and terminating memory operation**

Memory operation can be stopped using one of two methods: Specify a stop command, or press a key on the machine operator’s panel.

- The stop commands include M00 (program stop), M01 (optional stop), and M02 and M30 (program end).
- There are two keys to stop memory operation: The feed hold key and reset key.

- **Program stop (M00)**

Memory operation is stopped after a block containing M00 is executed. When the program is stopped, all existing modal information remains unchanged as in single block operation. The memory operation can be restarted by pressing the cycle start button. Operation may vary depending on the machine tool builder. Refer to the manual supplied by the machine tool builder.

- **Optional stop (M01)**

Similarly to M00, memory operation is stopped after a block containing M01 is executed. This code is only effective when the Optional Stop switch on the machine operator’s panel is set to ON. Operation may vary depending on the machine tool builder. Refer to the manual supplied by the machine tool builder.

- **Program end (M02, M30)**

When M02 or M30 (specified at the end of the main program) is read, memory operation is terminated and the reset state is entered. In some machines, M30 returns control to the top of the program. For details, refer to the manual supplied by the machine tool builder.

- **Feed hold**

When Feed Hold button on the operator’s panel is pressed during memory operation, the tool decelerates to a stop at a time.

- **Reset**

Automatic operation can be stopped and the system can be made to the reset state by using \[\text{RESET}\] key on the MDI panel or external reset signal. When reset operation is applied to the system during a tool moving status, the motion is slowed down then stops.
<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Optional block skip</strong></td>
<td>When the optional block skip switch on the machine operator’s panel is turned on, blocks containing a slash (/) are ignored.</td>
</tr>
<tr>
<td><strong>Cycle start for the two-path control</strong></td>
<td>For the two-path control, a cycle start switch is provided for each tool post. This allows the operator to activate a single tool post to operate them at the same time in memory operation or MDI operation. In general, select the tool post to be operated with the tool post selection switch on the machine operator’s panel and then press the cycle start button to activate the selected tool post. (The procedure may vary with the machine tool builder. Refer to the appropriate manual issued by the machine tool builder.)</td>
</tr>
<tr>
<td><strong>Calling a subprogram stored in an external input/output device</strong></td>
<td>A file (subprogram) in an external input/output device such as a Floppy Cassette can be called and executed during memory operation. For details, see Section 4.7.</td>
</tr>
</tbody>
</table>
4.2 MDI OPERATION

In the MDI mode, a program consisting of up to 10 lines can be created in the same format as normal programs and executed from the MDI panel. MDI operation is used for simple test operations. The following procedure is given as an example. For actual operation, refer to the manual supplied by the machine tool builder.

**Procedure for MDI Operation**

**Procedure**

1. Press the MDI mode selection switch. For the two-path control, select the tool post for which a program is to be created with the tool post selection switch. Create a separate program for each tool post.

2. Press the PROG function key on the MDI panel to select the program screen. The following screen appears:

```
PROGRAM (MDI)  0010  00002
O0000;

G00  G90  G94  G40  G80  G50  G54  G69
G17  G22  G21  G49  G98  G67  G64  G15
         B     M
         T     D
         F     S
>-
MDI  ***  ***  ***  20:40:05
( PRGRM ) ( MDI ) ( CURRT ) ( NEXT ) ( OPRT )
```

Program number O0000 is entered automatically.

3. Prepare a program to be executed by an operation similar to normal program editing. M99 specified in the last block can return control to the beginning of the program after operation ends. Word insertion, modification, deletion, word search, address search, and program search are available for programs created in the MDI mode. For program editing, see III–9.

4. To entirely erase a program created in MDI mode, use one of the following methods:

   a. Enter address O, then press the DELETE key on the MDI panel.

   b. Alternatively, press the RESET key. In this case, set bit 7 of parameter MCL No. 3203 to 1 in advance.
5. To execute a program, set the cursor on the head of the program. (Start from an intermediate point is possible.) Push Cycle Start button on the operator’s panel. By this action, the prepared program will start. (For the two-path control, select the tool post to be operated with the tool post selection switch on the machine operator’s panel beforehand.) When the program end (M02, M30) or ER(%) is executed, the prepared program will be automatically erased and the operation will end.

By command of M99, control returns to the head of the prepared program.

6. To stop or terminate MDI operation in midway through, follow the steps below.

   a. Stopping MDI operation

   Press the feed hold switch on the machine operator’s panel. The feed hold LED goes on and the cycle start LED goes off. The machine responds as follows:

   (i) When the machine was moving, feed operation decelerates and stops.

   (ii) When dwell was being performed, dwell is stopped.

   (iii) When M, S, or T was being executed, the operation is stopped after M, S, or T is finished.

   When the cycle start switch on the machine operator’s panel is pressed, machine operation restarts.

   b. Terminating MDI operation

   Press the [RESET] key on the MDI panel.

   Automatic operation is terminated and the reset state is entered. When a reset is applied during movement, movement decelerates then stops.
Explanation

The previous explanation of how to execute and stop memory operation also applies to MDI operation, except that in MDI operation, M30 does not return control to the beginning of the program (M99 performs this function).

- Erasing the program

Programs prepared in the MDI mode will be erased in the following cases:

- In MDI operation, if M02, M30 or ER(%) is executed. (If bit 6 (MER) of parameter No. 3203 is set to 1, however, the program is erased when execution of the last block of the program is completed by single–block operation.)
- In MEMORY mode, if memory operation is performed.
- In EDIT mode, if any editing is performed.
- Background editing is performed.
- When the and keys are pressed.
- Upon reset when bit 7 (MCL) of parameter No. 3203 is set to 1

- Restart

After the editing operation during the stop of MDI operation was done, operation starts from the current cursor position.

- Editing a program during MDI operation

A program can be edited during MDI operation. The editing of a program, however, is disabled until the CNC is reset, when bit 5 (MIE) of parameter No. 3203 is set accordingly.

Limitations

- Program registration

Programs created in MDI mode cannot be registered.

- Number of lines in a program

A program can have as many lines as can fit on one page of the screen. A program consisting of up to six lines can be created. When parameter MDL (No. 3107 #7) is set to 0 to specify a mode that suppresses the display of continuous–state information, a program of up to 10 lines can be created.

If the created program exceeds the specified number of lines, % (ER) is deleted (prevents insertion and modification).

- Subprogram nesting

Calls to subprograms (M98) can be specified in a program created in the MDI mode. This means that a program registered in memory can be called and executed during MDI operation. In addition to the main program executed by automatic operation, up to two levels of subprogram nesting are allowed (when the custom macro option is provided, up to four levels are allowed).

![Fig. 4.2 (a) Nesting Level of Subprograms Called from the MDI Program](image-url)
• **Macro call**

When the custom macro option is provided, macro programs can also be created, called, and executed in the MDI mode. However, macro call commands cannot be executed when the mode is changed to MDI mode after memory operation is stopped during execution of a subprogram.

• **Memory area**

When a program is created in the MDI mode, an empty area in program memory is used. If program memory is full, no programs can be created in the MDI mode.
4.3 DNC OPERATION

By activating automatic operation during the DNC operation mode (RMT), it is possible to perform machining (DNC operation) while a program is being read in via reader/puncher interface, or remote buffer. If the floppy cassette directory display option is available, it is possible to select files (programs) saved in an external input/output unit of a floppy format (Handy File, Floppy Cassettes, or FA card) and specify (schedule) the sequence and frequency of execution for automatic operation. (see III–4.6)

To use the DNC operation function, it is necessary to set the parameters related to the reader/punch interface, and remote buffer in advance.

DNC OPERATION

Procedure

1. Search for the program (file) to be executed.

2. Press the REMOTE switch on the machine operator’s panel to set RMT mode, then press the cycle start switch. The selected file is executed. For details of the use of the REMOTE switch, refer to the relevant manual supplied by the machine tool builder.

Program check screen

(Seven soft key type LCD)

<table>
<thead>
<tr>
<th>PROGRAM CHECK</th>
</tr>
</thead>
<tbody>
<tr>
<td>O0001 N00020</td>
</tr>
</tbody>
</table>

| N020 X100.0 Z100.0 (DNC–PROG) ; |
| N030 X200.0 Z200.0 ; |
| N050 X400.0 Z400.0 ; |

X 100.000 X 0.000 G22 G94 G21
Y 100.000 Y 0.000 G41 G49 G80
Z 0.000 Z 0.000 G98 G50 G67
A 0.000 A 0.000 B
C 0.000 C 0.000 H M
HD.T NX.T D M
F S M
ACT.F SACT REPEAT
RMT STRT MTN *** *** 21:20:05
[ ABS ] [ REL ] [ ] [ ] [ (OPRT) ]
• **Program screen**  
(Seven soft key type LCD)

<table>
<thead>
<tr>
<th>PROGRAM</th>
<th>O0001 N00020</th>
</tr>
</thead>
<tbody>
<tr>
<td>N020 X100.0 Z100.0 (DNC–PROG) ;</td>
<td></td>
</tr>
<tr>
<td>N030 X200.0 Z200.0 ;</td>
<td></td>
</tr>
<tr>
<td>N040 X300.0 Z300.0 ;</td>
<td></td>
</tr>
<tr>
<td>N050 X400.0 Z400.0 ;</td>
<td></td>
</tr>
<tr>
<td>N060 X500.0 Z500.0 ;</td>
<td></td>
</tr>
<tr>
<td>N070 X600.0 Z600.0 ;</td>
<td></td>
</tr>
<tr>
<td>N080 X700.0 Z400.0 ;</td>
<td></td>
</tr>
<tr>
<td>N090 X800.0 Z400.0 ;</td>
<td></td>
</tr>
<tr>
<td>N100 X900.0 z400.0 ;</td>
<td></td>
</tr>
<tr>
<td>N110 x1000.0 z1000.0 ;</td>
<td></td>
</tr>
<tr>
<td>N120 x800.0 z800.0 ;</td>
<td></td>
</tr>
</tbody>
</table>

RMT STRT MTN *** *** 21:20:05  
[PRGRM] [CHECK] [ ] [ ] [OPRT]

• **Program screen**  
(Twelve soft key type LCD)

<table>
<thead>
<tr>
<th>PROGRAM</th>
<th>F0001 N00020</th>
</tr>
</thead>
<tbody>
<tr>
<td>N020 X100.0 (DNC–PROG) ;</td>
<td></td>
</tr>
<tr>
<td>N030 X90.0 ;</td>
<td></td>
</tr>
<tr>
<td>N040 X80.0 ;</td>
<td></td>
</tr>
<tr>
<td>N050 X70.0 ;</td>
<td></td>
</tr>
<tr>
<td>N060 X60.0 ;</td>
<td></td>
</tr>
<tr>
<td>N070 X50.0 ;</td>
<td></td>
</tr>
<tr>
<td>N080 X40.0 ;</td>
<td></td>
</tr>
<tr>
<td>N090 X30.0 ;</td>
<td></td>
</tr>
<tr>
<td>N100 X20.0 ;</td>
<td></td>
</tr>
<tr>
<td>N110 X10.0 ;</td>
<td></td>
</tr>
<tr>
<td>N120 X0.0 ;</td>
<td></td>
</tr>
<tr>
<td>N130 Z100.0 ;</td>
<td></td>
</tr>
<tr>
<td>N140 Z90.0 ;</td>
<td></td>
</tr>
<tr>
<td>N150 Z80.0 ;</td>
<td></td>
</tr>
<tr>
<td>N160 Z70.0 ;</td>
<td></td>
</tr>
<tr>
<td>N170 Z60.0 ;</td>
<td></td>
</tr>
</tbody>
</table>

RMT STRT MTN *** *** 22:23:24  
[PRGRM] [CHECK] [OPRT]

During DNC operation, the program currently being executed is displayed on the program check screen and program screen. The number of displayed program blocks depends on the program being executed. Any comment enclosed between a control–out mark (() and control–in mark ()) within a block is also displayed.

**Explanations**

- During DNC operation, programs stored in memory can be called.
- During DNC operation, macro programs stored in memory can be called.
Limitations

- **Limit on number of characters**
  In program display, no more than 256 characters can be displayed. Accordingly, character display may be truncated in the middle of a block.

- **M198 (command for calling a program from within an external input/output unit)**
  In DNC operation, M198 cannot be executed. If M198 is executed, P/S alarm No. 210 is issued.

- **Custom macro**
  In DNC operation, custom macros can be specified, but no repeat instruction and branch instruction can be programmed. If a repeat instruction or branch instruction is executed, P/S alarm No. 123 is issued. When reserved words (such as IF, WHILE, COS, and NE) used with custom macros in DNC operation are displayed during program display, a blank is inserted between adjacent characters.

  Example
  
  - [During DNC operation]
    - 
      
  - Example
  
  - M99
  When control is returned from a subprogram or macro program to the calling program during DNC operation, it becomes impossible to use a return command (M99P****) for which a sequence number is specified.

Alarm

<table>
<thead>
<tr>
<th>Number</th>
<th>Message</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>086</td>
<td>DR SIGNAL OFF</td>
<td>When entering data in the memory by using Reader / Puncher interface, the ready signal (DR) of reader / puncher was turned off. Power supply of I/O unit is off or cable is not connected or a P.C.B. is defective.</td>
</tr>
<tr>
<td>123</td>
<td>CAN NOT USE MACRO COMMAND IN DNC</td>
<td>Macro control command is used during DNC operation. Modify the program.</td>
</tr>
<tr>
<td>210</td>
<td>CAN NOT COMAND M198/M199</td>
<td>Or M198 is executed in the DNC operation. Modify the program.</td>
</tr>
</tbody>
</table>
4.4 SIMULTANEOUS INPUT/OUTPUT

While an automation operation is being performed, a program input from an I/O device connected to the reader/punch interface can be executed and output through the reader/punch interface at the same time.

Simultaneous Input/Output

Procedure

- Basic simultaneous input procedure
  1. Search for the program (file) to be output and executed.
  2. Press the REMOTE switch on the machine operator’s panel to set RMT mode. For details of the use of the REMOTE switch, refer to the relevant manual supplied by the machine tool builder.
  3. Set the simultaneous output operation mode select signal to 1.
  4. Press the cycle start switch.
  5. Program output and execution is performed on a block–by–block basis.

Program check screen

When a program is displayed, three blocks are displayed: the block currently being executed and the next two to be executed. When the single block function is selected, only the block currently being executed is displayed.

Any comment enclosed between a control–out mark (() and control–in mark ()) within a block is not displayed.

- Basic simultaneous output procedure
  1. Search for the program (file) to be output and executed.
  2. Press the REMOTE switch on the machine operator’s panel to set RMT mode. For details of the use of the REMOTE switch, refer to the relevant manual supplied by the machine tool builder.
  3. Set the simultaneous output operation mode select signal to 1.
  4. Press the cycle start switch.
  5. Program output and execution is performed on a block–by–block basis.
Limitations

- M198 (command for calling a program from within an external input/output unit)
  M198 cannot be executed in the input, output and run simultaneous mode. An attempt to do so results in alarm No. 210.

- Macro control command
  A macro control command cannot be executed in the input, output and run simultaneous mode. An attempt to do so results in P/S alarm No. 123.

- Alarm
  If an alarm condition occurs during the input, output and run simultaneous mode, a block being processed when the alarm condition occurs and all blocks before that are input or output.

- File name
  In the output and run simultaneous mode, if a device used is a floppy disk drive or FA card, the file name is the execution program number.

- Sub program call
  When a program is being executed in the output and run simultaneous mode, if a subprogram is called, only the main program is output.

Alarm

<table>
<thead>
<tr>
<th>Number</th>
<th>Message</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>123</td>
<td>CAN NOT USE MACRO COMMAND IN DNC</td>
<td>Macro control command is used during DNC operation. Modify the program.</td>
</tr>
<tr>
<td>210</td>
<td>CAN NOT COMMAND M198/M199</td>
<td>M198 or M199 is executed in the DNC operation. M198 is executed in the DNC operation. Modify the program.</td>
</tr>
<tr>
<td>222</td>
<td>DNC OP. NOT ALLOWED IN BG.--EDIT</td>
<td>Input and output are executed at a time in the background edition. Execute a correct operation.</td>
</tr>
</tbody>
</table>
4.5 PROGRAM RESTART

This function specifies Sequence No. of a block to be restarted when a tool is broken down or when it is desired to restart machining operation after a day off, and restarts the machining operation from that block. It can also be used as a high-speed program check function.

There are two restart methods: the P-type method and Q-type method.

<table>
<thead>
<tr>
<th>P TYPE</th>
<th>Operation can be restarted anywhere. This restart method is used when operation is stopped because of a broken tool.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Program start point (machining start point)</td>
</tr>
<tr>
<td></td>
<td>Return operation</td>
</tr>
<tr>
<td></td>
<td>Restart position</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Q TYPE</th>
<th>Before operation can be restarted, the machine must be moved to the programmed start point (machining start point)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Program start point (machining start point)</td>
</tr>
<tr>
<td></td>
<td>Return operation</td>
</tr>
<tr>
<td></td>
<td>Restart position</td>
</tr>
</tbody>
</table>
Procedure for Program Restart by Specifying a Sequence Number

**Procedure 1**

[P TYPE ]

1. Retract the tool and replace it with a new one. When necessary, change the offset. (Go to step 2.)

[ Q TYPE ]

1. When power is turned ON or emergency stop is released, perform all necessary operations at that time, including the reference position return.

2. Move the machine manually to the program starting point (machining start point), and keep the modal data and coordinate system in the same conditions as at the machining start.

3. If necessary, modify the offset amount.

**Procedure 2**

[COMMON TO P TYPE / Q TYPE]

1. Turn the program restart switch on the machine operator’s panel ON.

2. Press [PROG] key to display the desired program.

3. Find the program head.

4. Enter the sequence number of the block to be restarted, then press the [P TYPE] or [Q TYPE] soft key.

If the same sequence number appears more than once, the location of the target block must be specified. Specify a frequency and a sequence number.
The sequence number is searched for, and the program restart screen appears on the LCD display.

<table>
<thead>
<tr>
<th>PROGRAM RESTART</th>
<th>O0002 N01000</th>
</tr>
</thead>
<tbody>
<tr>
<td>DESTINATION M</td>
<td>1 2</td>
</tr>
<tr>
<td>X 57.096</td>
<td>1</td>
</tr>
<tr>
<td>Y 56.877</td>
<td>1</td>
</tr>
<tr>
<td>Z 56.943</td>
<td>1</td>
</tr>
<tr>
<td>*****************</td>
<td>1 2</td>
</tr>
<tr>
<td>DISTANCE TO GO</td>
<td>******</td>
</tr>
<tr>
<td>1 X 1.459</td>
<td>T***********</td>
</tr>
<tr>
<td>2 Y 10.309</td>
<td>S***********</td>
</tr>
<tr>
<td>3 Z 7.320</td>
<td>S 0</td>
</tr>
<tr>
<td>MEM ***********</td>
<td>T0000</td>
</tr>
<tr>
<td>MEM ***********</td>
<td>10:10:40</td>
</tr>
</tbody>
</table>

**DESTINATION** shows the position at which machining is to restart. **DISTANCE TO GO** shows the distance from the current tool position to the position where machining is to restart. A number to the left of each axis name indicates the order of axes (determined by parameter setting) along which the tool moves to the restart position.

The coordinates and amount of travel for restarting the program can be displayed for up to five axes. If your system supports six or more axes, pressing the [RSTR] soft key again displays the data for the sixth and subsequent axes. (The program restart screen displays only the data for CNC-controlled axes.)

- **M**: Fourteen most recently specified M codes
- **T**: Two most recently specified T codes
- **S**: Most recently specified S code
- **B**: Most recently specified B code

Codes are displayed in the order in which they are specified. All codes are cleared by a program restart command or cycle start in the reset state.

6 Turn the program re-start switch OFF. At this time, the figure at the left side of axis name **DISTANCE TO GO** blinks.

7 Check the screen for the M, S, T, and B codes to be executed. If they are found, enter the MDI mode, then execute the M, S, T, and B functions. After execution, restore the previous mode.

8 Check that the distance indicated under **DISTANCE TO GO** is correct. Also check whether there is the possibility that the tool might hit a workpiece or other objects when it moves to the machining restart position. If such a possibility exists, move the tool manually to a position from which the tool can move to the machining restart position without encountering any obstacles.

9 Press the cycle start button. The tool moves to the machining restart position at the dry run feedrate sequentially along axes in the order specified by parameter settings (No. 7310). Machining is then restarted.
4. AUTOMATIC OPERATION

Procedure for Program Restart by Specifying a Block Number

Procedure 1

1. Retract the tool and replace it with a new one. When necessary, change the offset. (Go to step 2.)

Procedure 2

1. When power is turned ON or emergency stop is released, perform all necessary operations at that time, including the reference position return.

2. Move the machine manually to the program starting point (machining start point), and keep the modal data and coordinate system in the same conditions as at the machining start.

3. If necessary, modify the offset amount.

Procedure 2

1. Turn the program restart switch on the machine operator’s panel ON.

2. Press the \texttt{PROG} key to display the desired program.

3. Find the program head. Press function \texttt{RESET} key.

4. Enter the number of the block to be restarted then press the \texttt{[P TYPE]} or \texttt{[Q TYPE]} soft key. The block number cannot exceed eight digits.

5. The block number is searched for, and the program restart screen appears on the CRT display.

\begin{verbatim}
PROGRAM RESTART
O0002 N01000
DESTINATION M 1 2
X 57.096 1 2
Y 56.877 1 2
Z 56.943 1 2
1 ********
DISTANCE TO GO
X 1.459 ********
Y 10.309 T ********
Z 7.320 S 0
S 0 T0000
MEM 10 : 10 : 40
\end{verbatim}

\texttt{DESTINATION} shows the position at which machining is to restart. \texttt{DISTANCE TO GO} shows the distance from the current tool position to the position where machining is to restart. A number to the left of each axis name indicates the order of axes (determined by parameter setting) along which the tool moves to the restart position.

---

805
The coordinates and amount of travel for restarting the program can be displayed for up to five axes. If your system supports six or more axes, pressing the [RSTR] soft key again displays the data for the sixth and subsequent axes. (The program restart screen displays only the data for CNC-controlled axes.)

- **M**: Fourteen most recently specified M codes
- **T**: Two most recently specified T codes
- **S**: Most recently specified S code
- **B**: Most recently specified B code

Codes are displayed in the order in which they are specified. All codes are cleared by a program restart command or cycle start in the reset state.

6 Turn the program restart switch OFF. At this time, the figure at the left side of axis name DISTANCE TO GO blinks.

7 Check the screen for the M, S, T, and B codes to be executed. If they are found, enter the MDI mode, then execute the M, S, T, and B functions. After execution, restore the previous mode. These codes are not displayed on the program restart screen.

8 Check that the distance indicated under DISTANCE TO GO is correct. Also check whether there is the possibility that the tool might hit a workpiece or other objects when it moves to the machining restart position. If such a possibility exists, move the tool manually to a position from which the tool can move to the machining restart position without encountering any obstacles.

9 Press the cycle start button. The tool moves to the machining restart position at the dry run feedrate sequentially along axes in the order specified by parameter settings (No. 7310). Machining is then restarted.

### Explanations

#### • Block number

When the CNC is stopped, the number of executed blocks is displayed on the program screen or program restart screen. The operator can specify the number of the block from which the program is to be restarted, by referencing the number displayed on the CRT. The displayed number indicates the number of the block that was executed most recently. For example, to restart the program from the block at which execution stopped, specify the displayed number, plus one.

The number of blocks is counted from the start of machining, assuming one NC line of a CNC program to be one block.

#### < Example 1 >

<table>
<thead>
<tr>
<th>CNC Program</th>
<th>Number of blocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>O 0001 ;</td>
<td>1</td>
</tr>
<tr>
<td>G90 G92 X0 Y0 Z0 ;</td>
<td>2</td>
</tr>
<tr>
<td>G01 X100. F100 ;</td>
<td>3</td>
</tr>
<tr>
<td>G03 X01 –50. F50 ;</td>
<td>4</td>
</tr>
<tr>
<td>M30 ;</td>
<td>5</td>
</tr>
</tbody>
</table>
< Example 2 >

<table>
<thead>
<tr>
<th>CNC Program</th>
<th>Number of blocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>O 0001 ;</td>
<td>1</td>
</tr>
<tr>
<td>G80 G92 X0 Y0 Z0 ;</td>
<td>2</td>
</tr>
<tr>
<td>G80 G00 Z100. ;</td>
<td>3</td>
</tr>
<tr>
<td>G81 X100, Y0, Z=120. R=80. F50. ;</td>
<td>4</td>
</tr>
<tr>
<td>#1 = #1 + 1 ;</td>
<td>4</td>
</tr>
<tr>
<td>#2 = #2 + 1 ;</td>
<td>4</td>
</tr>
<tr>
<td>#3 = #3 + 1 ;</td>
<td>4</td>
</tr>
<tr>
<td>G00 X0 Z0 ;</td>
<td>5</td>
</tr>
<tr>
<td>M30 ;</td>
<td>6</td>
</tr>
</tbody>
</table>

Macro statements are not counted as blocks.

- **Storing / clearing the block number**
  
  The block number is held in memory while no power is supplied. The number can be cleared by cycle start in the reset state.

- **Block number when a program is halted or stopped**
  
  The program screen usually displays the number of the block currently being executed. When the execution of a block is completed, the CNC is reset, or the program is executed in single–block stop mode, the program screen displays the number of the program that was executed most recently.

  When a CNC program is halted or stopped by feed hold, reset, or single–block stop, the following block numbers are displayed:
  - Feed hold : Block being executed
  - Reset : Block executed most recently
  - Single–block stop : Block executed most recently

  For example, when the CNC is reset during the execution of block 10, the displayed block number changes from 10 to 9.

- **MDI intervention**
  
  When MDI intervention is performed while the program is stopped by single–block stop, the CNC commands used for intervention are not counted as a block.

- **Block number exceeding eight digits**
  
  When the block number displayed on the program screen exceeds eight digits, the block number is reset to 0 and counting continues.

**Limitations**

- **P–type restart**
  
  Under any of the following conditions, P–type restart cannot be performed:
  - When automatic operation has not been performed since the power was turned on
  - When automatic operation has not been performed since an emergency stop was released
  - When automatic operation has not been performed since the coordinate system was changed or shifted (change in an external offset from the workpiece reference point)

- **Restart block**
  
  The block to be restarted need not be the block which was interrupted; operation can restart with any block. When P–type restart is performed, the restart block must use the same coordinate system as when operation was interrupted.
When single block operation is ON during movement to the restart position, operation stops every time the tool completes movement along an axis. When operation is stopped in the single block mode, MDI intervention cannot be performed.

During movement to the restart position, manual intervention can be used to perform a return operation for an axis if it has not yet been performed for the axis. A return operation cannot be done further on axes for which a return has already been completed.

Never reset during the time from the start of a search at restart until machining is restarted. Otherwise, restart must be performed again from the first step.

Regardless of whether machining has started or not, manual operation must be performed when the manual absolute mode is on.

If no absolute–position detector (absolute pulse coder) is provided, be sure to perform reference position return after turning on the power and before performing restart.

<table>
<thead>
<tr>
<th>Alarm No.</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>071</td>
<td>The specified block number for restarting the program is not found.</td>
</tr>
<tr>
<td>094</td>
<td>After interruption, a coordinate system was set, then P–type restart was specified.</td>
</tr>
<tr>
<td>095</td>
<td>After interruption, the coordinate system shift was changed, then P–type restart was specified.</td>
</tr>
<tr>
<td>096</td>
<td>After interruption, the coordinate system was changed, then P–type restart was specified.</td>
</tr>
<tr>
<td>097</td>
<td>When automatic operation has not been performed since the power was turned on, emergency stop was released, or P/S alarm 094 to 097 was reset, P–type restart was specified.</td>
</tr>
<tr>
<td>098</td>
<td>After the power was turned on, restart operation was performed without reference position return, but a G28 command was found in the program.</td>
</tr>
<tr>
<td>099</td>
<td>A move command was specified from the MDI panel during a restart operation.</td>
</tr>
<tr>
<td>5020</td>
<td>An erroneous parameter was specified for restarting a program.</td>
</tr>
</tbody>
</table>

As a rule, the tool cannot be returned to a correct position under the following conditions. Special care must be taken in the following cases since none of them cause an alarm:

- Manual operation is performed when the manual absolute mode is OFF.
- Manual operation is performed when the machine is locked.
- When the mirror image is used.
- When manual operation is performed in the course of axis movement for returning operation.
- When the program restart is commanded for a block between the block for skip cutting and subsequent absolute command block.
4.6 SCHEDULING FUNCTION

The schedule function allows the operator to select files (programs) registered on a floppy disk in an external input/output device (Handy File, Floppy Cassette, or FA Card) and specify the execution order and number of repetitions (scheduling) for performing automatic operation. It is also possible to select only one file from the files in the external input/output device and execute it during automatic operation. This function is effective, when the floppy cassette directory display option is available and the floppy cassette is selected as the valid I/O device.

<table>
<thead>
<tr>
<th>FILE NO.</th>
<th>FILE NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>0001</td>
<td>O0010</td>
</tr>
<tr>
<td>0002</td>
<td>O0020</td>
</tr>
<tr>
<td>0003</td>
<td>O0030</td>
</tr>
<tr>
<td>0004</td>
<td>O0040</td>
</tr>
</tbody>
</table>

List of files in an external input/output device

Set file number and number of repetitions.

<table>
<thead>
<tr>
<th>ORDER</th>
<th>FILE NO</th>
<th>REPETITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>0002</td>
<td>2</td>
</tr>
<tr>
<td>02</td>
<td>0003</td>
<td>1</td>
</tr>
<tr>
<td>03</td>
<td>0004</td>
<td>3</td>
</tr>
<tr>
<td>04</td>
<td>0001</td>
<td>2</td>
</tr>
</tbody>
</table>

Scheduling screen

Executing automatic operation
Procedure for Scheduling Function

Procedure

- Procedure for executing one file

1. Press the MEMORY switch on the machine operator’s panel, then press the PROG function key on the MDI panel.

2. Press the rightmost soft key (continuous menu key), then press the [FL. SDL] soft key. A list of files registered in the Floppy Cassette is displayed on screen No. 1. To display more files that are not displayed on this screen, press the page key on the MDI panel. Files registered in the Floppy Cassette can also be displayed successively.

Screen No.1

3. Press the [(OPRT)] and [SELECT] soft keys to display “SELECT FILE NO.” (on screen No. 2). Enter a file number, then press the [F SET] and [EXEC] soft keys. The file for the entered file number is selected, and the file name is indicated after “CURRENT SELECTED:”.

Screen No.2
4. AUTOMATIC OPERATION

4  Press the **REMOTE** switch on the machine operator’s panel to enter the **RMT** mode, then press the cycle start switch. The selected file is executed. For details on the **REMOTE** switch, refer to the manual supplied by the machine tool builder. The selected file number is indicated at the upper right corner of the screen as an F number (instead of an O number).

**FILE DIRECTORY**

- **RMT** 13:27:54
- **CURRENT SELECTED**: O0040

**Screen No.3**

**Procedure for executing the scheduling function**

1. Display the list of files registered in the Floppy Cassette. The display procedure is the same as in steps 1 and 2 for executing one file.

2. On screen No. 2, press the **[(OPRT)]** and **[SELECT]** soft keys to display “SELECT FILE NO.”

3. Enter file number 0, and press the **[F SET]** and **[EXEC]** soft keys. “SCHEDULE” is indicated after “CURRENT SELECTED:”.

4. Press the leftmost soft key (return menu key) and the **[SCHDUL]** soft key. Screen No. 4 appears.

**FILE DIRECTORY**

- **MEM** 22:07:00
- **ORDER FILE NO.**
  - 01
  - 02
  - 03
  - 04
  - 05
  - 06
  - 07
  - 08
  - 09
  - 10

**Screen No.4**
Move the cursor and enter the file numbers and number of repetitions in the order in which to execute the files. At this time, the current number of repetitions “CUR.REP” is 0.

5 Press the REMOTE switch on the machine operator’s panel to enter the RMT mode, then press the start switch. The files are executed in the specified order. When a file is being executed, the cursor is positioned at the number of that file. The current number of repetitions CUR.REP is increased when M02 or M30 is executed in the program being run.

<table>
<thead>
<tr>
<th>ORDER</th>
<th>FILE NO.</th>
<th>REQ.REP</th>
<th>CUR.REP</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>0007</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>02</td>
<td>0003</td>
<td>23</td>
<td>23</td>
</tr>
<tr>
<td>03</td>
<td>0004</td>
<td>9999</td>
<td>156</td>
</tr>
<tr>
<td>04</td>
<td>0005</td>
<td>LOOP</td>
<td>0</td>
</tr>
<tr>
<td>05</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>06</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>07</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>08</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>09</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

RMT 10:10:40

Screen No.5

Explanations

- **Specifying no file number**
  
  If no file number is specified on screen No. 4 (the file number field is left blank), program execution is stopped at that point. To leave the file number field blank, press numeric key 0 then INPUT.

- **Endless repetition**
  
  If a negative value is set as the number of repetitions, <LOOP> is displayed, and the file is repeated indefinitely.

- **Clear**
  
  When the [(OPRT)], [CLEAR], and [EXEC] soft keys are pressed on screen No. 4, all data is cleared. However, these keys do not function while a file is being executed.

- **Return to the program screen**
  
  When the soft key [PRGRM] is pressed on screen No. 1, 2, 3, 4, or 5, the program screen is displayed.

Restrictions

- **Number of repetitions**
  
  Up to 9999 can be specified as the number of repetitions. If 0 is set for a file, the file becomes invalid and is not executed.

- **Number of files registered**
  
  By pressing the page key on screen No. 4, up to 20 files can be registered.

- **M code**
  
  When M codes other than M02 and M30 are executed in a program, the current number of repetitions is not increased.
4. AUTOMATIC OPERATION

- **Displaying the floppy disk directory during file execution**
  
  During the execution of file, the floppy directory display of background editing cannot be referenced.

- **Restarting automatic operation**
  
  To resume automatic operation after it is suspended for scheduled operation, press the reset button.

- **Scheduling function for the two–path control**
  
  The scheduling function can be used only for a single tool post.

### Alarm

<table>
<thead>
<tr>
<th>Alarm No.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>086</td>
<td>An attempt was made to execute a file that was not registered in the floppy disk.</td>
</tr>
<tr>
<td>210</td>
<td>M198 and M099 were executed during scheduled operation, or M198 was executed during DNC operation.</td>
</tr>
</tbody>
</table>
4.7 SUBPROGRAM CALL FUNCTION (M198)

The subprogram call function is provided to call and execute subprogram files stored in an external input/output device (Handy File, FLOPPY CASSETTE, FA Card) during memory operation. When the following block in a program in CNC memory is executed, a subprogram file in the external input/output device is called:

To use this function, the Floppy Cassette directory display option must be installed.

Format

1. FS15 tape format

M198 P0000 LAAAA ;

Number of repetitions
File number for a file in the I/O device
I/O devices call instruction

2. Other than FS15 tape format

M198 P0000 AAAAA ;

File number for a file in the I/O device
Number of repetitions
I/O devices call instruction

Explanation

The subprogram call function is enabled when parameter No.0102 for the input/output device is set to 3. When the custom macro option is provided, either format 1 or 2 can be used. A different M code can be used for a subprogram call depending on the setting of parameter No.6030. In this case, M198 is executed as a normal M code. The file number is specified at address P. If the SBP bit (bit 2) of parameter No.3404 is set to 1, a program number can be specified. When a file number is specified at address P, Fxxxx is indicated instead of Oxxxx.

Fig. 4.7 (a) Program Flow When M198 is Specified
Restrictions

- **Subprogram call function with two–path control**

For the two–path control, subprograms in a floppy cassette cannot be called for the two tool posts at the same time.

<table>
<thead>
<tr>
<th>NOTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 When M198 in the program of the file saved in a floppy cassette is executed, a P/S alarm (No.210) is given. When a program in the memory of CNC is called and M198 is executed during execution of a program of the file saved in a floppy cassette, M198 is changed to an ordinary M–code.</td>
</tr>
<tr>
<td>2 When MDI is intervened and M198 is executed after M198 is commanded in the memory mode, M198 is changed to an ordinary M–code. When the reset operation is done in the MDI mode after M198 is commanded in the MEMORY mode, it does not influence on the memory operation and the operation is continued by restarting it in the MEMORY mode.</td>
</tr>
</tbody>
</table>
4.8 MANUAL HANDLE INTERRUPTION

The movement by manual handle operation can be done by overlapping it with the movement by automatic operation in the automatic operation mode.

![Diagram of Manual Handle Interruption]

- Handle interruption axis selection signals
  For the handle interruption axis selection signals, refer to the manual supplied by the machine tool builder.
  During automatic operation, handle interruption is enabled for an axis if the handle interruption axis selection signal for that axis is on. Handle interruption is performed by turning the handle of the manual pulse generator.

**WARNING**

The travel distance by handle interruption is determined according to the amount by which the manual pulse generator is turned and the handle feed magnification (x1, x10, xM, xN).
Since this movement is not accelerated or decelerated, it is very dangerous to use a large magnification value for handle interruption.
The move amount per scale at x1 magnification is 0.001 mm (metric output) or 0.0001 inch (inch output).

**NOTE**

Handle interruption is disabled when the machine is locked during automatic operation.
Explanations

• Relation with other functions

The following table indicates the relation between other functions and the movement by handle interrupt.

<table>
<thead>
<tr>
<th>Display</th>
<th>Relation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machine lock</td>
<td>Machine lock is effective. The tool does not move even when this signal turns on.</td>
</tr>
<tr>
<td>Interlock</td>
<td>Interlock is effective. The tool does not move even when this signal turns on.</td>
</tr>
<tr>
<td>Mirror image</td>
<td>Mirror image is not effective. Interrupt functions on the plus direction by plus direction command, even if this signal turns on.</td>
</tr>
</tbody>
</table>

• Position display

The following table shows the relation between various position display data and the movement by handle interrupt.

<table>
<thead>
<tr>
<th>Display</th>
<th>Relation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absolute coordinate value</td>
<td>Handle interruption does not change absolute coordinates.</td>
</tr>
<tr>
<td>Relative coordinate value</td>
<td>Handle interruption does not change relative coordinates.</td>
</tr>
<tr>
<td>Machine coordinate value</td>
<td>Machine coordinates are changed by the travel distance specified by handle interruption.</td>
</tr>
</tbody>
</table>

• Travel distance display

Press the function key \( \text{POS} \), then press the chapter selection soft key [HNDL].

The move amount by the handle interrupt is displayed. The following 4 kinds of data are displayed concurrently.

```
HANDLE INTERRUPTION (INPUT UNIT)
  X   69.594
  Y 137.783
  Z  -61.439

(RELATIVE)
  X   0.000
  Y   0.000
  Z   0.000

(DISTANCE TO GO)
  X   0.000
  Y   0.000
  Z   0.000

PART COUNT 287
RUN TIME   1H 12M CYCLE TIME   0H 0M 0S
MDI  10:29:51
```
(a) INPUT UNIT : Handle interrupt move amount in input unit system
Indicates the travel distance specified by handle interruption according to the least input increment.

(b) OUTPUT UNI : Handle interrupt move amount in output unit system
Indicates the travel distance specified by handle interruption according to the least command increment.

(c) RELATIVE : Position in relative coordinate system
These values have no effect on the travel distance specified by handle interruption.

(d) DISTANCE TO GO : The remaining travel distance in the current block has no effect on the travel distance specified by handle interruption.

The handle interrupt move amount is cleared when the manual reference position return ends every axis.

**Display for five-axis systems or better**

Systems having five or more axes provide the same display as the overall position display. See III–11.1.3.
4.9 MIRROR IMAGE

During automatic operation, the mirror image function can be used for movement along an axis. To use this function, set the mirror image switch to ON on the machine operator’s panel, or set the mirror image setting to ON from the MDI panel.

The following procedure is given as an example. For actual operation, refer to the manual supplied by the machine tool builder.

1. Press the single block switch to stop automatic operation. When the mirror image function is used from the beginning of operation, this step is omitted.

2. Press the mirror image switch for the target axis on the machine operator’s panel.
   Alternatively, turn on the mirror image setting by following the steps below:

   2–1 Set the MDI mode.

   2–2 Press the OFFSET function key.

   2–3 Press the [SETTING] soft key for chapter selection to display the setting screen.

![Fig 4.9 Mirror Image](image-url)
2–4 Move the cursor to the mirror image setting position, then set the target axis to 1.

3 Enter an automatic operation mode (memory mode or MDI mode), then press the cycle start button to start automatic operation.

**Explanations**

- The mirror image function can also be turned on and off by setting bit 0 of parameter 0012 (MIRx) to 1 or 0.
- For the mirror image switches, refer to the manual supplied by the machine tool builder.

**Limitations**

The direction of movement during manual operation, the direction of movement from an intermediate point to the reference position during automatic reference position return (G28), the direction of approach during unidirectional positioning (G60), and the shift direction in a boring cycle (G76, G87) cannot be reserved.
4.10 TOOL WITHDRAWAL AND RETURN

The tool can be withdrawn from a workpiece in order to replace the tool when it is damaged during machining, or merely to check the status of machining. The tool can then be advanced again to restart machining efficiently.

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>✗</td>
<td>Position where the TOOL WITHDRAW switch is turned on</td>
</tr>
<tr>
<td>●</td>
<td>Programmed position</td>
</tr>
<tr>
<td>○</td>
<td>Position to which the tool is retracted by manual operation</td>
</tr>
<tr>
<td>➔</td>
<td>Retraction path</td>
</tr>
<tr>
<td>➔</td>
<td>Manual operation (withdraw path)</td>
</tr>
<tr>
<td>➔</td>
<td>Return path</td>
</tr>
<tr>
<td>➔</td>
<td>Repositioning</td>
</tr>
</tbody>
</table>

Procedure for tool withdrawal and return

**Procedure1 Programming**

Specify a retraction axis and distance in command G10.6IP_ beforehand. In the sample program below, the N20 block specifies that the Z-axis is the retraction axis and the retraction distance is to be 50 mm.

(Sample program)
N10 G91 Z–50. ;
N20 G10.6 Z50. ;
N30 G01 X150. F500. ;
Suppose that the TOOL WITHDRAW switch on the machine operator’s panel is turned on when the tool is positioned at point A during execution of the N30 block.

Next, the tool withdrawal mode is set and the TOOL BEING WITHDRAWN LED goes on. At this time, automatic operation is temporarily halted. The tool is then retracted by the programmed distance. If point A is the end point of the block, retraction is performed after automatic operation is stopped. Retraction is based on linear interpolation. The dry run feedrate is used for retraction. Upon completion of retraction, the RETRACT POSITION LED on the operator’s panel goes on.

During retraction, the screen displays PTRR and STRT.

- PTRR blinks in the field for indicating states such as the program editing status.
- STRT is displayed in the automatic operation status field.
- MTN is displayed in the field for indicating status such as movement along an axis.
Set the manual operation mode, then withdraw the tool. For manual operation, either jog feed or handle feed is possible.
Procedure 4
Return

After withdrawing the tool and any additional operation such as replacing the tool, move the tool back to the previous retraction position. To return the tool to the retraction position, return the mode to automatic operation mode, then turn the TOOL RETURN switch on the operator’s panel on then off again. The tool returns to the retraction position at the dry run feedrate, regardless of whether the dry run switch is on or off. When the tool has returned to the retraction position, the RETRACTION POSITION LED comes on.

Screen

During return operation, the CRT screen displays PTRR and MSTR.

- PTRR blinks in the field for indicating states such as program editing status.
- MSTR is displayed in the automatic operation status field.
- MTN is displayed in the field for indicating states such as movement along an axis.
Procedure 5
Repositioning

While the tool is at the retraction position (point E in the figure below) and the RETRACTION POSITION LED is on, press the cycle start switch. The tool is then repositioned at the point where retraction was started (i.e. where the TOOL WITHDRAW switch was turned on).

Upon completion of repositioning, the tool withdraw mode is cancelled, and the TOOL BEING WITHDRAWN LED goes off and restart N30.

Explanation 1
Retraction

• When no retraction distance is specified

If no retraction distance or direction required for retraction are specified, retraction is not performed when the TOOL WITHDRAW switch on the operator’s panel is turned on. Instead, the block being executed in automatic operation is interrupted (automatic operation is held or stopped). In this state, the tool can be withdrawn and returned.

• Retraction from the automatic operation hold or stop state

When the single block switch is turned on during automatic operation, or the TOOL WITHDRAW switch is turned on after the automatic operation hold or stop state is set by feed hold: Retraction is performed, then the automatic operation hold or stop state is set again.

• Stopping retraction

During retraction, feed hold operation is ignored. However, reset operation is enabled (retraction is stopped at reset). When an alarm is issued during retraction, the retraction is stopped immediately.

• Repositioning immediately after retraction

After retraction is completed, tool repositioning can be started without performing the withdraw and return operations.
To move the tool along an axis, select the corresponding axis selection signal. Never specify axis selection signals for two or more axes at a time.

When the tool is moved in manual operation along an axis, the control unit memorizes up to ten paths of movements. If the tool is stopped after being moved along a selected axis and is then moved along another selected axis, the position where this switch takes place is memorized. After ten paths have been memorized, the control unit does not memorize any additional switching points.

Upon reset, memorized position data is lost and the tool withdraw mode is cancelled.

When there are more than ten return paths, the tool first moves to the tenth position, then to the ninth position, then to the eighth position, and so forth until the retraction position is reached.

The single block switch is enabled during return operation. If the single block switch is turned off, continuous return operation is performed. If the single block switch is turned off, the tool stops at each memorized position. In this case, return operation can be resumed by turning the TOOL RETURN switch on then off again.

When an alarm is issued during return operation, return operation stops.

The feed hold function is enabled during return operation.

The feed hold function is disabled during repositioning.

The operation after completion of repositioning depends on the automatic operation state present when the TOOL WITHDRAW switch is turned on.

1. When automatic operation is being started
   After completion of repositioning, the interrupted execution of the block is resumed.

2. When automatic operation is held or stopped
   After completion of repositioning, the tool stops once at the repositioned point, then the original automatic operation hold or stop state is set. When the cycle start switch is pressed, automatic operation is resumed.
4.11 RETRACE FUNCTION

With the retrace function, the tool can be moved in the reverse direction (reverse movement) by using the REVERSE switch during automatic operation to trace the programmed path. The retrace function also enables the user to move the tool in the forward direction again (forward return movement) along the retraced path until the retrace start position is reached. When the tool reaches the retrace start position, the tool resumes movement according to the program.

Procedure for Retrace Operation

Procedure

- **Forward movement → Reverse movement**

To move the tool in the forward direction, turn off the REVERSE switch on the operator’s panel, then press the cycle start switch. If the REVERSE switch on the operator’s panel is on, the tool moves in the reverse direction or completes reverse movement.

Three methods are available for moving the tool in the reverse direction along the programmed path.

1) When the tool is moving in the forward direction, turn on the REVERSE switch on the operator’s panel during block execution.

2) When the tool is moving in the forward direction, turn on the REVERSE switch on the operator’s panel after a single block stop.

3) When the tool is moving in the forward direction, turn on the REVERSE switch on the operator’s panel after a feed hold stop.

In the case of 1) above, the tool starts reverse movement after completion of the block currently being executed (after execution up to the position of a single block stop). Turning on the REVERSE switch on the operator’s panel does not immediately start reverse movement.

In the case of 2) above, the tool starts reverse movement at the position of a single block stop when the cycle start switch is pressed.

In the case of 3) above, the tool starts reverse movement at the position of a feed hold stop when the cycle start switch is pressed.
Three methods are available for moving the tool in the forward direction again along the retraced path.

1) When the tool is moving in the reverse direction, turn off the REVERSE switch on the operator’s panel during block execution.

2) When the tool is moving in the reverse direction, turn off the REVERSE switch on the operator’s panel after a single block stop.

3) When the tool is moving in the reverse direction, turn off the REVERSE switch on the operator’s panel after a feed hold stop.

In the case of 1) above, the tool starts forward return movement after completion of the block currently being executed (after execution up to the position of a single block stop). Turning off the REVERSE switch on the operator’s panel does not immediately start forward return movement.

In the case of 2) above, the tool starts forward return movement at the position of a single block stop when the cycle start switch is pressed.

In the case of 3) above, the tool starts forward return movement at the position of a feed hold stop when the cycle start switch is pressed.
4. AUTOMATIC OPERATION

- **Reverse movement** → Reverse movement completion → Forward return movement

When there are no more blocks for which to perform reverse movement (when the tool has moved back to the initial forward movement block or the tool has not yet started forward movement), the reverse movement completion state is entered and operation stops. Even when the cycle start switch is pressed with the REVERSE switch on the operator’s panel turned on, no operation is performed (the reverse movement completion state remains unchanged). When the cycle start switch is pressed after turning off the REVERSE switch on the operator’s panel, the tool starts forward return movement or forward movement.

- **Forward return movement** → Forward movement

When the tool completes a forward return movement up to the block where reverse movement was started, the tool automatically resumes forward movement. Programmed commands are read and program execution is continued. No particular operation is required to resume forward movement.

When tool movement switches from forward return movement to forward movement, the display of RTRY (Re-TRY) in the lower-right corner of the CRT screen disappears.

If the tool moves in the reverse direction after a feed hold stop, the tool stops forward return movement at the position of the feed hold stop, then resumes forward movement. If the tool moves in the reverse direction after a single block stop, the tool also stops forward return movement at the position of the single block stop.
Explanations

• **Forward movement and reverse movement**
  In automatic operation, a program is usually executed in the order that commands are specified. This mode of execution is referred to as forward movement. The retrace function can execute in reverse, program blocks that have already been executed. This mode of execution is referred to as reverse movement. In reverse movement, the tool can retrace the tool path followed by forward movement.
  A program can be executed in the reverse direction only for those blocks that have already been executed in the forward direction.
  Approximately 40 to 80 blocks can be executed in the reverse direction, depending on the program.
  During reverse movement, the REVERSE MOVEMENT LED is on and RVRS blinks in the lower–right corner of the screen to indicate that the tool is undergoing reverse movement.
  The tool can perform reverse movement one block at a time when the single block mode is set.

• **Forward return movement**
  The tool can be moved again along the retraced path of the blocks in the forward direction up to the block where reverse movement was started. This movement is referred to as forward return movement. In forward return movement, the tool moves along the same path as forward movement up to the position where reverse movement started.
  When the tool returns to the block where reverse movement was started, the tool resumes forward movement according to the program.
  In forward return movement, the REVERSE MOVEMENT LED is off and RTRY (Re–TRY) blinks in the lower–right corner of the screen to indicate that the tool is undergoing forward return movement. When the tool switches from forward return movement to forward movement, RTRY (Re–TRY) disappears from the lower–right corner of the screen.
  The tool can perform forward return movement one block at a time when the single block mode is set.

• **Reverse movement completion**
  When there are no more blocks for which to perform reverse movement (when the tool has moved back along the path of all memorized blocks or the tool has not yet started forward movement), operation stops. This is referred to as reverse movement completion.
  Upon reverse movement completion, the REVERSE MOVEMENT LED goes off, and RVED (ReVerse EnD) blinks in the lower–right corner of the screen to indicate that reverse movement is completed.
• Reset

Upon reset (when the RESET key on the MDI panel is pressed, the external reset signal is applied, or the reset and rewind signal is applied), the memorized reverse movement blocks are cleared.

• Feedrate

A feedrate for reverse movement can be specified using parameter (No. 1414). When this parameter is set to 0, the feedrate used for forward movement is used.

For forward return movement, the feedrate for forward movement is always used.

In reverse movement and forward return movement, the feedrate override function, rapid traverse override function, and dry run function are enabled.

Limitations

• Block that disables reverse movement

Reverse movement stops when any of the commands or modes listed below appears. If an attempt is made during forward movement to stop forward movement with feed hold stop and then move the tool in the reverse direction when any of the commands and modes below is specified, the reverse movement completion state occurs.

- Involute interpolation (G02.2/ G03.2)
- Exponential interpolation (G02.3/ G03.3)
- Cylindrical interpolation (G07.1, G107)
- Polar coordinate interpolation mode (G12.1)
- Inch/metric conversion (G20/ G21)
- Reference position return check (G27)
- Return to reference position (G28)
- Return from reference position (G29)
- 2nd, 3rd, and 4th reference position return (G30)
- Floating reference position return (G30.1)
- Thread cutting (G33)
- Machine coordinate system selection (G53)
- Chopping operation command (G81.1)
  (See the chopping function described later.)
- Rigid tapping cycle (M29, G84)
- High speed cycle machining (G05)
- High speed remote buffer A (G05)
- High speed remote buffer B (G05)
- High precision contour control (RISC) (G05)
- Advanced preview control (G08)
- Cs contour control
4. AUTOMATIC OPERATION

• Circular interpolation (G02, G03)
  Be sure to specify the radius of an arc with R.

[WARNING]
If an end point is not correctly placed on an arc (if a leading line is produced) when an arc center is specified using I, J, and K, the tool does not perform correct reverse movement.

• Interrupt-type custom macro
  1. Never initiate an interrupt during reverse movement.
  2. Never perform reverse movement for an interrupted block and the program that has issued the interrupt.

• Tool life management
  The retrace function does not support the tool life management function.

• Switching automatic operation mode
  If the operation mode is switched after a single block stop from memory operation to MDI operation or vice versa during reverse movement or forward return movement, reverse movement, forward return movement, and forward movement can no longer be performed. To restart operation, return the mode to the original mode, then press the cycle start switch.

• Positioning (G00)
  When the tool is positioned based on nonlinear interpolation by setting bit 1 (LRP) of parameter No. 1401 to 0, the path of the tool for reverse movement does not match the path for forward movement. The path for forward return movement is the same as the path for forward movement. When the tool is positioned based on linear interpolation by setting bit 1 (LRP) of parameter No. 1401 to 1, the path of the tool for reverse movement matches the path for forward movement.

Positioning based on nonlinear interpolation (LRP=0)  Positioning based on linear interpolation (LRP=1)

X  Y  
  Forward movement  Reverse movement  Forward return movement

• Dwell (G04)
  The dwell command (G04) is executed in reverse movement and forward return movement in the same way as during ordinary operation.

• Programmable data setting (G10)
  A tool compensation value, parameter, pitch error data, workpiece zero point offset value, and tool life management setting specified or modified using the programmable data setting code (G10) are ignored in reverse movement and forward return movement.

• Stored stroke check function on/off (G22,G23)
  The on/off state of the stored stroke check function present at the end of forward movement remains unchanged during reverse movement and forward return movement. This means that the actual on/off state may differ from the modal G22/G23 indication. When reverse movement or forward return movement is cancelled upon reset, the modal G22/G23 indication at that time becomes valid. The setting of an area with G22 X_Y_Z_I_J_K at the end of forward movement remains unchanged.
In reverse movement and forward return movement, the skip signal and automatic tool length measurement signal are ignored. In reverse movement and forward return movement, the tool moves along the path actually followed in forward movement.

### Skip function (G31), automatic tool length measurement (G37)

Whether the chopping operation is performed in reverse movement and forward return movement is determined by whether the chopping operation was performed at the end of forward movement.

If the tool starts reverse movement with the chopping mode off and moves in the reverse direction along the path of a block where the chopping mode is on, the chopping axis maintains its position at point R.

When a block specifying G81.1 (chopping command) appears during reverse movement, reverse movement ends and operation stops.

Along the path of a block where the tool moved according to inverse time feed in forward movement, the tool moves in the reverse direction according to the feedrate specified by parameter No. 1414 (= 0) for reverse movement.

If parameter No. 1414 for specifying the feedrate for reverse movement is not set (= 0), the tool moves in the reverse direction at the same feedrate as during forward movement.

If the on/off mode of constant surface speed control is specified in reverse movement, the specified mode is used in subsequent reverse movement. In other words, when a block specifying G96Sxxxx; appears in reverse movement, constant surface speed control is on for subsequent reverse movement. When a block specifying G97Sxxxx; appears in reverse movement, constant surface speed control is off for subsequent reverse movement.

Note that the on/off mode of constant surface speed control in forward movement is reversed in reverse movement.

If the command for clamping maximum spindle speed is specified in reverse movement, the specified clamp is applied to subsequent reverse movement. In other words, when G92Sxxxx appears in reverse movement, the spindle speed is clamped at Sxxxx. Note, however, that the spindle speed is clamped only when the G96 mode is set.
• **Auxiliary function**  
The M, S, and T functions, and secondary auxiliary functions (B functions) are output directly in reverse movement and forward return movement.  
When an M, S, or T function, or secondary auxiliary function (B function) is specified in a block containing a move command, the function and the move command are output at the same time in forward movement, reverse movement, and forward return movement. This means that the position where an M, S, or T function, or secondary auxiliary function (B function) is output differs in forward movement, reverse movement, and forward return movement.

• **Tool compensation value**  
Even if a cutter compensation value or tool length compensation value is modified in reverse movement or forward return movement, the tool moves according to the compensation value used when the block was executed in the forward movement.

• **Custom macro operation**  
All custom macro operations are ignored in reverse movement and forward return movement.  
The values of macro variables present at the end of forward movement remain unchanged.

• **Manual intervention**  
When the tool has been moved by manual intervention, return the tool to the original position before moving the tool in the reverse direction after a feed hold stop or single block stop. In reverse movement, the tool cannot move along the path made during manual intervention. All movements made by manual intervention are ignored in reverse movement and forward return movement.

• **Tool withdrawal and return function**  
The tool cannot move along the path retraction or repositioning performed using the tool withdrawal and return function. All retraction and repositioning operations are ignored in reverse movement and forward return movement.

• **Mirror image**  
When a block with the mirror image function specified by a signal or setting is memorized in forward movement, the mirror image function is eliminated; the block is memorized as originally programmed.  
Accordingly, in reverse movement and forward return movement, the tool moves along the programmed path. In reverse movement or forward return movement, the mirror image function can be specified by a signal or setting.  
When the tool performs reverse movement or forward return movement for a block where the mirror image function is specified by the programmable mirror image code (G51.1), the tool moves along the actual path incorporating the mirror image function.
4.12 MANUAL INTERVENTION AND RETURN

In cases such as when tool movement along an axis is stopped by feed hold during automatic operation so that manual intervention can be used to replace the tool: When automatic operation is restarted, this function returns the tool to the position where manual intervention was started. To use the conventional program restart function and tool withdrawal and return function, the switches on the operator’s panel must be used in conjunction with the MDI keys. This function does not require such operations.

Before this function can be used, MIN (bit 0 of parameter No. 7001) must be set to 1.

Explanations

- Manual absolute on/off
  In manual absolute off mode, the tool does not return to the stop position, but instead operates according to the manual absolute on/off function.

- Override
  For the return operation, the dry run feedrate is used, and the jog feedrate override function is enabled.

- Return operation
  Return operation is performed according to positioning based on nonlinear interpolation.

- Single block
  If the single block stop switch is on during return operation, the tool stops at the stop position and restarts movement when the cycle start switch is pressed.

- Cancellation
  If a reset occurs or an alarm is issued during manual intervention or the return operation, this function is cancelled.

- MDI mode
  This function can be used in the MDI mode as well.

Limitations

- Enabling and disabling manual intervention and return
  This function is enabled only when the automatic operation hold LED is on. When there is no travel distance remaining, this function has no effect even if a feed hold stop is performed with the automatic operation hold signal *SP (bit 5 of G008).

- Offset
  When the tool is replaced using manual intervention for a reason such as damage, the tool movement cannot be restarted by a changed offset in the middle of the interrupted block.

- Machine lock, mirror image, and scaling
  When performing manual intervention, never use the machine lock, mirror image, or scaling functions.
Example

1. The N1 block cuts a workpiece

2. The tool is stopped by pressing the feed hold switch in the middle of the N1 block (point A).

3. After retracting the tool manually to point B, tool movement is restarted.

4. After automatic return to point A at the dry run feedrate, the remaining move command of the N1 block is executed.

WARNING
When performing manual intervention, pay particular attention of machining and the shape of the workpiece so that the machine and tool are not damaged.
4.13
DNC OPERATION WITH MEMORY CARD

4.13.1 Specification

“DNC operation with Memory Card” is a function that it is possible to perform machining with executing the program in the memory card, which is assembled to the memory card interface, where is the left side of the screen.

There are two methods to use this function as follows.
(a) By starting automatic operation (cycle start) during the DNC operation mode (RMT), it is possible to perform machining (DNC operation) while a program is being read from a memory card, as by using the external input/output unit such as a floppy cassette and so on. (Fig. 4.13.1 (a))
(b) It is possible to read sub–programs written in the memory card and execute them by the command Subprogram call (M198). (Fig. 4.13.1 (b))

![Diagram of DNC operation with Memory Card]

Fig. 4.13.1 (a)

![Diagram of Subprogram call (M198)]

Fig. 4.13.1 (b)
4.13.2 Operations

4.13.2.1 DNC Operation

Procedure

Please set the parameter of No.0020 to 4 in the setting screen in advance.

(1) Change to RMT mode.
(2) Push [PROGRAM] function key.
(3) Push [>] soft key (continuance menu).
(4) When [DNC–CD] soft key is pushed, the following screen is displayed.

(5) The screen can be scrolled by page key. An arbitrary file number is input, and [F SRH] soft key is pushed. Then the arbitrary file name is displayed at the top of DNC operation (memory card) screen.

(6) When the file number that is executed is input and the [DNC–ST] soft key is pushed, the file name that is selected is set to DNC FILE.

(7) When the cycle start is done, the program that is selected is executed.
When the following block in a program in CNC memory is executed, a subprogram file in memory card is called.

### Format

<table>
<thead>
<tr>
<th>M198</th>
<th>P</th>
<th>ΔΔΔΔ ;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>File number for a file in the memory card</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Number of repetition</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Memory card call instruction</td>
</tr>
</tbody>
</table>

2. FS15 tape format

<table>
<thead>
<tr>
<th>M198</th>
<th>P</th>
<th>L ΔΔΔΔ ;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>File number of repetition</td>
</tr>
<tr>
<td></td>
<td></td>
<td>File number for a file in the memory card</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Memory card call instruction</td>
</tr>
</tbody>
</table>

### Explanation

When the custom macro option is provided, both format 1 and 2 can be used. A different M code can be used for a subprogram call depending on the setting of parameter No. 6030. In this case, M198 is executed as a normal M code. The file number is specified at address P. If the SBP (bit 2) of parameter No. 3404 is set to 1, a program number can be specified. When a file number is specified at address P, Fxxxx is indicated instead of Oxxxx.

### NOTE

Please set the parameter of No. 0020 to 4 in the setting screen in advance.
4.13.3 Limitation and Notes

1. The memory card cannot be accessed, such as displaying the memory card list and so on, during the DNC operation with memory card.

2. It is possible to execute the DNC operation with memory card on a multi-path system. However, it is not possible to call programs from the plural paths at the same time.

3. The selection of CNC operation file that is set at CNC OPERATION screen is cleared by the power supply turn off and on. After the power supply is turned on again, it is necessary to select the CNC operation file again.

4. Please do not pull out and insert memory card during the CNC operation with memory card.

5. It is not possible to call a program in the memory card from the CNC operation program.

6. In case of using this function, the PMCIA card attachment written at section 6 must be used to prevent the poor connection or drop out of the memory card occurring by vibration of the machine.

7. In case of the stand-alone type i series that the display unit is a Display link unit, this function cannot be used.

8. The memory card interface on the stand-alone type controller is not available. Please use the memory card interface on the display unit.

4.13.4 Parameter

<table>
<thead>
<tr>
<th>#0</th>
<th>#1</th>
<th>#2</th>
<th>#3</th>
<th>#4</th>
<th>#5</th>
<th>#6</th>
<th>#7</th>
</tr>
</thead>
<tbody>
<tr>
<td>DNM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

[Data type] Bit

#7 (DNM) The CNC operation with memory card function is

0: disable.

1: enable.
4.13.5
Connecting PCMCIA Card Attachment

4.13.5.1
Specification Number

<table>
<thead>
<tr>
<th>Specification</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>A02B–0236–K160</td>
<td>For 7.2” LCD or 8.4” LCD</td>
</tr>
<tr>
<td>A02B–0236–K161</td>
<td>For 9.5” LCD or 10.4” LCD</td>
</tr>
</tbody>
</table>

4.13.5.2
Assembling

1) How to assemble to the unit
   Assemble an attachment guide and a control unit to the cabinet by screwing together as follow figure.
   The attachment guide is 1.6mm thick. Pay attention for the length of the screws when you assemble them.
2) How to mount the card
   (a) Insert the card to slit of the attachment. Please pay attention to the direction of the card. (Please mach the direction of ditch on the card.)
   (b) Push up the card to the upper end of the attachment.

3) Assembling of the attachment
   Insert the memory card with the attachment into the memory card interface as following figure. And, fix the attachment guide by screwing the screw of the attachment guide by manual.
4) Appearance after connection

NOTE
1 In both case of stand-alone type i series and LCD-mounted type i series, the memory card interface where is the left side of the screen of the display unit. (The memory card interface on the stand-alone type controller is not available.)
2 It is impossible to assemble the display unit and the attachment guide from inside of the cabinet.
3 The memory card must be used in the condition, as the coolant cannot be poured directly on it.

4.13.6 Recommended Memory Card

<table>
<thead>
<tr>
<th>Maker</th>
<th>Type</th>
<th>Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hitachi LTD</td>
<td>HB289016A4</td>
<td>16MB</td>
</tr>
<tr>
<td></td>
<td>HB289032A4</td>
<td>32MB</td>
</tr>
<tr>
<td></td>
<td>HB289160A4</td>
<td>160MB</td>
</tr>
<tr>
<td>Matushita electric</td>
<td>BN–012AB</td>
<td>12MB</td>
</tr>
<tr>
<td></td>
<td>BN–020AB</td>
<td>20MB</td>
</tr>
<tr>
<td></td>
<td>BN–040AB</td>
<td>40MB</td>
</tr>
<tr>
<td>SanDisk</td>
<td>SDP3B–4</td>
<td>4MB</td>
</tr>
<tr>
<td></td>
<td>SDP3B–20</td>
<td>20MB</td>
</tr>
<tr>
<td></td>
<td>SDP3B–40</td>
<td>40MB</td>
</tr>
</tbody>
</table>
The following functions are used to check before actual machining whether the machine operates as specified by the created program.

5.1 Machine Lock and Auxiliary Function Lock
5.2 Feedrate Override
5.3 Rapid Traverse Override
5.4 Dry Run
5.5 Single Block
5.1 MACHINE LOCK AND AUXILIARY FUNCTION LOCK

To display the change in the position without moving the tool, use machine lock. There are two types of machine lock: all-axis machine lock, which stops the movement along all axes, and specified-axis machine lock, which stops the movement along specified axes only. In addition, auxiliary function lock, which disables M, S, and T commands, is available for checking a program together with machine lock.

![Machine Lock Diagram]

Fig. 5.1 Machine lock

Procedure for Machine Lock and Auxiliary Function Lock

- **Machine Lock**

  Press the machine lock switch on the operator’s panel. The tool does not move but the position along each axis changes on the display as if the tool were moving.

  Some machines have a machine lock switch for each axis. On such machines, press the machine lock switches for the axes along which the tool is to be stopped. Refer to the appropriate manual provided by the machine tool builder for machine lock.

  **WARNING**
  The positional relationship between the workpiece coordinates and machine coordinates may differ before and after automatic operation using machine lock. In such a case, specify the workpiece coordinate system by using a coordinate setting command or by performing manual reference position return.

- **Auxiliary Function Lock**

  Press the auxiliary function lock switch on the operator’s panel. M, S, T and B codes are disabled and not executed. Refer to the appropriate manual provided by the machine tool builder for auxiliary function lock.
Restrictions

- **M, S, T, B command by only machine lock**
  M, S, T and B commands are executed in the machine lock state.

- **Reference position return under Machine Lock**
  When a G27, G28, or G30 command is issued in the machine lock state, the command is accepted but the tool does not move to the reference position and the reference position return LED does not go on.

- **M codes not locked by auxiliary function lock**
  M00, M01, M02, M30, M98, and M99 commands are executed even in the auxiliary function lock state. M codes for calling a subprogram (parameters No. 6071 to 6079) and those for calling a custom macro (parameter No. 6080 to 6089) are also executed.
5.2 FEEDRATE OVERRIDE

A programmed feedrate can be reduced or increased by a percentage (%) selected by the override dial. This feature is used to check a program. For example, when a feedrate of 100 mm/min is specified in the program, setting the override dial to 50% moves the tool at 50 mm/min.

Fig. 5.2 Feedrate override

Procedure for Feedrate Override

Set the feedrate override dial to the desired percentage (%) on the machine operator’s panel, before or during automatic operation. On some machines, the same dial is used for the feedrate override dial and jog feedrate dial. Refer to the appropriate manual provided by the machine tool builder for feedrate override.

Restrictions

- **Override Range**
  The override that can be specified ranges from 0 to 254%. For individual machines, the range depends on the specifications of the machine tool builder.

- **Override during thread**
  During threading, the override is ignored and the feedrate remains as specified by program.
5. TEST OPERATION

5.3 RAPID TRAVERSE OVERRIDE

An override of four steps (F0, 25%, 50%, and 100%) can be applied to the rapid traverse rate. F0 is set by a parameter (No. 1421).

Rapid Traverse Override

Procedure

Select one of the four feedrates with the rapid traverse override switch during rapid traverse. Refer to the appropriate manual provided by the machine tool builder for rapid traverse override.

Explanation

The following types of rapid traverse are available. Rapid traverse override can be applied for each of them.
1) Rapid traverse by G00
2) Rapid traverse during a canned cycle
3) Rapid traverse in G27, G28, G29, G30, G53
4) Manual rapid traverse
5) Rapid traverse of manual reference position return

Fig. 5.3 Rapid traverse override
5.4 DRY RUN

The tool is moved at the feedrate specified by a parameter regardless of the feedrate specified in the program. This function is used for checking the movement of the tool under the state that the workpiece is removed from the table.

![Fig. 5.4 Dry run](image)

**Procedure for Dry Run**

**Procedure**

Press the dry run switch on the machine operator’s panel during automatic operation.
The tool moves at the feedrate specified in a parameter. The rapid traverse switch can also be used for changing the feedrate.
Refer to the appropriate manual provided by the machine tool builder for dry run.

**Explanation**

- **Dry run feedrate**

The dry run feedrate changes as shown in the table below according to the rapid traverse switch and parameters.

<table>
<thead>
<tr>
<th>Rapid traverse button</th>
<th>Program command</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rapid traverse rate</td>
<td>Feed</td>
</tr>
<tr>
<td>ON</td>
<td>Dry run speed × JV, or rapid traverse rate *1)</td>
</tr>
<tr>
<td>OFF</td>
<td>Dry run feedrate × Max. JV *2)</td>
</tr>
</tbody>
</table>

Max. cutting feedrate . . . . . Setting by parameter No.1422
Rapid traverse rate . . . . . Setting by parameter No.1420
Dry run feedrate . . . . . . Setting by parameter No.1410
JV: Jog feedrate override

*1) Dry run feedrate x JV when parameter RDR (bit 6 of No. 1401) is 1.
Rapid traverse rate when parameter RDR is 0.

*2) Clamped to the maximum cutting feedrate
JVmax: Maximum value of jog feedrate override
5.5 SINGLE BLOCK

Pressing the single block switch starts the single block mode. When the cycle start button is pressed in the single block mode, the tool stops after a single block in the program is executed. Check the program in the single block mode by executing the program block by block.

Fig. 5.5 (a) Single block

Procedure for Single block

Procedure

1. Press the single block switch on the machine operator’s panel. The execution of the program is stopped after the current block is executed.

2. Press the cycle start button to execute the next block. The tool stops after the block is executed.

Refer to the appropriate manual provided by the machine tool builder for single block execution.
Explanations

- **Reference position return and single block**: If G28 to G30 are issued, the single block function is effective at the intermediate point.

- **Single block during a canned cycle**: In a canned cycle, the single block stop points are the end of 1, 2, and 6 shown below. When the single block stop is made after the point 1 or 2, the feed hold LED lights.

- **Subprogram call and single block**: Single block stop is not performed in a block containing M98P_; M99; or G65.
  However, single block stop is even performed in a block with M98P_ or M99 command, if the block contains an address other than O, N, P, L.
To immediately stop the machine for safety, press the Emergency stop button. To prevent the tool from exceeding the stroke ends, Overtravel check and Stroke check are available. This chapter describes emergency stop, overtravel check, and stroke check.
6.1 EMERGENCY STOP

If you press Emergency Stop button on the machine operator’s panel, the machine movement stops in a moment.

This button is locked when it is pressed. Although it varies with the machine tool builder, the button can usually be unlocked by twisting it.

Explanation

EMERGENCY STOP interrupts the current to the motor. Causes of trouble must be removed before the button is released.
6.2 OVERTRAVEL

When the tool tries to move beyond the stroke end set by the machine tool limit switch, the tool decelerates and stops because of working the limit switch and an OVER TRAVEL is displayed.

![Diagram of Deceleration and stop](image)

**Fig. 6.2 Overtravel**

**Explanation**

- **Overtravel during automatic operation**
  
  When the tool touches a limit switch along an axis during automatic operation, the tool is decelerated and stopped along all axes and an overtravel alarm is displayed.

- **Overtravel during manual operation**
  
  In manual operation, the tool is decelerated and stopped only along the axis for which the tool has touched a limit switch. The tool still moves along the other axes.

- **Releasing overtravel**
  
  Press the reset button to reset the alarm after moving the tool to the safety direction by manual operation. For details on operation, refer to the operator’s manual of the machine tool builder.

**Alarm**

<table>
<thead>
<tr>
<th>Alarm No.</th>
<th>Message</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>506</td>
<td>Overtravel: +n</td>
<td>The tool has exceeded the hardware-specified overtravel limit along the positive nth axis (n: 1 to 8).</td>
</tr>
<tr>
<td>507</td>
<td>Overtravel: −n</td>
<td>The tool has exceeded the hardware-specified overtravel limit along the negative nth axis (n: 1 to 8).</td>
</tr>
</tbody>
</table>
Three areas which the tool cannot enter can be specified with stored stroke check 1, stored stroke check 2, and stored stroke check 3.

![Diagram](image)

When the tool exceeds a stored stroke limit, an alarm is displayed and the tool is decelerated and stopped. When the tool enters a forbidden area and an alarm is generated, the tool can be moved in the reverse direction from which the tool came.

**Explanation**

- **Stored stroke check 1**

  Parameters (Nos. 1320, 1321 or Nos. 1326, 1327) set boundary. Outside the area of the set limits is a forbidden area. The machine tool builder usually sets this area as the maximum stroke.

- **Stored stroke check 2 (G22, G23)**

  Parameters (Nos. 1322, 1323) or commands set these boundaries. Inside or outside the area of the limit can be set as the forbidden area. Parameter OUT (No. 1300#0) selects either inside or outside as the forbidden area.

  In case of program command a G22 command forbids the tool to enter the forbidden area, and a G23 command permits the tool to enter the forbidden area. Each of G22; and G23; should be commanded independently of another commands in a block.

  The command below creates or changes the forbidden area:

  ```
  OUT (No. 1300#0) selects either inside or outside as the forbidden area.
  ```
6. SAFETY FUNCTIONS

OPERATION

B–63534EN/02

When setting the area by parameters, points A and B in the figure below must be set.

In stored stroke check 2, even if you mistake the order of the coordinate value of the two points, a rectangular, with the two points being the apexes, will be set as the area.

When you set the forbidden area through parameters (Nos. 1322, 1323), the data should be specified by the distance from the machine coordinate system in the least command increment. (Output increment)

If it is set by a G22 command, specify the data by the distance from the machine coordinate system in the least input increment. (Input increment.)

The programmed data are then converted into the numerical values in the least command increment, and the values are set as the parameters.

- Stored stroke check 3

Set the boundary with parameters No. 1324 and 1325. The area inside the boundary becomes the forbidden area.

---

**Fig. 6.3 (b) Creating or changing the forbidden area using a program**

G 22X_Y_Z_I_J_K_

\[(X,Y,Z)\]

\[(I,J,K)\]

\[X>I, Y>J, Z>K\]

\[X-I >\zeta (\text{In least command increment})\]

\[Y-J >\zeta (\text{In least command increment})\]

\[Z-K >\zeta (\text{In least command increment})\]

\[\zeta (\text{mm}) = \frac{F}{7500}\]

\[F = \text{Rapid traverse speed (mm/min)}\]

---

**Fig. 6.3 (c) Creating or changing the forbidden area using a parameters**

\[A (X,Y,Z)\]

\[B (I,J,K)\]

\[X>I, Y>J, Z>K\]

\[X-I >\zeta (\text{In least command increment})\]

\[Y-J >\zeta (\text{In least command increment})\]

\[Z-K >\zeta (\text{In least command increment})\]

\[\zeta (\text{mm}) = \frac{F}{7500}\]

\[F = \text{Rapid traverse speed (mm/min)}\]
• Checkpoint for the forbidden area

Confirm the checking position (the top of the tool or the tool chuck) before programming the forbidden area. If point A (The top of the tool) is checked in Fig. 6.3 (d), the distance “a” should be set as the data for the stored stroke limit function. If point B (The tool chuck) is checked, the distance “b” must be set. When checking the tool tip (like point A), and if the tool length varies for each tool, setting the forbidden area for the longest tool requires no re-setting and results in safe operation.

![Fig. 6.3 (d) Setting the forbidden area](image)

• Forbidden area over lapping

Area can be set in piles.

![Fig. 6.3 (e) Setting the forbidden area over lapping](image)

• Overrun amount of stored stroke limit

If the maximum rapid traverse rate is F (mm/min), the maximum overrun amount, L (mm), of the stored stroke limit is obtained from the following expression:

\[
L (\text{mm}) = F / 7500
\]

The tool enters the specified inhibited area by up to L (mm). Bit 7 (BFA) of parameter No. 1300 can be used to stop the tool when it reaches a point L mm short of the specified area. In this case, the tool will not enter the inhibited area.

• Effective time for a forbidden area

Each limit becomes effective after the power is turned on and manual reference position return or automatic reference position return by G28 has been performed. After the power is turned on, if the reference position is in the forbidden area of each limit, an alarm is generated immediately. (Only in G22 mode for stored stroke limit 2).
If the enters a forbidden area and an alarm is generated, the tool can be moved only in the backward direction. To cancel the alarm, move the tool backward until it is outside the forbidden area and reset the system. When the alarm is canceled, the tool can be moved both backward and forward.

When G23 is switched to G22 in the forbidden area, the following results.

(1) When the forbidden area is inside, an alarm is informed in the next move.

(2) When the forbidden area is outside, an alarm is informed immediately.

Parameter BFA (bit 7 of No. 1300) selects whether an alarm is displayed immediately before the tool enters the forbidden area or immediately after the tool has entered the forbidden area.

For two-path control, set a forbidden area for each path.

NOTE
In setting a forbidden area, if the two points to be set are the same, the area is as follows:

(1) When the forbidden area is stored stroke check 1, all areas are forbidden areas.

(2) When the forbidden area is stored stroke check 2 or stored stroke check 3, all areas are movable areas.

### Alarms

<table>
<thead>
<tr>
<th>Alarm Number</th>
<th>Message</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>OVER TRAVEL: +n</td>
<td>Exceeded the n-th axis (1–8) + side stored stroke limit I.</td>
</tr>
<tr>
<td>501</td>
<td>OVER TRAVEL: −n</td>
<td>Exceeded the n-th axis (1–8) − side stored stroke limit I.</td>
</tr>
<tr>
<td>502</td>
<td>OVER TRAVEL: +n</td>
<td>Exceeded the n-th axis (1–8) + side stored stroke limit II.</td>
</tr>
<tr>
<td>503</td>
<td>OVER TRAVEL: −n</td>
<td>Exceeded the n-th axis (1–8) − side stored stroke limit II.</td>
</tr>
<tr>
<td>504</td>
<td>OVER TRAVEL: +n</td>
<td>Exceeded the n-th axis (1–8) + side stored stroke limit III.</td>
</tr>
<tr>
<td>505</td>
<td>OVER TRAVEL: −n</td>
<td>Exceeded the n-th axis (1–8) − side stored stroke limit III.</td>
</tr>
</tbody>
</table>
During automatic operation, before the movement specified by a given block is started, whether the tool enters the inhibited area defined by stored stroke limit 1, 2, or 3 is checked by determining the position of the end point from the current position of the machine and a specified amount of travel. If the tool is found to enter the inhibited area defined by a stored stroke limit, the tool is stopped immediately upon the start of movement for that block, and an alarm is displayed.

**WARNING**

Whether the coordinates of the end point, reached as a result of traversing the distance specified in each block, are in an inhibited area is checked. In this case, the path followed by a move command is not checked. However, if the tool enters the inhibited area defined by stored stroke limit 1, 2, or 3, an alarm is issued. (See the examples below.)

**Example 1)**

Inhibited area defined by stored stroke limit 1 or 2

```
Start point

The tool is stopped at point a according to stored stroke limit 1 or 2.
```

Inhibited area defined by stored stroke limit 1 or 2

```
End point

Immediately upon movement commencing from the start point, the tool is stopped to enable a stroke limit check to be performed before movement.
```
Example 2)

Inhibited area defined by stored stroke limit 1 or 2

Start point

End point

The tool is stopped at point a according to stored stroke limit 1 or 2.

Inhibited area defined by stored stroke limit 1 or 2

End point

Immediately upon movement commencing from the start point, the tool is stopped to enable a stroke limit check to be performed before movement.

Explanations

When a stroke limit check prior to movement is performed, whether to check the movement performed by a G31 (skip) block and G37 (automatic tool length measurement) block can be determined using NPC (bit 2 of parameter No. 1301).

Limitations

• Machine lock
  If machine lock is applied at the start of movement, no stroke limit check made before movement is performed.

• G23
  When stored stroke limit 2 is disabled (G23 mode), no check is made to determine whether the tool enters the inhibited area defined by stored stroke limit 2.

• Program restart
  When a program is restarted, an alarm is issued if the restart position is within a inhibited area.

• Manual intervention following a feed hold stop
  When the execution of a block is restarted after manual intervention following a feed hold stop, no alarm is issued even if the end point following a manual intervention is within a inhibited area.

• A block consisting of multiple operations
  If a block consisting of multiple operations (such as a canned cycle and exponential interpolation) is executed, an alarm is issued at the start point of any operation whose end point falls within a inhibited area.
In cylindrical interpolation mode, no check is made.

In polar coordinate interpolation mode, no check is made.

When the angular axis control option is selected, no check is made.

In simple synchronous control, only the master axis is checked; no slave axes are checked.

In three-dimensional coordinate conversion mode, no check is made.

No check is performed while drawing is being performed as part of dynamic graphic display (only drawing (no machining) is being performed).

No check is made for a movement based on PMC axis control.

No check is made for a movement based on high-speed, high-precision contour control (HPCC).

### Alarm

<table>
<thead>
<tr>
<th>Number</th>
<th>Message</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>510</td>
<td>OVER TRAVEL : +n</td>
<td>The pre-movement stroke limit check reveals that the block end point enters the prohibited area for the positive stroke limit along the n axis. Correct the program.</td>
</tr>
<tr>
<td>511</td>
<td>OVER TRAVEL : −n</td>
<td>The pre-movement stroke limit check reveals that the block end point enters the prohibited area for the negative stroke limit along the n axis. Correct the program.</td>
</tr>
</tbody>
</table>
When an alarm occurs, the corresponding alarm screen appears to indicate the cause of the alarm. The causes of alarms are classified by error codes. Up to 25 previous alarms can be stored and displayed on the screen (alarm history display).

The system may sometimes seem to be at a halt, although no alarm is displayed. In this case, the system may be performing some processing. The state of the system can be checked using the self-diagnostic function.
7.1 ALARM DISPLAY

Explanations

- Alarm screen

  When an alarm occurs, the alarm screen appears.

  ![Alarm Screen Example](image)

- Another method for alarm displays

  In some cases, the alarm screen does not appear, but an ALM is displayed at the bottom of the screen.

  ![Parameter Display Example](image)

In this case, display the alarm screen as follows:

1. Press the function key [MESSAGE].
2. Press the chapter selection soft key [ALARM].
7. ALARM AND SELF–DIAGNOSIS
FUNCTIONS

• Reset of the alarm

Error codes and messages indicate the cause of an alarm. To recover from an alarm, eliminate the cause and press the reset key.

• Error codes

The error codes are classified as follows:
No. 000 to 255: P/S alarm (Program errors) (*)
No. 300 to 349: Absolute pulse coder (APC) alarms
No. 350 and 399: Serial pulse coder (SPC) alarms
No. 400 to 499: Servo alarms
No. 500 to 599: Overtravel alarms
No. 700 to 739: Overheat alarms
No. 740 to 748: Rigid tapping alarms
No. 749 to 799: Spindle alarms
No. 900 to 999: System alarms
No. 5000 to: P/S alarm (Program errors)

* For an alarm (No. 000 to 255) that occurs in association with background operation, the indication “xxxP/S alarm” is provided (where xxx is an alarm number). Only a P/S alarm is provided for No. 140.

See the error code list in the Appendix G for details of the error codes.
7.2 ALARM HISTORY DISPLAY

Up to 25 of the most recent CNC alarms are stored and displayed on the screen.
Display the alarm history as follows:

**Procedure for Alarm History Display**

**Procedure**

1. Press the function key \([\text{MESSAGE}]\).

2. Press the chapter selection soft key \([\text{HISTORY}]\).
   The alarm history appears.
   The following information items are displayed.
   (1) The date the alarm was issued
   (2) Alarm No.
   (3) Alarm message (some contain no message)
   (4) Page No.

3. Change the page by the 1–page change key.

4. To delete the recorded information, press the softkey \([\text{(OPRT)}]\) then the \([\text{DELETE}]\) key.

<table>
<thead>
<tr>
<th>ALARM HISTORY</th>
<th>O0100  N00001</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)01.02.14 16:43:48</td>
<td>PAGE=1</td>
</tr>
<tr>
<td>(2)010  (3)MPROPER G–CODE</td>
<td></td>
</tr>
<tr>
<td>01.02.13 8:22:21</td>
<td></td>
</tr>
<tr>
<td>506 OVER TRAVEL : +1</td>
<td></td>
</tr>
<tr>
<td>01.02.12 20:15:43</td>
<td></td>
</tr>
<tr>
<td>417 SERVO ALARM : X AXIS DGTL PARAM</td>
<td></td>
</tr>
</tbody>
</table>

MEM **** *** *** 19:47:45

(ALARM) (MSG) [HISTORY] (OPRT)
7.3 CHECKING BY SELF–DIAGNOSTIC SCREEN

The system may sometimes seem to be at a halt, although no alarm has occurred. In this case, the system may be performing some processing. The state of the system can be checked by displaying the self–diagnostic screen.

Procedure for Diagnosis

1. Press the function key [SYSTEM].
2. Press the chapter select key [DGNOS].
3. The diagnostic screen has more than 1 pages. Select the screen by the following operation.
   (1) Change the page by the 1–page change key.
   (2) Method by soft key
       – Key input the number of the diagnostic data to be displayed.
       – Press [N SRCH].

Explanations

- Self diagnostic screen at 2–path control
  For the two–path control, the diagnostic screen for the path selected with the path selection switch is displayed. When displaying the diagnostic screen for the other tool post, specify the path with the tool post selection switch.
7. ALARM AND SELF–DIAGNOSIS FUNCTIONS

Explanations

Diagnostic numbers 000 to 015 indicate states when a command is being specified but appears as if it were not being executed. The table below lists the internal states when 1 is displayed at the right end of each line on the screen.

Table 7.3 (a) Alarm displays when a command is specified but appears as if it were not being executed

<table>
<thead>
<tr>
<th>No.</th>
<th>Display</th>
<th>Internal status when 1 is displayed</th>
</tr>
</thead>
<tbody>
<tr>
<td>000</td>
<td>WAITING FOR FIN SIGNAL</td>
<td>M, S, T function being executed</td>
</tr>
<tr>
<td>001</td>
<td>MOTION</td>
<td>Move command in automatic operation being executed</td>
</tr>
<tr>
<td>002</td>
<td>DWELL</td>
<td>Dwell being executed</td>
</tr>
<tr>
<td>003</td>
<td>IN–POSITION CHECK</td>
<td>In–position check being executed</td>
</tr>
<tr>
<td>004</td>
<td>FEEDRATE OVERRIDE 0%</td>
<td>Cutting feed override 0%</td>
</tr>
<tr>
<td>005</td>
<td>INTERLOCK/START–LOCK</td>
<td>Interlock ON</td>
</tr>
<tr>
<td>006</td>
<td>SPINDLE SPEED ARRIVAL CHECK</td>
<td>Waiting for spindle speed arrival signal to turn on</td>
</tr>
<tr>
<td>010</td>
<td>PUNCHING</td>
<td>Data being output via reader puncher interface</td>
</tr>
<tr>
<td>011</td>
<td>READING</td>
<td>Data being input via reader puncher interface</td>
</tr>
<tr>
<td>012</td>
<td>WAITING FOR (UN) CLAMP</td>
<td>Waiting for index table clamp/unclamp before B axis index table indexing start/after B axis index table indexing end to complete</td>
</tr>
<tr>
<td>013</td>
<td>JOG FEEDRATE OVERRIDE 0%</td>
<td>Jog override 0%</td>
</tr>
<tr>
<td>014</td>
<td>WAITING FOR RESET.ESP.RRW.OFF</td>
<td>Emergency stop, external reset, reset &amp; rewind, or MDI panel reset key on</td>
</tr>
<tr>
<td>015</td>
<td>EXTERNAL PROGRAM NUMBER SEARCH</td>
<td>External program number searching</td>
</tr>
</tbody>
</table>

Diagnostic numbers 020 to 025 indicate states when an automatic operation is stopped or paused.

Table 7.3 (b) Alarm displays when an automatic operation is stopped or paused.

<table>
<thead>
<tr>
<th>No.</th>
<th>Display</th>
<th>Internal status when 1 is displayed</th>
</tr>
</thead>
<tbody>
<tr>
<td>020</td>
<td>CUT SPEED UP/DOWN</td>
<td>Set when emergency stop turns on or when servo alarm occurs</td>
</tr>
<tr>
<td>021</td>
<td>RESET BUTTON ON</td>
<td>Set when reset key turns on</td>
</tr>
<tr>
<td>022</td>
<td>RESET AND REWIND ON</td>
<td>Reset and rewind turned on</td>
</tr>
<tr>
<td>023</td>
<td>EMERGENCY STOP ON</td>
<td>Set when emergency stop turns on</td>
</tr>
<tr>
<td>024</td>
<td>RESET ON</td>
<td>Set when external reset, emergency stop, reset, or reset &amp; rewind key turns on</td>
</tr>
<tr>
<td>025</td>
<td>STOP MOTION OR DWELL</td>
<td>A flag which stops pulse distribution. It is set in the following cases. (1) External reset turned on. (2) Reset &amp; rewind turned on. (3) Emergency stop turned on. (4) Feed hold turned on. (5) The MDI panel reset key turned on. (6) Switched to the manual mode(JOG/HANDLE/INC). (7) Other alarm occurred. (There is also alarm which is not set.)</td>
</tr>
</tbody>
</table>
The table below shows the signals and states which are enabled when each diagnostic data item is 1. Each combination of the values of the diagnostic data indicates a unique state.

<table>
<thead>
<tr>
<th>No.</th>
<th>Display</th>
<th>Meaning of data</th>
</tr>
</thead>
<tbody>
<tr>
<td>020</td>
<td>CUT SPEED UP/DOWN</td>
<td></td>
</tr>
<tr>
<td>021</td>
<td>RESET BUTTON ON</td>
<td></td>
</tr>
<tr>
<td>022</td>
<td>RESET ANDREWIND ON</td>
<td></td>
</tr>
<tr>
<td>023</td>
<td>EMERGENCY STOP ON</td>
<td></td>
</tr>
<tr>
<td>024</td>
<td>RESET ON</td>
<td></td>
</tr>
<tr>
<td>025</td>
<td>STOP MOTION OR DWELL</td>
<td></td>
</tr>
</tbody>
</table>

Diagnostic numbers 030 and 031 indicate TH alarm states.

<table>
<thead>
<tr>
<th>No.</th>
<th>Display</th>
<th>Meaning of data</th>
</tr>
</thead>
<tbody>
<tr>
<td>030</td>
<td>CHARACTER NUMBER TH DATA</td>
<td>The position of the character which caused TH alarm is displayed by the number of characters from the beginning of the block at TH alarm</td>
</tr>
<tr>
<td>031</td>
<td>TH DATA</td>
<td>Read code of character which caused TH alarm</td>
</tr>
</tbody>
</table>
NC data is transferred between the NC and external input/output devices such as the Handy File.
The memory card interface located to the left of the display can be used to read information on a memory card in the CNC or write it to the card.
The following types of data can be entered and output:
1. Program
2. Offset data
3. Parameter
4. Pitch error compensation data
5. Custom macro common variable
Before an input/output device can be used, the input/output related parameters must be set.
For how to set parameters, see III–2 “OPERATIONAL DEVICES”.
Of the external input/output devices, the FANUC Handy File use floppy disks as their input/output medium. In this manual, these input/output medium is generally referred to as a floppy. Unlike an NC tape, a floppy allows the user to freely choose from several types of data stored on one medium on a file–by–file basis. Input/output is possible with data extending over more than one floppy disk.

**Files**

- **What is a File**
  The unit of data, which is input/output between the floppy and the CNC by one input/output operation (pressing the VREADW or VPUNCHW key), is called a HfileI. When inputting CNC programs from, or outputting them to the floppy, for example, one or all programs within the CNC memory are handled as one file.
  Files are assigned automatically file numbers 1,2,3,4 and so on, with the lead file as 1.

- **Request for floppy replacement**
  When one file has been entered over two floppies, LEDs on the adaptor flash alternately on completion of data input/output between the first floppy and the CNC, prompting floppy replacement. In this case, take the first floppy out of the adaptor and insert a second floppy in its place. Then, data input/output will continue automatically.
  Floppy replacement is prompted when the second floppy and later is required during file search–out, data input/output between the CNC and the floppy, or file deletion.
  Floppy 1

<table>
<thead>
<tr>
<th>File 1</th>
<th>File 2</th>
<th>File 3</th>
<th>...</th>
<th>File n</th>
<th>Blank</th>
</tr>
</thead>
</table>

Floppy 2

<table>
<thead>
<tr>
<th>Continuation of file k</th>
<th>File (k+1)</th>
<th>...</th>
<th>File n</th>
<th>Blank</th>
</tr>
</thead>
</table>

Since floppy replacement is processed by the input/output device, no special operation is required. The CNC will interrupt data input/output operation until the next floppy is inserted into the adaptor.

When reset operation is applied to the CNC during a request for floppy replacement, the CNC is not reset at once, but reset after the floppy has been replaced.
• **Protect switch**

The floppy is provided with the write protect switch. Set the switch to the write enable state. Then, start output operation.

![Write protect switch of a cassette]

(1) Write-protected
(Only reading is possible.)

(2) Write-enabled
(Reading, writing, and deletion are possible.)

**Fig. 8.1 Protect switch**

• **Writing memo**

Once written in the cassette or card, data can subsequently be read out by correspondence between the data contents and file numbers. This correspondence cannot be verified, unless the data contents and file numbers are output to the CNC and displayed. The data contents can be displayed with display function for directory of floppy disk (See Section III–8.8).

To display the contents, write the file numbers and the contents on the memo column which is the back of floppy.

(Entry example on MEMO)

File 1  CNC parameters
File 2  Offset data
File 3  NC program O0100
        ...
        ...
        ...
File (n–1) NC program O0500
File n  NC program O0600
When the program is input from the floppy, the file to be input first must be searched. For this purpose, proceed as follows:

<table>
<thead>
<tr>
<th>File 1</th>
<th>File 2</th>
<th>File 3</th>
<th>File n</th>
<th>Blank</th>
</tr>
</thead>
</table>

File searching of the file n

**Procedure**

1. Press the EDIT or MEMORY switch on the machine operator’s panel.
2. Press function key [PROG], then the program contents display screen or program check screen appears.
3. Press soft key [(OPRT)].
4. Press the rightmost soft key (next-menu key).
5. Enter address N.
6. Enter the number of the file to search for.
   - N0
     The beginning of the cassette or card is searched.
   - One of N1 to N9999
     Of the file Nos. 1 to 9999, a designated file is searched.
   - N–9999
     The file next to that accessed just before is searched.
   - N–9998
     When N–9998 is designated, N–9999 is automatically inserted each time a file is input or output. This condition is reset by the designation of N1,N1 to 9999, or N–9999 or reset.
7. Press soft keys [F SRH] and [EXEC].

**Explanation**

- **File search by N–9999**
  The same result is obtained both by sequentially searching the files by specifying Nos. N1 to N9999 and by first searching one of N1 to N9999 and then using the N–9999 searching method. The searching time is shorter in the latter case.
## Alarm

<table>
<thead>
<tr>
<th>Alarm No.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>86</td>
<td>The ready signal (DR) of an input/output device is off. An alarm is not immediately indicated in the CNC even when an alarm occurs during head searching (when a file is not found, or the like). An alarm is given when the input/output operation is performed after that. This alarm is also raised when N1 is specified for writing data to an empty floppy. (In this case, specify No.)</td>
</tr>
</tbody>
</table>
Files stored on a floppy can be deleted file by file as required.

**8.3 FILE DELETION**

---

**File deletion**

**Procedure**

1. Insert the floppy into the input/output device so that it is ready for writing.
2. Press the EDIT switch on the machine operator’s panel.
3. Press function key \( \text{PROG} \), then the program contents display screen appears.
4. Press soft key \([\text{OPRT}]\).
5. Press the rightmost soft key \([\rightarrow]\) (next-menu key).
6. Enter address N.
7. Enter the number (from 1 to 9999) of the file to delete.
8. Press soft key \([\text{DELETE}]\) and then press soft key \([\text{DELETE}]\).
The file specified in step 7 is deleted.

**Explanations**

- **File number after the file is deleted**
  
  When a file is deleted, the file numbers after the deleted file are each decremented by one. Suppose that a file numbered \( k \) was deleted. In this case, files are renumbered as follows:

<table>
<thead>
<tr>
<th>Before deletion</th>
<th>after deletion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 to ((k&gt;1))</td>
<td>1 to ((k&gt;1))</td>
</tr>
<tr>
<td>( k )</td>
<td>Deleted</td>
</tr>
<tr>
<td>((k+1)) to ( n )</td>
<td>( k ) to ((n&gt;1))</td>
</tr>
</tbody>
</table>

- **Protect switch**
  
  Set the write protect switch to the write enable state to delete the files.
8.4 PROGRAM INPUT/OUTPUT

8.4.1 Inputting a Program

This section describes how to load a program into the CNC from a floppy or NC tape.

**Procedure**

1. Make sure the input device is ready for reading. For the two-path control, select the tool post for which a program to be input is used with the tool post selection switch.

2. Press the EDIT switch on the machine operator’s panel.

3. When using a floppy, search for the required file according to the procedure in III–8.2.

4. Press function key [PROG], then the program contents display screen or program directory screen appears.

5. Press soft key [(OPRT)].

6. Press the rightmost soft key [(next-menu key)].

7. After entering address O, specify a program number to be assigned to the program. When no program number is specified here, the program number used on the floppy or NC tape is assigned.

8. Press soft keys [READ] and [EXEC]

   The program is input and the program number specified in step 7 is assigned to the program.

**Explanations**

- **Collation**

  If a program is input while the data protect key on the machine operator’s panel turns ON, the program loaded into the memory is verified against the contents of the floppy or NC tape.

  If a mismatch is found during collation, the collation is terminated with an alarm (P/S No. 079).

  If the operation above is performed with the data protection key turns OFF, collation is not performed, but programs are registered in memory.

- **Inputting multiple programs from an NC tape**

  When a tape holds multiple programs, the tape is read up to ER (or %).
• Program numbers on a NC tape

When a program is entered without specifying a program number.
- The O–number of the program on the NC tape is assigned to the program.
  If the program has no O–number, the N–number in the first block is assigned to the program.
- When the program has neither an O–number nor N–number, the previous program number is incremented by one and the result is assigned to the program.
- When the program does not have an O–number but has a five–digit sequence number at the start of the program, the lower four digits of the sequence number are used as the program number. If the lower four digits are zeros, the previously registered program number is incremented by one and the result is assigned to the program.

• When a program is entered with a program number
  The O–number on the NC tape is ignored and the specified number is assigned to the program. When the program is followed by additional programs, the first additional program is given the program number. Additional program numbers are calculated by adding one to the last program.

• Program registration in the background

The method of registration operation is the same as the method of foreground operation. However, this operation registers a program in the background editing area. As with edit operation, the operations described below are required at the end to register a program in foreground program memory.

[(OPRT)] [BG–END]

• Additional program input

You can input a program to be appended to the end of a registered program.

<table>
<thead>
<tr>
<th>Registered program</th>
<th>Input program</th>
<th>Program after input</th>
</tr>
</thead>
<tbody>
<tr>
<td>○1234 ;</td>
<td>○5678 ;</td>
<td>○1234 ;</td>
</tr>
<tr>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
</tbody>
</table>

In the above example, all lines of program O5678 are appended to the end of program O1234. In this case, program number O5678 is not registered. When inputting a program to be appended to a registered program, press the [READ] soft key without specifying a program number in step 8. Then, press the [CHAIN] and [EXEC] soft keys.

• In entire program input, all lines of a program are appended, except for its O number.

• When canceling additional input mode, press the reset key or the [CAN] or [STOP] soft key.
• Pressing the **[CHAIN]** soft key positions the cursor to the end of the registered program. Once a program has been input, the cursor is positioned to the start of the new program.

• Additional input is possible only when a program has already been registered.

---

**Defining the same program number as that of an existing program**

If an attempt has been made to register a program having the same number as that of a previously registered program, P/S alarm 073 is issued and the program cannot be registered.

### Alarm

<table>
<thead>
<tr>
<th>Alarm No.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>70</td>
<td>The size of memory is not sufficient to store the input programs</td>
</tr>
<tr>
<td>73</td>
<td>An attempt was made to store a program with an existing program number.</td>
</tr>
<tr>
<td>79</td>
<td>The verification operation found a mismatch between a program loaded into memory and the contents of the program on the floppy or NC tape.</td>
</tr>
</tbody>
</table>
8.4.2 Outputting a Program

A program stored in the memory of the CNC unit is output to a floppy or NC tape.

Outputting a program

Procedure

1. Make sure the output device is ready for output. For the two-path control, select the tool post for which a program to be output is used with the tool post selection switch.

2. To output to an NC tape, specify the punch code system (ISO or EIA) using a parameter.

3. Press the EDIT switch on the machine operator’s panel.

4. Press function key [PROC], then the program contents display screen or program directory screen appears.

5. Press soft key [(OPRT)].

6. Press the rightmost soft key (next-menu key).

7. Enter address O.

8. Enter a program number. If –9999 is entered, all programs stored in memory are output. To output multiple programs at one time, enter a range as follows: OΔΔΔΔ, OΔΔΔΔ/9999/C0086/C0086/C0086/C0086 Programs No.ΔΔΔΔ to No.ΔΔΔΔ are output. The program library screen displays program numbers in ascending order when bit 4 (SOR) of parameter No. 3107 is set to 1.

9. Press soft keys [PUNCH] and [EXEC]. The specified program or programs are output.

Explanations (Output to a floppy)

• File output location

When output is conducted to the floppy, the program is output as the new file after the files existing in the floppy. New files are to be written from the beginning with making the old files invalid, use the above output operation after the N0 head searching.

• An alarm while a program is output

When P/S alarm (No. 86) occurs during program output, the floppy is restored to the condition before the output.

• Outputting a program after file heading

When program output is conducted after N1 to N9999 head searching, the new file is output as the designated n-th position. In this case, 1 to n–1 files are effective, but the files after the old n-th one are deleted. If an alarm occurs during output, only the 1 to n–1 files are restored.

• Efficient use of memory

To efficiently use the memory in the cassette or card, output the program by setting parameter NFD (No. 0101#7, No. 0111#7 or 0121#7) to 1. This parameter makes the feed is not output, utilizing the memory efficiently.
• **On the memo record**

Head searching with a file No. is necessary when a file output from the CNC to the floppy is again input to the CNC memory or compared with the content of the CNC memory. Therefore, immediately after a file is output from the CNC to the floppy, record the file No. on the memo.

• **Punching programs in the background**

Punch operation can be performed in the same way as in the foreground. This function alone can punch out a program selected for foreground operation.

<\(O\) (Program No.) [PUNCH] [EXEC]: Punches out a specified program.

<\(O\) H–99991 [PUNCH] [EXEC]: Punches out all programs.

**Explanations (Output to an NC tape)**

• **Format**

A program is output to paper tape in the following format:

```
- - - - - - - - - - ER Program ER - - - - - - - - - -
 Feed of 3 feet
```

If three–feet feeding is too long, press the **CAN** key during feed punching to cancel the subsequent feed punching.

• **TV check**

A space code for TV check is automatically punched.

• **ISO code**

When a program is punched in ISO code, two CR codes are punched after an LF code.

```
- - - - - - - - - - LF CR CR
```

By setting NCR (bit 3 of parameter No. 0100), CRs can be omitted so that each LF appears without a CR.

• **Stopping the punch**

Press the **RESET** key to stop punch operation.

• **Punching all programs**

All programs are output to paper tape in the following format.

```
- - - - - - - - - - ER Program Program Program ER - - - - - - - - - -
 Feed of 1–feet Feed of 3–feet
```

The sequence of the programs punched is undefined.
8.5 OFFSET DATA INPUT AND OUTPUT

8.5.1 Inputting Offset Data

Offset data is loaded into the memory of the CNC from a floppy or NC tape. The input format is the same as for offset value output. See III–8.5.2. When an offset value is loaded which has the same offset number as an offset number already registered in the memory, the loaded offset data replaces existing data.

Procedure

1. Make sure the input device is ready for reading. For the two-path control, select the tool post for which offset data to be input is used with the tool post selection switch.
2. Press the EDIT switch on the machine operator’s panel.
3. When using a floppy, search for the required file according to the procedure in III–8.2.
4. Press function key [OFFSET SETTING], then the tool compensation screen appears.
5. Press soft keys [(OPRT)].
6. Press rightmost soft key (next menu key).
7. Press soft keys [READ] and [EXEC].
8. The input offset data will be displayed on the screen after completion of input operation.
8.5.2 Outputting Offset Data

All offset data is output in a output format from the memory of the CNC to a floppy or NC tape.

Procedure

1. Make sure the output device is ready for output. For the two-path control, select the tool post for which offset data to be input is used with the tool post selection switch.

2. Specify the punch code system (ISO or EIA) using a parameter.

3. Press the EDIT switch on the machine operator’s panel.

4. Press function key OFFSET SETTING, then the tool compensation screen appears.

5. Press soft key [(OPRT)].

6. Press the rightmost soft key (next-menu key)

7. Press soft keys [PUNCH] and [EXEC].

Offset data is output in the output format described below.

Explanations

• Output format

Output format is as follows:

Format

(1) For tool compensation memory A

G10 G90 P_R_;  
where P_: Offset No.  
R_: Tool compensation amount  
With OSI/Ethernet or DNC1/Ethernet, the output format is as follows:

(2) For tool compensation memory B

Setting/changing the geometric compensation amount

G10 G90 L10 P_R_;  
Setting/changing the wear compensation amount

G10 G90 L11 P_R_;  

(3) For tool compensation memory C

Setting/changing the geometric compensation amount for H code

G10 G90 L10 P_R_;  
Setting/changing the geometric compensation amount for D code

G10 G90 L12 P_R_;  
Setting/changing the wear compensation amount for H code

G10 G90 L11 P_R_;  
Setting/changing the wear compensation amount for D code

G10 G90 L13 P_R_;  

The L1 command may be used instead of L11 for format compatibility of the conventional CNC.

• Output file name

When the floppy disk directory display function is used, the name of the output file is OFFSET.
Parameters and pitch error compensation data are input and output from different screens, respectively. This chapter describes how to enter them.

### 8.6 INPUTTING AND OUTPUTTING PARAMETERS AND PITCH ERROR COMPENSATION DATA

#### 8.6.1 Inputting Parameters

Parameters are loaded into the memory of the CNC unit from a floppy or NC tape. The input format is the same as the output format. See III–8.6.2. When a parameter is loaded which has the same data number as a parameter already registered in the memory, the loaded parameter replaces the existing parameter.

**Procedure**

1. Make sure the input device is ready for reading. For the two-path control, select the tool post for which parameters to be input are used with the tool post selection switch.
2. When using a floppy, search for the required file according to the procedure in III–8.2.
3. Press the EMERGENCY STOP button on the machine operator’s panel.
4. Press function key \[OFFSET\] SETTING. 
5. Press the soft key \[SETTING\] for chapter selection, then the setting screen appears.
6. Enter 1 in response to the prompt for “PARAMETER WRITE (PWE)” in setting data. Alarm P/S100 (indicating that parameters can be written) appears.
7. Press soft key \[SYSTEM\]. 
8. Press chapter selection soft key \[PARAM\], then the parameter screen appears.
9. Press soft key \[(OPRT)\].
10. Press the rightmost soft key \(\rightarrow\) (next-menu key).
11. Press soft keys \[READ\] and \[EXEC\]. Parameters are read into memory. Upon completion of input, the “INPUT” indicator at the lower-right corner of the screen disappears.
12. Press function key \[SETTING\].
13. Press soft key \[SETTING\] for chapter selection.
14. Enter 0 in response to the prompt for “PARAMETER WRITE (PWE)” in setting data.
15 Turn the power to the CNC back on.
16 Release the EMERGENCY STOP button on the machine operator’s panel.

8.6.2 Outputting Parameters

All parameters are output in the defined format from the memory of the CNC to a floppy or NC tape.

Outputting parameters

Procedure

1 Make sure the output device is ready for output.
   For the two–path control, select the tool post for which parameters to be input are used with the tool post selection switch.
2 Specify the punch code system (ISO or EIA) using a parameter.
3 Press the EDIT switch on the machine operator’s panel.
4 Press function key [PARAM], then the parameter screen appears.
5 Press chapter selection soft key [PARAM].
6 Press soft key [(OPRT)].
7 Press rightmost soft key (next–menu key).
8 Press soft keys [PUNCH].
9 To output all parameters, press the [ALL] soft key. To output only parameters which are set to other than 0, press the [NON–0] soft key.
10 Press soft key [EXEC].
   All parameters are output in the defined format.

Explanations

• Output format

Output format is as follows:
N . . . P . . . . ;
N . . . P . . . . ;

N . . . : Parameter No.
A . . . : Axis No. (n is the number of control axis)
P . . . : Parameter setting value.

• Suppressing output of parameters set to 0

To suppress the output of the following parameters, press the [PUNCH] soft key then [NON–0] soft key.

<table>
<thead>
<tr>
<th>Other than axis type</th>
<th>Axis type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bit type Parameter for which all bits are set to 0</td>
<td>Parameter for an axis for which all bits are set to 0.</td>
</tr>
<tr>
<td>Value type Parameter whose value is 0.</td>
<td>Parameter for an axis for which the value is 0.</td>
</tr>
</tbody>
</table>
When the floppy disk directory display function is used, the name of the output file is PARAMETER. Once all parameters have been output, the output file is named ALL PARAMETER. Once only parameters which are set to other than 0 have been output, the output file is named NON–0. PARAMETER.

Pitch error compensation data are loaded into the memory of the CNC from a floppy or NC tape. The input format is the same as the output format. See III–8.6.4. When a pitch error compensation data is loaded which has the corresponding data number as a pitch error compensation data already registered in the memory, the loaded data replaces the existing data.

**Pitch error compensation data**

**Procedure**

1. Make sure the input device is ready for reading. For the two–path control, select the tool post for which pitch error compensation data to be input is used with the tool post selection switch.

2. When using a floppy, search for the required file according to the procedure in III–8.2.

3. Press the EMERGENCY STOP button on the machine operator’s panel.

4. Press function key [OFFSET SETTING].

5. Press the soft key [SETTING] for chapter selection.

6. Enter 1 in response to the prompt for writing parameters (PWE). Alarm P/S100 (indicating that parameters can be written) appears.

7. Press soft key [SYSTEM].

8. Press the rightmost soft key [next–menu key] and press chapter selection soft key [PITCH].

9. Press soft key [(OPRT)].

10. Press the rightmost soft key [next–menu key].

11. Press soft keys [READ] and [EXEC]. Parameters are read into memory. Upon completion of input, the “INPUT” indicator at the lower–right corner of the screen disappears.

12. Press function key [OFFSET SETTING].


14. Enter 0 in response to the prompt for “PARAMETER WRITE (PWE)” in setting data.
15  Turn the power to the CNC back on.
16  Release the EMERGENCY STOP button on the machine operator’s panel.

Explanations

• Pitch error compensation

Parameters 3620 to 3624 and pitch error compensation data must be set correctly to apply pitch error compensation correctly (See III–11.5.2).

8.6.4
Outputting Pitch Error Compensation Data

All pitch error compensation data are output in the defined format from the memory of the CNC to a floppy or NC tape.

Procedure for Outputting Pitch Error Compensation Data

1  Make sure the output device is ready for output.
   For the two–path control, select the tool post for which pitch error compensation data to be output is used with the tool post selection switch.
2  Specify the punch code system (ISO or EIA) using a parameter.
3  Press the EDIT switch on the machine operator’s panel.
4  Press function key [SYSTEM].
5  Press the rightmost soft key (next–menu key) and press chapter selection soft key [PITCH].
6  Press soft key [OPRT].
7  Press rightmost soft key (next–menu key).
8  Press soft keys [PUNCH] and [EXEC].
   All pitch error compensation data are output in the defined format.

Explanations

• Output format

Output format is as follows:
N10000 P... ;
N11023 P... ;
   N : Pitch error compensation point + 10000
   P : Pitch error compensation data
When bi–directional pitch error compensation is used, output format is as follows:
N20000 P... ;
N21023 P... ;
N23000 P... ;
N24023 P... ;
   N : Pitch error compensation point + 20000
   P : Pitch error compensation data

• Output file name

When the floppy disk directory display function is used, the name of the output file is “PITCH ERROR”.

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8.7 INPUTTING/OUTPUTTING CUSTOM MACRO COMMON VARIABLES

8.7.1 Inputting Custom Macro Common Variables

The value of a custom macro common variable (#500 to #999) is loaded into the memory of the CNC from a floppy or NC tape. The same format used to output custom macro common variables is used for input. See III–8.7.2. For a custom macro common variable to be valid, the input data must be executed by pressing the cycle start button after data is input. When the value of a common variable is loaded into memory, this value replaces the value of the same common variable already existing (if any) in memory.

Inputting custom macro common variables

**Procedure**

1. Register the program which has been output, as described in Section III–8.7.2, in memory according to the program input procedure described in Section III–8.4.1.

2. Press the MEMORY switch on the machine operator’s panel upon completing input.

3. Press the cycle start button to execute the loaded program.

4. Display the macro variable screen to check whether the values of the common variables have been set correctly.

   **Display of the macro variable screen**
   
   - Press function key OFFSET SETTING.
   - Press the rightmost soft key (next-menu key).
   - Press soft key [MACRO].
   - Select a variable with the page keys or numeric keys and soft key [NO.SRH].

**Explanations**

- **Common variables**

  The common variables (#500 to #531) can be input and output. When the option for adding a common variable is specified, values from #500 to #999 can be input and output. #100 to #199 can be input and output when bit 3 (PU5) of parameter No. 6001 is set to 1.
8.7.2 
**Outputting Custom Macro Common Variable**

Custom macro common variables (#500 to #999) stored in the memory of the CNC can be output in the defined format to a floppy or NC tape.

### Procedure

1. Make sure the output device is ready for output.
2. Specify the punch code system (ISO or EIA) using a parameter.
3. Press the EDIT switch on the machine operator’s panel.
4. Press function key OFFSET.
5. Press the rightmost soft key (next-menu key), then press soft key [MACRO].
6. Press soft key [(OPRT)].
7. Press the rightmost soft key (next-menu key).
8. Press soft keys [PUNCH] and [EXEC].

Common variables are output in the defined format.

### Explanations

- **Output format**
  
  The output format is as follows:

  ```
  %
  #500=[25283*65536+65536]/134217728 ............... (1)
  #501=#0; ...................................... (2)
  #502=0; ........................................ (3)
  #503= ; ........................................
  ..............................................
  #531= ; ........................................
  M02;
  %
  ```

  (1) The precision of a variable is maintained by outputting the value of the variable as <expression>.

  (2) Undefined variable

  (3) When the value of a variable is 0

- **Output file name**
  
  When the floppy disk directory display function is used, the name of the output file is “MACRO VAR”.

- **Common variable**
  
  The common variables (#500 to #531) can be input and output. When the option for adding a common variable is specified, values from #500 to #999 can be input and output.

  #100 to #199 can be input and output when bit 3 (PU5) of parameter No. 6001 is set to 1.
On the floppy directory display screen, a directory of the FANUC Handy File, FANUC Floppy Cassette, or FANUC FA Card files can be displayed. In addition, those files can be loaded, output, and deleted.

<table>
<thead>
<tr>
<th>NO.</th>
<th>FILE NAME</th>
<th>VOL</th>
</tr>
</thead>
<tbody>
<tr>
<td>0001</td>
<td>PARAMETER</td>
<td>58.5</td>
</tr>
<tr>
<td>0002</td>
<td>O0001</td>
<td>1.9</td>
</tr>
<tr>
<td>0003</td>
<td>O0002</td>
<td>1.9</td>
</tr>
<tr>
<td>0004</td>
<td>O0010</td>
<td>1.3</td>
</tr>
<tr>
<td>0005</td>
<td>O0040</td>
<td>1.3</td>
</tr>
<tr>
<td>0006</td>
<td>O0050</td>
<td>1.9</td>
</tr>
<tr>
<td>0007</td>
<td>O0100</td>
<td>1.9</td>
</tr>
<tr>
<td>0008</td>
<td>O1000</td>
<td>1.9</td>
</tr>
<tr>
<td>0009</td>
<td>O9500</td>
<td>1.6</td>
</tr>
</tbody>
</table>

EDIT  ****  11:51:12
( PRGRM ) ( DIR ) ( OPRT )
8.8.1
Displaying the Directory

Displaying the directory of floppy cassette files

Procedure 1

Use the following procedure to display a directory of all the files stored in a floppy:

1. Press the EDIT switch on the machine operator’s panel.
2. Press function key PROG.
3. Press the rightmost soft key (next-menu key).
4. Press soft key [FLOPPY].
5. Press page key or .
6. The screen below appears.

```
DIRECTORY (FLOPPY)  O0001 N00000
NO.  FILE NAME      (METER)  VOL
0001  PARAMETER     58.5     
0002  O0001         1.9      
0003  O0002         1.9      
0004  O0010         1.9      
0005  O0040         1.3      
0006  O0050         1.3      
0007  O0100         1.9      
0008  O1000         1.9      
0009  O9500         1.6      
```

EDIT ..... 11:53:04

```
F SRH READ PUNCH DELETE
```

Fig. 8.8.1 (a)

7. Press a page key again to display another page of the directory.
Procedure 2

Use the following procedure to display a directory of files starting with a specified file number:

1. Press the EDIT switch on the machine operator’s panel.

2. Press function key [PROG].

3. Press the rightmost soft key (next-menu key).

4. Press soft key [FLOPPY].

5. Press soft key [(OPRT)].

6. Press soft key [F SRH].

7. Enter a file number.

8. Press soft keys [F SET] and [EXEC].

9. Press a page key to display another page of the directory.

10. Press soft key [CAN] to return to the soft key display shown in the screen of Fig 8.8.1 (a).

Fig. 8.8.1 (b)
Explanations

- **Screen fields and their meanings**

  - **NO:** Displays the file number
  - **FILE NAME:** Displays the file name.
  - **(METER):** Converts and prints out the file capacity to paper tape length. You can also produce **H FEET** by setting the INPUT UNIT to INCH of the setting data.
  - **VOL.:** When the file is multi-volume, that state is displayed.

  - **(Ex.) Floppy or card A**
    - **C01**
    - **C02**
    - **L03**

  - **(Ex.) Floppy or card B**
  - **Floppy or card C**

  - **C(number) means CONTINUE**
  - **L(number) means LAST**
  - **number** number of floppies or cards
The contents of the specified file number are read to the memory of NC.

Reading Files

Procedure

1. Press the EDIT switch on the machine operator’s panel. For the two–path control, select the tool post for which a file is to be input in memory with the tool post selection switch.

2. Press function key \text{PROG}.

3. Press the rightmost soft key $\rightarrow$ (next–menu key).

4. Press soft key [FLOPPY].

5. Press soft key [\text{OPRT}].

6. Press soft key [READ].

7. Enter a file number.

8. Press soft key [F SET].

9. To modify the program number, enter the program number, then press soft key [O SET].

10. Press soft key [EXEC]. The file number indicated in the lower–left corner of the screen is automatically incremented by one.

11. Press soft key [CAN] to return to the soft key display shown in the screen of Fig. 8.8.1(a).
8.8.3 Outputting Programs

Any program in the memory of the CNC unit can be output to a floppy as a file.

Outputting programs

Procedure

1. Press the EDIT switch on the machine operator’s panel. For the two-path control, select the tool post for which a file is to be input in memory with the tool post selection switch.

2. Press function key [PROG].

3. Press the rightmost soft key [ ] (next-menu key).

4. Press soft key [FLOPPY].

5. Press soft key [[OPRT]].

6. Press soft key [PUNCH].

7. Enter a program number. To write all programs into a single file, enter 9999 in the program number field. In this case, the file name “ALL.PROGRAM” is registered.

8. Press soft key [O SET].

9. Press soft key [EXEC]. The program or programs specified in step 7 are written after the last file on the floppy. To output the program after deleting files starting with an existing file number, key in the file number, then press soft key [F SET] followed by soft key [EXEC].

10. Press soft key [CAN] to return to the soft key display shown in the screen of Fig. 8.8.1 (a).
8.8.4 Deleting Files

The file with the specified file number is deleted.

Deleting files

**Procedure**

1. Press the EDIT switch on the machine operator’s panel.
2. Press function key [PROG].
3. Press the rightmost soft key (next-menu key).
4. Press soft key [FLOPPY].
5. Press soft key [(OPRT)].
6. Press soft key [DELETE].

<table>
<thead>
<tr>
<th>DIRECTORY (FLOPPY)</th>
<th>O0001 N00000</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO.</td>
<td>FILE NAME</td>
</tr>
<tr>
<td>0001</td>
<td>PARAMETER</td>
</tr>
<tr>
<td>0002</td>
<td>O0001</td>
</tr>
<tr>
<td>0003</td>
<td>O0002</td>
</tr>
<tr>
<td>0004</td>
<td>O0010</td>
</tr>
<tr>
<td>0005</td>
<td>O0040</td>
</tr>
<tr>
<td>0006</td>
<td>O0050</td>
</tr>
<tr>
<td>0007</td>
<td>O0100</td>
</tr>
<tr>
<td>0008</td>
<td>O1000</td>
</tr>
<tr>
<td>0009</td>
<td>O9500</td>
</tr>
</tbody>
</table>

7. Specify the file to be deleted. When specifying the file with a file number, type the number and press soft key [F SET]. When specifying the file with a file name, type the name and press soft key [F NAME].

8. Press soft key [EXEC]. The file specified in the file number field is deleted. When a file is deleted, the file numbers after the deleted file are each decremented by one.

9. Press soft key [CAN] to return to the soft key display shown in the screen of Fig. 8.8.1 (a).
Restrictions

• **Inputting file numbers and program numbers with keys**
  If [F SET] or [O SET] is pressed without key inputting file number and program number, file number or program number shows blank. When 0 is entered for file numbers or program numbers, 1 is displayed.

• **I/O devices**
  To use channel 0, set a device number in parameter (No. 102).
  Set the I/O device number to parameter (No. 112) when channel 1 is used.
  Set it to (No. 0122) when channel 2 is used.

• **Significant digits**
  For the numeral input in the data input area with FILE No. and PROGRAM No., only lower 4 digits become valid.

• **Collation**
  When the data protection key on the machine operator’s panel is ON, no programs are read from the floppy. They are verified against the contents of the memory of the CNC instead.

### ALARM

<table>
<thead>
<tr>
<th>Alarm No.</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>71</td>
<td>An invalid file number or program number was entered. (Specified program number is not found.)</td>
</tr>
<tr>
<td>79</td>
<td>Verification operation found a mismatch between a program loaded into memory and the contents of the floppy</td>
</tr>
<tr>
<td>86</td>
<td>The dataset–ready signal (DR) for the input/output device is turned off. (The no file error or duplicate file error occurred on the input/output device because an invalid file number, program number, or file name was entered.)</td>
</tr>
</tbody>
</table>
8.9 OUTPUTTING A PROGRAM LIST FOR A SPECIFIED GROUP

CNC programs stored in memory can be grouped according to their names, thus enabling the output of CNC programs in group units. Section III–11.3.2 explains the display of a program listing for a specified group.

Procedure for Outputting a Program List for a Specified Group

**Procedure**

1. Display the program list screen for a group of programs, as described in Section III–11.3.2.

   ![Program Directory Screen]

<table>
<thead>
<tr>
<th>PROGRAM DIRECTORY (GROUP)</th>
<th>O0001</th>
<th>N00010</th>
</tr>
</thead>
<tbody>
<tr>
<td>PROGRAM (NUM.)</td>
<td>MEMORY (CHAR.)</td>
<td></td>
</tr>
<tr>
<td>USED: 60</td>
<td>3321</td>
<td></td>
</tr>
<tr>
<td>FREE: 2</td>
<td>429</td>
<td></td>
</tr>
<tr>
<td>O0020 (GEAR–1000 MAIN)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>O0040 (GEAR–1000 SUB–1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>O0200 (GEAR–1000 SUB–2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>O2000 (GEAR–1000 SUB–3)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

   > EDIT 16:52:13

   ![Operation Soft Keys]

2. Press the [(OPRT)] operation soft key.

3. Press the right–most soft key (continuous menu key).

4. Press the [PUNCH] operation soft key.

5. Press the [AL–GRP] operation soft key.

   The CNC programs in the group for which a search is made are output. When these programs are output to a floppy disk, they are output to a file named GROUP.PROGRAM.
8.10     DATA INPUT/OUTPUT ON THE ALL IO SCREEN

To input/output a particular type of data, the corresponding screen is usually selected. For example, the parameter screen is used for parameter input from or output to an external input/output unit, while the program screen is used for program input or output. However, programs, parameters, offset data, and macro variables can all be input and output using a single common screen, that is, the ALL IO screen.

**READ/PUNCH (PROGRAM)**

<table>
<thead>
<tr>
<th>I/O CHANNEL</th>
<th>3</th>
<th>TV CHECK</th>
<th>OFF</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEVICE NUM.</td>
<td>0</td>
<td>PUNCH CODE</td>
<td>ISO</td>
</tr>
<tr>
<td>BAUDRATE</td>
<td>4800</td>
<td>INPUT CODE</td>
<td>ASCII</td>
</tr>
<tr>
<td>STOP BIT</td>
<td>2</td>
<td>FEED OUTPUT</td>
<td>FEED</td>
</tr>
<tr>
<td>NULL INPUT (EIA)</td>
<td>NO</td>
<td>EOB OUTPUT (ISO)</td>
<td>CR</td>
</tr>
<tr>
<td>TV CHECK (NOTES)</td>
<td>ON</td>
<td>BAUDRATE CLK.</td>
<td>INNER</td>
</tr>
<tr>
<td>CD CHECK (232C)</td>
<td>OFF</td>
<td>RESET/ALARM</td>
<td>ON</td>
</tr>
<tr>
<td>PARITY BIT</td>
<td>OFF</td>
<td>SAT COMMAND</td>
<td>HOST</td>
</tr>
<tr>
<td>INTERFACE</td>
<td>RS422</td>
<td>COM PROTOCOL</td>
<td>A</td>
</tr>
<tr>
<td>END CODE</td>
<td>EXT</td>
<td>COM CODE</td>
<td>ASCII</td>
</tr>
</tbody>
</table>

(0:EIA  1:ISO)>1_

MDI  *****  ***  ***  ***  12:34:56

Fig. 8.10  ALL IO screen (when channel 3 is being used for input/output)
8.10.1 Setting Input/Output–Related Parameters

Input/output–related parameters can be set on the ALL IO screen. Parameters can be set, regardless of the mode.

Procedure

1. Press function key \[\text{SYSTEM}\].
2. Press the rightmost soft key \[\text{[←]}\] (next–menu key) several times.
3. Press soft key \[\text{[ALL IO]}\] to display the ALL IO screen.

NOTE

1. If program or floppy is selected in EDIT mode, the program directory or floppy screen is displayed.
2. When the power is first turned on, program is selected by default.

<table>
<thead>
<tr>
<th>READ/PUNCH (PROGRAM)</th>
<th>O1234 N12345</th>
</tr>
</thead>
<tbody>
<tr>
<td>I/O CHANNEL</td>
<td>3</td>
</tr>
<tr>
<td>DEVICE NUM.</td>
<td>0</td>
</tr>
<tr>
<td>BAUDRATE</td>
<td>4800</td>
</tr>
<tr>
<td>STOP BIT</td>
<td>2</td>
</tr>
<tr>
<td>NULL INPUT (EIA)</td>
<td>NO</td>
</tr>
<tr>
<td>TV CHECK (NOTES)</td>
<td>ON</td>
</tr>
<tr>
<td>CD CHECK (232C)</td>
<td>OFF</td>
</tr>
<tr>
<td>PARITY BIT</td>
<td>OFF</td>
</tr>
<tr>
<td>INTERFACE</td>
<td>RS422</td>
</tr>
<tr>
<td>END CODE</td>
<td>EXT</td>
</tr>
<tr>
<td>TV CHECK</td>
<td>OFF</td>
</tr>
<tr>
<td>Baudrate CLK. INNER</td>
<td></td>
</tr>
<tr>
<td>EOB OUTPUT (ISO)</td>
<td>CR</td>
</tr>
<tr>
<td>FEED OUTPUT FEED</td>
<td></td>
</tr>
<tr>
<td>INPUT CODE ISO</td>
<td></td>
</tr>
<tr>
<td>FEED</td>
<td></td>
</tr>
<tr>
<td>ASCII</td>
<td></td>
</tr>
<tr>
<td>ASCII</td>
<td></td>
</tr>
</tbody>
</table>

(0:EIA 1:ISO)>1_

MDI • • • • • 12:34:56

( \[\text{PRGRM}\] \[\text{PARAM}\] \[\text{OFFSET}\] \[\text{MACRO}\] \[\text{(OPRT)}\] )

NOTE

Baud rate clock, CD check (232C), reset/alarm report, and the parity bit for parameter No. 134, as well as the communication code, end code, communication protocol, interface, and SAT command for parameter No. 135 are displayed only when channel 3 is being used for input/output.

4. Select the soft key corresponding to the desired type of data (program, parameter, and so forth).
5. Set the parameters corresponding to the type of input/output unit to be used. (Parameter setting is possible regardless of the mode.)
8.10.2 Inputting and Outputting Programs

A program can be input and output using the ALL IO screen. When entering a program using a cassette or card, the user must specify the input file containing the program (file search).

File search

Procedure

1. Press soft key [PRGRM] on the ALL IO screen, described in Section 8.10.1.

2. Select EDIT mode. A program directory is displayed.

3. Press soft key [(OPRT)]. The screen and soft keys change as shown below.

   - A program directory is displayed only in EDIT mode. In all other modes, the ALL IO screen is displayed.

```
PROGRAM (NUM.) MEMORY (CHAR.)
USED : 60 3321
FREE : 2 429

O0010 O0001 O0003 O0002 O0555 O0999
O0062 O0004 O0005 O1111 O0969 O6666
O0021 O1234 O0588 O0020 O0040

> EDIT **** *** *** 14:46:09
F SRH READ PUNCH DELETE (OPRT)
```

4. Enter address N.

5. Enter the number of the file to be found.
    - N0
      The first floppy file is found.
    - One of N1 to N9999
      Among the files numbered from 1 to 9999, a specified file is found.
    - N~9999
      The file immediately after that used most recently is found.
    - N~9998
      When ~9998 is specified, the next file is found. Then, each time a file input/output operation is performed, N~9999 is automatically inserted. This means that subsequent files can be sequentially found automatically.
      This state is canceled by specifying N0, N1 to N9999, or N~9999, or upon a reset.
6 Press soft keys [F SRH] and [EXEC].
The specified file is found.

Explanations

• Difference between N0 and N1
  When a file already exists in a cassette or card, specifying N0 or N1 has
  the same effect. If N1 is specified when there is no file on the cassette or
  card, an alarm is issued because the first file cannot be found. Specifying
  N0 places the head at the start of the cassette or card, regardless of whether
  the cassette/card already contains files. So, no alarm is issued in this case.
  N0 can be used, for example, when a program is written into a new
  cassette or card, or when a previously used cassette or card is used once
  all the files it contains have been erased.

• Alarm issue during file search
  If an alarm (file search failure, for example) is generated during file
  search, the CNC does not issue an alarm immediately. However, a P/S
  alarm (No. 086) is issued if input/output is subsequently performed on
  that file.

• File search using N–9999
  Instead of sequentially searching for files by specifying actual file
  numbers every time, the user can specify the first file number, then find
  the subsequent files by specifying N–9999. When N–9999 is specified,
  the time required for file search can be reduced.
Inputting a program

Procedure

1. Press soft key [PRGRM] on the ALL IO screen, described in Section 8.10.1.

2. Select EDIT mode. A program directory is displayed.

3. Press soft key [(OPRT)]. The screen and soft keys change as shown below.
   - A program directory is displayed only in EDIT mode. In all other modes, the ALL IO screen is displayed.

4. To specify a program number to be assigned to an input program, enter address O, followed by the desired program number. If no program number is specified, the program number in the file or on the NC tape is assigned as is.

5. Press soft key [READ], then [EXEC].
   The program is input with the program number specified in step 4 assigned.
   To cancel input, press soft key [CAN].
   To stop input prior to its completion, press soft key [STOP].
Outputting programs

**Procedure**

1. Press soft key [PRGRM] on the ALL IO screen, described in Section 8.10.1.

2. Select EDIT mode. A program directory is displayed.

3. Press soft key [(OPRT)]. The screen and soft keys change as shown below.
   - A program directory is displayed only in EDIT mode. In all other modes, the ALL IO screen is displayed.

   ![Program Directory Example]

4. Enter address O.

5. Enter a desired program number.
   - If –9999 is entered, all programs in memory are output.
   - To output a range of programs, enter OΔΔΔΔ, OΔΔΔΔ/ΔΔΔΔ. The programs numbered from ΔΔΔΔ to ΔΔΔΔ are output.
   - When bit 4 (SOR) of parameter No. 3107 for sorted display is set to 1 on the program library screen, programs are output in order, starting from those having the smallest program numbers.

6. Press soft key [PUNCH], then [EXEC].
   - The specified program or programs are output. If steps 4 and 5 are omitted, the currently selected program is output.
   - To cancel output, press soft key [CAN].
   - To stop output prior to its completion, press soft key [STOP].
Deleting files

**Procedure**

1. Press soft key [PRGRM] on the ALL IO screen, described in Section 8.10.1.
2. Select EDIT mode. A program directory is displayed.
3. Press soft key [(OPRT)]. The screen and soft keys change as shown below.
   - A program directory is displayed only in EDIT mode. In all other modes, the ALL IO screen is displayed.

```
PROGRAM (NUM.)  MEMORY (CHAR.)
USED :  60  3321
FREE :  2  429
```

4. Press soft key [DELETE].
5. Enter a file number, from 1 to 9999, to indicate the file to be deleted.
6. Press soft key [EXEC]. The k-th file, specified in step 5, is deleted.

**Explanations**

- **File numbers after deletion**
  After deletion of the k-th file, the previous file numbers (k+1) to n are decremented by 1 to k to (n–1).

<table>
<thead>
<tr>
<th>Before deletion</th>
<th>After deletion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 to (k–1)</td>
<td>1 to (k–1)</td>
</tr>
<tr>
<td>K</td>
<td>Delete</td>
</tr>
<tr>
<td>(k+1) to n</td>
<td>k to (n–1)</td>
</tr>
</tbody>
</table>

- **Write protect**
  Before a file can be deleted, the write protect switch of the cassette must be set to make the cassette writable.
8. DATA INPUT/OUTPUT

8.10.3 Parameters can be input and output using the ALL IO screen.

Inputting and Outputting Parameters

### Inputting parameters

**Procedure**

1. Press soft key **[PARAM]** on the ALL IO screen, described in Section 8.10.1.

2. Select EDIT mode.

3. Press soft key **[(OPRT)]**. The screen and soft keys change as shown below.

```
READ/PUNCH (PARAMETER) O1234 N12345
I/O CHANNEL 3          TV CHECK OFF
DEVICE NUM. 0          PUNCH CODE ISO
BAUDRATE 4800          INPUT CODE ASCII
STOP BIT 2             FEED OUTPUT FEED
NULL INPUT (EIA) NO    EOB OUTPUT (ISO) CR
TV CHECK (NOTES) ON    BAUDRATE CLK. INNER
CD CHECK (232C) OFF    RESET/ALARM ON
PARITY BIT OFF         COM CODE ASCII
END CODE EXT           COM PROTOCOL A
INTERFACE RS422        SAT COMMAND HOST
0: (EIA 1:ISO)>1_
MDI   ****  ***  ***  ***  12:34:56
      (       )       (       )       (       )
      (       )       (       )       (       )
```

4. Press soft key **[READ]**, then **[EXEC]**. The parameters are read, and the "INPUT" indicator blinks at the lower–right corner of the screen. Upon the completion of input, the "INPUT" indicator is cleared from the screen. To cancel input, press soft key **[CAN]**.
Outputting parameters

**Procedure**

1. Press soft key [PARAM] on the ALL IO screen, described in Section 8.10.1.

2. Select EDIT mode.

3. Press soft key [(OPRT)]. The screen and soft keys change as shown below.

```
READ/PUNCH (PARAMETER)      O1234 N12345
I/O CHANNEL       3   TV CHECK       OFF
DEVICE NUM.        0   PUNCH CODE     ISO
BAUDRATE           4800 INPUT CODE    ASCII
STOP BIT           2   FEED OUTPUT    FEED
NULL INPUT (EIA)   NO   EOB OUTPUT (ISO) CR
TV CHECK (NOTES)   ON   BAUDRATE CLK. INNER
CD CHECK (232C)    OFF  RESET/ALARM ON
PARITY BIT         OFF  COM CODE        ASCII
END CODE           EXT  COM PROTOCOL  A
INTERFACE         RS422  SAT COMMAND  HOST
                      (0:EIA 1:ISO)>1_
MDI   ......   ***   ***   ***   12:34:56

                                          READ
                                          PUNCH
                                          ( )  ( )
                                          CAN  [EXEC]
```

4. Press soft key [PUNCH], then [EXEC].

   The parameters are output, and the "OUTPUT" indicator blinks at the lower–right corner of the screen. Upon the completion of output, the "OUTPUT" indicator is cleared from the screen.

   To cancel output, press soft key [CAN].
8.10.4 Offset data can be input and output using the ALL IO screen.

Inputting offset data

Procedure

1. Press soft key **OFFSET** on the ALL IO screen, described in Section 8.10.1.

2. Select EDIT mode.

3. Press soft key **[OPRT]**. The screen and soft keys change as shown below.

   READ/PUNCH (OFFSET)       O1234 N12345
   I/O CHANNEL               3  TV CHECK           OFF
   DEVICE NUM.               0  PUNCH CODE         ISO
   BAUDRATE                  4800  INPUT CODE      ASCII
   STOP BIT                  2  FEED OUTPUT       FEED
   NULL INPUT (EIA)          NO  EOB OUTPUT (ISO)  CR
   TV CHECK (NOTES)          ON  BAUDRATE CLK.    INNER
   CD CHECK (232C)           OFF  RESET/ALARM     ON
   PARITY BIT                OFF  COM CODE         ASCII
   END CODE                  EXT  COM PROTOCOL    A
   INTERFACE                RS422  SAT COMMAND   HOST
   (0:EIA 1:ISO)>1
   MDI   ****   ***   ***   ***   12:34:56
   (   ) (  READ  ) ( PUNCH ) (   ) (   )

4. Press soft key **[READ]**, then **[EXEC]**. The offset data is read, and the "INPUT" indicator blinks at the lower–right corner of the screen. Upon the completion of input, the "INPUT" indicator is cleared from the screen. To cancel input, press soft key **[CAN]**.
Outputting offset data

**Procedure**

1. Press soft key **[OFFSET]** on the ALL IO screen, described in Section 8.10.1.

2. Select EDIT mode.

3. Press soft key **[(OPRT)]**. The screen and soft keys change as shown below.

   READ/PUNCH (OFFSET)  
   O1234 N12345

<table>
<thead>
<tr>
<th>I/O CHANNEL</th>
<th>3</th>
<th>TV CHECK</th>
<th>OFF</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEVICE NUM.</td>
<td>0</td>
<td>PUNCH CODE</td>
<td>ISO</td>
</tr>
<tr>
<td>BAUDRATE</td>
<td>4800</td>
<td>INPUT CODE</td>
<td>ASCII</td>
</tr>
<tr>
<td>STOP BIT</td>
<td>2</td>
<td>FEED OUTPUT</td>
<td>FEED</td>
</tr>
<tr>
<td>NULL INPUT (EIA)</td>
<td>NO</td>
<td>EOB OUTPUT (ISO)</td>
<td>CR</td>
</tr>
<tr>
<td>TV CHECK (NOTES)</td>
<td>ON</td>
<td>BAUDRATE CLK.</td>
<td>INNER</td>
</tr>
<tr>
<td>CD CHECK (232C)</td>
<td>OFF</td>
<td>RESET/ALARM</td>
<td>ON</td>
</tr>
<tr>
<td>PARITY BIT</td>
<td>OFF</td>
<td>COM CODE</td>
<td>ASCII</td>
</tr>
<tr>
<td>END CODE</td>
<td>EXT</td>
<td>COM PROTOCOL</td>
<td>A</td>
</tr>
<tr>
<td>INTERFACE</td>
<td>RS422</td>
<td>SAT COMMAND</td>
<td>HOST</td>
</tr>
<tr>
<td>(0:EIA 1:ISO)&gt;1_</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MDI</td>
<td>****</td>
<td>***</td>
<td>***</td>
</tr>
</tbody>
</table>

4. Press soft key **[PUNCH]**, then **[EXEC]**. The offset data is output, and the "OUTPUT" indicator blinks at the lower–right corner of the screen. Upon the completion of output, the "OUTPUT" indicator is cleared from the screen. To cancel output, press soft key **[CAN]**.
8.10.5
Outputting Custom Macro Common Variables

Custom macro common variables can be output using the ALL IO screen.

Outputting custom macro common variables

**Procedure**

1. Press soft key [MACRO] on the ALL IO screen, described in Section 8.10.1.

2. Select EDIT mode.

3. Press soft key [(OPRT)]. The screen and soft keys change as shown below.

```
READ/PUNCH (MACRO)  O1234 N12345
I/O CHANNEL          3  TV CHECK OFF
DEVICE NUM.          0  PUNCH CODE ISO
BAUDRATE             4800 INPUT CODE ASCII
STOP BIT             2  FEED OUTPUT FEED
NULL INPUT (EIA)     NO EOB OUTPUT (ISO) CR
TV CHECK (NOTES)     ON BAUDRATE CLK. INNER
CD CHECK (232C)      OFF RESET/ALARM ON
PARITY BIT           OFF COM CODE ASCII
END CODE             EXT COM PROTOCOL A
INTERFACE            RS422 SAT COMMAND HOST
(0:EIA 1:ISO)>1_ MDI    12:34:56
                    READ PUNCH
```

4. Press soft key [PUNCH], then [EXEC]. The custom macro common variables are output, and the "OUTPUT" indicator blinks at the lower-right corner of the screen. Upon the completion of output, the "OUTPUT" indicator is cleared from the screen.

   To cancel output, press soft key [CAN].

**NOTE**

To input a macro variable, read the desired custom macro statement as a program, then execute the program.
The ALL IO screen supports the display of a directory of floppy files, as well as the input and output of floppy files.

### Displaying a file directory

**Procedure**

1. Press the rightmost soft key (next-menu key) on the ALL IO screen, described in Section 8.10.1.

2. Press soft key [FLOPPY].

3. Select EDIT mode. The floppy screen is displayed.

4. Press soft key [(OPRT)]. The screen and soft keys change as shown below.

   The floppy screen is displayed only in EDIT mode. In all other modes, the ALL IO screen is displayed.

   ![Floppy Screen](image.png)

5. Press soft key [F SRH].

6. Enter the number of the desired file, then press soft key [F SET].

7. Press soft key [EXEC]. A directory is displayed, with the specified file uppermost. Subsequent files in the directory can be displayed by pressing the page key.
A directory in which the first file is uppermost can be displayed simply by pressing the page key. (Soft key [F SRH] need not be pressed.)
Inputting a file

Procedure

1. Press the rightmost soft key (next–menu key) on the ALL IO screen, described in Section 8.10.1.

2. Press soft key [FLOPPY].

3. Select EDIT mode. The floppy screen is displayed.

4. Press soft key [(OPRT)]. The screen and soft keys change as shown below. The floppy screen is displayed only in EDIT mode. In all other modes, the ALL IO screen is displayed.

5. Press soft key [READ].

6. Enter the number of a file or program to be input.
   - Setting a file number: Enter the number of the desired file, then press soft key [F SET].
   - Setting a program number: Enter the number of the desired program, then press soft key [O SET].

7. Press soft key [EXEC]. The specified file or program is read, and the "INPUT" indicator blinks at the lower–right corner of the screen. Upon the completion of input, the "INPUT" indicator is cleared from the screen.
Outputting a file

Procedure

1. Press the rightmost soft key (next-menu key) on the ALL IO screen, described in Section 8.10.1.
2. Press soft key [FLOPPY].
3. Select EDIT mode. The floppy screen is displayed.
4. Press soft key [(OPRT)]. The screen and soft keys change as shown below.
   The floppy screen is displayed only in EDIT mode. In all other modes, the ALL IO screen is displayed.

   READ/PUNCH (FLOPPY)  O1234 N12345

   MDI  ****  ***  ***  ***  12:34:56
   (F SRH ) (READ ) (PUNCH ) (DELETE )

5. Press soft key [PUNCH].
6. Enter the number of the program to be output, together with a desired output file number.
   - Setting a file number: Enter the number of the desired file, then press soft key [F SET].
   - Setting a program number: Enter the number of the desired program, then press soft key [O SET].
7. Press soft key [EXEC].
   The specified program is output, and the "OUTPUT" indicator blinks at the lower–right corner of the screen. Upon the completion of output, the "OUTPUT" indicator is cleared from the screen.
   If no file number is specified, the program is written at the end of the currently registered files.
Deleting a file

**Procedure**

1. Press the rightmost soft key (next-menu key) on the ALL IO screen, described in Section 8.10.1.

2. Press soft key [FLOPPY].

3. Select EDIT mode. The floppy screen is displayed.

4. Press soft key [(OPRT)]. The screen and soft keys change as shown below.
   The floppy screen is displayed only in EDIT mode. In all other modes, the ALL IO screen is displayed.

   ![](READ/PUNCH (FLOPPY) O1234 N12345)

   ![](MDI **** *** *** *** 12:34:56)

   ![](READ PUNCH DELETE)

   ![](EXEC)

5. Press soft key [DELETE].

6. Enter the number of the desired file, then press soft key [F SET].

7. Press soft key [EXEC]. The specified file is deleted. After the file has been deleted, the subsequent files are shifted up.
By setting the I/O channel (parameter No. 0020) to 4, files on a memory card inserted into the memory card interface located to the left of the display can be referenced. Different types of data such as part programs, parameters, and offset data on a memory card can also be input and output in text file format.

The major functions are listed below.

- Displaying a directory of stored files
  The files stored on a memory card can be displayed on the directory screen.
- Searching for a file
  A search is made for a file on a memory card and, if found, it is displayed on the directory screen.
- Reading a file
  Text-format files can be read from a memory card.
- Writing a file
  Data such as part programs can be stored to a memory card in text file format.
- Deleting a file
  A file can be selected and deleted from a memory card.
Displaying a directory of stored files

**Procedure**

1. Press the EDIT switch on the machine operator's panel.

2. Press function key [PROG].

3. Press the rightmost soft key (next-menu key).

4. Press soft key [CARD]. The screen shown below is displayed. Using page keys and , the screen can be scrolled.

   **DIRECTORY (M–CARD)**

<table>
<thead>
<tr>
<th>No.</th>
<th>FILE NAME</th>
<th>SIZE</th>
<th>DATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0001</td>
<td>O1000</td>
<td>123456</td>
<td>96/07/10</td>
</tr>
<tr>
<td>0002</td>
<td>O1001</td>
<td>8458</td>
<td>96/07/30</td>
</tr>
<tr>
<td>0003</td>
<td>O0002</td>
<td>3250</td>
<td>96/07/30</td>
</tr>
<tr>
<td>0004</td>
<td>O2000</td>
<td>73456</td>
<td>96/07/31</td>
</tr>
<tr>
<td>0005</td>
<td>O2001</td>
<td>3444</td>
<td>96/07/31</td>
</tr>
<tr>
<td>0006</td>
<td>O3001</td>
<td>8483</td>
<td>96/08/02</td>
</tr>
<tr>
<td>0007</td>
<td>O3300</td>
<td>406</td>
<td>96/08/05</td>
</tr>
<tr>
<td>0008</td>
<td>O3400</td>
<td>2420</td>
<td>96/07/31</td>
</tr>
<tr>
<td>0009</td>
<td>O3500</td>
<td>7460</td>
<td>96/07/31</td>
</tr>
</tbody>
</table>

5. Comments relating to each file can be displayed by pressing soft key [DIR+].

   **DIRECTORY (M–CARD)**

<table>
<thead>
<tr>
<th>No.</th>
<th>FILE NAME</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>0001</td>
<td>O1000</td>
<td>(COMMENT )</td>
</tr>
<tr>
<td>0002</td>
<td>O1001</td>
<td>(SUB PROGRAM )</td>
</tr>
<tr>
<td>0003</td>
<td>O0002</td>
<td>(12345678 )</td>
</tr>
<tr>
<td>0004</td>
<td>O2000</td>
<td>( )</td>
</tr>
<tr>
<td>0005</td>
<td>O2001</td>
<td>( )</td>
</tr>
<tr>
<td>0006</td>
<td>O3001</td>
<td>(SKIP–K )</td>
</tr>
<tr>
<td>0007</td>
<td>O3300</td>
<td>(HI–SPEED )</td>
</tr>
<tr>
<td>0008</td>
<td>O3400</td>
<td>( )</td>
</tr>
<tr>
<td>0009</td>
<td>O3500</td>
<td>(TEST PROGRAM)</td>
</tr>
</tbody>
</table>

6. Repeatedly pressing soft key [DIR+] toggles the screen between the display of comments and the display of sizes and dates.

   Any comment described after the O number in the file is displayed. Up to 18 characters can be displayed on the screen.
Searching for a file

**Procedure**

1. Press the EDIT switch on the machine operator’s panel.

2. Press function key **PROG**.

3. Press the rightmost soft key **(next-menu key)**.

4. Press soft key **[CARD]**. The screen shown below is displayed.

<table>
<thead>
<tr>
<th>No.</th>
<th>FILE NAME</th>
<th>SIZE</th>
<th>DATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0001</td>
<td>O1000</td>
<td>123456</td>
<td>96/07/10</td>
</tr>
<tr>
<td>0002</td>
<td>O1001</td>
<td>8458</td>
<td>96/07/30</td>
</tr>
<tr>
<td>0003</td>
<td>O0002</td>
<td>3250</td>
<td>96/07/30</td>
</tr>
<tr>
<td>0004</td>
<td>O2000</td>
<td>73456</td>
<td>96/07/31</td>
</tr>
<tr>
<td>0005</td>
<td>O2001</td>
<td>3444</td>
<td>96/07/31</td>
</tr>
<tr>
<td>0006</td>
<td>O3001</td>
<td>8483</td>
<td>96/08/02</td>
</tr>
<tr>
<td>0007</td>
<td>O3300</td>
<td>406</td>
<td>96/08/05</td>
</tr>
<tr>
<td>0008</td>
<td>O3400</td>
<td>2420</td>
<td>96/07/31</td>
</tr>
<tr>
<td>0009</td>
<td>O3500</td>
<td>7460</td>
<td>96/07/31</td>
</tr>
</tbody>
</table>

5. Press soft key **[(OPRT)]**.

6. Set the number of the desired file number with soft key **[F SRH]**. Then, start the search by pressing soft key **[EXEC]**. If found, the file is displayed at the top of the directory screen.

When a search is made for file number 19
Reading a file

**Procedure**

1. Press the EDIT switch on the machine operator’s panel.
2. Press function key PROG.
3. Press the rightmost soft key (next—menu key).
4. Press soft key [CARD]. Then, the screen shown below is displayed.

```
PROG (OPRT) DIR
+ DIRECTORY (M–CARD)
No. FILE NAME SIZE DATE
0001 O1000 123456 96/07/10
0002 O1001 8458 96/07/30
0003 O0002 3250 96/07/30
0004 O2000 73456 96/07/31
0005 O2001 3444 96/07/31
0006 O3001 8483 96/08/02
0007 O3300 406 96/08/05
0008 O3400 2420 96/07/31
0009 O3500 7460 96/07/31
```

5. Press soft key [(OPRT)].

6. To specify a file number, press soft key [F READ]. The screen shown below is displayed.

```
F NAME EXEC STOPO SET CAN
DIRECTORY (M–CARD)
No. FILE NAME COMMENT
0019 O1000 (MAIN PROGRAM)
0020 O1010 (SUBPROGRAM–1)
0021 O1030 (COMMENT)
```

7. Enter file number 20 from the MDI panel, then set the file number by pressing soft key [F SET]. Next, enter program number 120, then set the program number by pressing soft key [O SET]. Then, press soft key [EXEC].

- File number 20 is registered as O0120 in the CNC.
- Set a program number to register a read file with a separate O number. If no program number is set, the O number in the file name column is registered.
8 To specify a file with its file name, press soft key [N READ] in step 6 above. The screen shown below is displayed.

```
FILE NAME
0012 O0050 (MAIN PROGRAM)
0013 TESTPRO (SUB PROGRAM-1)
0014 O0060 (MACRO PROGRAM)
```

9 To register file name TESTPRO as O1230, enter file name TESTPRO from the MDI panel, then set the file name with soft key [F NAME]. Next, enter program number 1230, then set the program number with soft key [O SET]. Then, press soft key [EXEC].
Writing a file

**Procedure**

1. Press the EDIT switch on the machine operator’s panel.
2. Press function key \[ prog \].
3. Press the rightmost soft key \[ \rightarrow \] (next-menu key).
4. Press soft key [CARD]. The screen shown below is displayed.

<table>
<thead>
<tr>
<th>No.</th>
<th>FILE NAME</th>
<th>SIZE</th>
<th>DATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0001</td>
<td>O1000</td>
<td>123456</td>
<td>96/07/10</td>
</tr>
<tr>
<td>0002</td>
<td>O1001</td>
<td>8458</td>
<td>96/07/30</td>
</tr>
<tr>
<td>0003</td>
<td>O0002</td>
<td>3250</td>
<td>96/07/30</td>
</tr>
<tr>
<td>0004</td>
<td>O2000</td>
<td>73456</td>
<td>96/07/31</td>
</tr>
<tr>
<td>0005</td>
<td>O2001</td>
<td>3444</td>
<td>96/07/31</td>
</tr>
<tr>
<td>0006</td>
<td>O3001</td>
<td>8483</td>
<td>96/08/02</td>
</tr>
<tr>
<td>0007</td>
<td>O3300</td>
<td>406</td>
<td>96/08/05</td>
</tr>
<tr>
<td>0008</td>
<td>O3400</td>
<td>2420</td>
<td>96/07/31</td>
</tr>
<tr>
<td>0009</td>
<td>O3500</td>
<td>7460</td>
<td>96/07/31</td>
</tr>
</tbody>
</table>

5. Press soft key \[ [OPRT] \].
6. Press soft key [PUNCH].
7. Enter a desired O number from the MDI panel, then set the program number with soft key [O SET].
   When soft key [EXEC] is pressed after the setting shown below has been made, for example, the file is written under program number O1230.

<table>
<thead>
<tr>
<th>FILE NAME</th>
<th>PROGRAM No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABCD12</td>
<td>1230</td>
</tr>
</tbody>
</table>

8. In the same way as for O number setting, enter a desired file name from the MDI panel, then set the file name with soft key [F SET].
   When soft key [EXEC] is pressed after the setting shown below has been made, for example, the file is written under program number O1230 and file name ABCD12.
Explanations

- **Registering the same file name**
  When a file having the same name is already registered in the memory card, the existing file will be overwritten.

- **Writing all programs**
  To write all programs, set program number = -9999. If no file name is specified in this case, file name PROGRAM.ALL is used for registration.

- **File name restrictions**
  The following restrictions are imposed on file name setting:
  
  `<File name setting>`  
  
  Not longer than 8 characters  
  Extension not longer than 3 characters
Deleting a file

**Procedure**

1. Press the EDIT switch on the machine operator’s panel.
2. Press function key [**PROG**].
3. Press the rightmost soft key (next-menu key).
4. Press soft key [**CARD**]. The screen shown below is displayed.

```
PROG (OPRT) DIR

DIRECTORY (M–CARD)
No. FILE NAME SIZE DATE
0001 O1000 123456 96/07/10
0002 O1001 8458 96/07/30
0003 O0002 3250 96/07/30
0004 O2000 73456 96/07/31
0005 O2001 3444 96/07/31
0006 O3001 8483 96/08/02
0007 O3300 406 96/08/05
0008 O3400 2420 96/07/31
0009 O3500 7460 96/07/31
```

5. Press soft key [**(OPRT)**].
6. Set the number of the desired file with soft key [**DELETE**], then press soft key [**EXEC**]. The file is deleted, and the directory screen is displayed again.

When file number 21 is deleted

```
PROG [DIR + ] [ (OPRT) ]
```

```
DIRECTORY (M–CARD)
No. FILE NAME COMMENT
0001 O1000 (MAIN PROGRAM)
0020 O1010 (SUBPROGRAM–1)
0021 O1020 (COMMENT )
0022 O1030 (COMMENT )
```

File name O1020 is deleted.

```
DIRECTORY (M–CARD)
No. FILE NAME COMMENT
0019 O1000 (MAIN PROGRAM)
0020 O1010 (SUBPROGRAM–1)
0021 O1020 (COMMENT )
0022 O1030 (COMMENT )
```

File number 21 is assigned to the next file name.
Batch input/output with a memory card

On the ALL IO screen, different types of data including part programs, parameters, offset data, pitch error data, custom macros, and workpiece coordinate system data can be input and output using a memory card; the screen for each type of data need not be displayed for input/output.

![Diagram of memory card to ALL IO screen]

**Procedure**

1. Press the EDIT switch on the machine operator’s panel.
2. Press function key **[SYSTEM]**.
3. Press the rightmost soft key (next–menu key) several times.
4. Press soft key **[ALL IO]**. The screen shown below is displayed.

```
READ/PUNCH (PROGRAM)     O0001 N00001
No.  FILE NAME  SIZE   DATE
*0001  O0222    332010  96–04–06
*0002  O1003    334450  96–05–04
*0003  MACROVAR.DAT  653400  96–05–12
*0004  O0002    341205  96–05–13
[PROGRAM]
*O0005  O0002  O0003  O0005  O0100  O0020
*O0006  O0004  O0110  O0200  O2200  O0441
*O0330
> EDIT  ...  .....  .....  10:07:37

[ PROG ] [ PARAM ] [ OFFSET ] [ ] (OPRT)
```

Upper part: Directory of files on the memory card
Lower part: Directory of registered programs

5. With cursor keys ↑ and ↓, the user can choose between upper part scrolling and lower part scrolling. (An asterisk (*) displayed at the left edge indicates the part for which scrolling is possible.)

   - ↑: Used for memory card file directory scrolling.
   - ↓: Used for program directory scrolling.

6. With page keys ↑ and ↓, scroll through the file directory or program directory.
Explanations

- **Each data item**

  When this screen is displayed, the program data item is selected. The soft keys for other screens are displayed by pressing the rightmost soft key (next-menu key).

  ![Soft keys](MACRO)(PITCH)(WORK)(OPRT)

  When a data item other than program is selected, the screen displays only a file directory.

  A data item is indicated, in parentheses, on the title line.

<table>
<thead>
<tr>
<th>READ/PUNCH (PARAMETER)</th>
<th>O0001 N00001</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td>FILE NAME</td>
</tr>
<tr>
<td>0001</td>
<td>O0222</td>
</tr>
<tr>
<td>0002</td>
<td>O1003</td>
</tr>
<tr>
<td>0003</td>
<td>MACROVAR.DAT</td>
</tr>
<tr>
<td>0004</td>
<td>O0003</td>
</tr>
<tr>
<td>0005</td>
<td>O0001</td>
</tr>
<tr>
<td>0006</td>
<td>O0002</td>
</tr>
<tr>
<td>0007</td>
<td>CNCPARAM.DAT</td>
</tr>
</tbody>
</table>

- **Program directory display**

  Program directory display does not match bit 0 (NAM) of parameter No. 3107, or bit 4 (SOR) of parameter No. 3107.

- **Using each function**

  Display the following soft keys with soft key [(OPRT)].

  ![Soft keys](F SRH)(F READ)(N READ)(PUNCH)(DELETE)

  The operation of each function is the same as on the directory (memory card) screen. Soft key [O SET], used for program number setting, and the "PROGRAM NUMBER =" indication are not displayed for data items other than program.

  - **[F SRH]**: Finds a specified file number.
  - **[F READ]**: Reads a specified file number.
  - **[PUNCH]**: Writes a file.
  - **[N READ]**: Reads a file under a specified file name.
  - **[DELETE]**: Deletes a specified file number.

**NOTE**

With a memory card, RMT mode operation and the subprogram call function (based on the M198 command) cannot be used.
File format and error messages

Format

All files that are read from and written to a memory card are of text format. The format is described below.

A file starts with % or LF, followed by the actual data. A file always ends with %. In a read operation, data between the first % and the next LF is skipped. Each block ends with an LF, not a semicolon (;).

- LF: 0A (hexadecimal) of ASCII code
- When a file containing lowercase letters, kana characters, and several special characters (such as $, \, and !) is read, those letters and characters are ignored.

Example:

```
% 
00001(MEMORY CARD SAMPLE FILE)
G17 G49 G97
G92 X–11.3 Y2.33
.
.
M30 
%
```

ASCII code is used for input/output, regardless of the setting parameter (ISO/EIA).

- Bit 3 of parameter No. 0100 can be used to specify whether the end of block code (EOB) is output as "LF" only, or as "LF, CR, CR."

Error messages

If an error occurs during memory card input/output, a corresponding error message is displayed.

```
~ 0028 O0003 7382 01–06–14 ~
M–CARD ERROR \ x x x 
FILE No. = 1 PROGRAM No. = 13
>_<
EDIT ***** ***** 15:40:21
(F SET) (O SET) (STOP) (CAN) (EXEC)
```

\ x x x x \ represents a memory card error code.
### Memory Card Error Codes

<table>
<thead>
<tr>
<th>Code</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>99</td>
<td>A part preceding the FAT area on the memory card is destroyed.</td>
</tr>
<tr>
<td>102</td>
<td>The memory card does not have sufficient free space.</td>
</tr>
<tr>
<td>105</td>
<td>No memory card is mounted.</td>
</tr>
<tr>
<td>106</td>
<td>A memory card is already mounted.</td>
</tr>
<tr>
<td>110</td>
<td>The specified directory cannot be found.</td>
</tr>
<tr>
<td>111</td>
<td>There are too many files under the root directory to allow a directory to be added.</td>
</tr>
<tr>
<td>114</td>
<td>The specified file cannot be found.</td>
</tr>
<tr>
<td>115</td>
<td>The specified file is protected.</td>
</tr>
<tr>
<td>117</td>
<td>The file has not yet been opened.</td>
</tr>
<tr>
<td>118</td>
<td>The file is already open.</td>
</tr>
<tr>
<td>119</td>
<td>The file is locked.</td>
</tr>
<tr>
<td>121</td>
<td>The memory card does not have sufficient free space.</td>
</tr>
<tr>
<td>122</td>
<td>The specified file name is invalid.</td>
</tr>
<tr>
<td>124</td>
<td>The extension of the specified file is invalid.</td>
</tr>
<tr>
<td>129</td>
<td>A non–corresponding function was specified.</td>
</tr>
<tr>
<td>130</td>
<td>The specification of a device is invalid.</td>
</tr>
<tr>
<td>131</td>
<td>The specification of a pathname is invalid.</td>
</tr>
<tr>
<td>133</td>
<td>Multiple files are open at the same time.</td>
</tr>
<tr>
<td>135</td>
<td>The device is not formatted.</td>
</tr>
<tr>
<td>140</td>
<td>The file has the read/write disabled attribute.</td>
</tr>
</tbody>
</table>
8.12
DATA INPUT/OUTPUT
BY EMBEDDED
ETHERNET

8.12.1
FTP File Transfer
Function

8.12.1.1
Host file list display

Procedure

1. Press the function key \texttt{PROG}.

2. Press the continuous menu key at the right end of the soft key display.

3. Press the [HOST] soft key. The host file list screen appears. The Ethernet functions currently available are displayed.

4. When you press the [EMBEDD] soft key, a list of the files held on the host computer specified with the embedded Ethernet port is displayed.

The operation of the FTP file transfer function is described below.

A list of the files held on the hard disk embedded to the host computer is displayed.

The upper row displays the usable embedded Ethernet function device. The embedded port or PCMCIA card is displayed.
The lower row displays the usable Ethernet option boards. When no option board is installed, no information is displayed.
NOTE
Depending on the FTP server software, the number of displayed programs may differ between the host file list screen above and the host file list (detail) screen described below.

5 When a list of files is larger than one page, the screen display can be switched using the page keys \[ \text{PAGE} \quad \text{PAGE} \].

6 Press the [UPDATE] soft key to update the screen display.

7 Press the [SWITCH] soft key. The host file list (detail) screen appears.
NOTE

The host file list (detail) screen shown above is an example of screen display, and information displayed may vary according to the specification of the FTP server used with the host computer.

Display items

- **Number of registered program files**
  The number of files registered in the directory (folder) of the host computer currently connected is displayed.

- **Currently connected host**
  The number of the host currently connected is displayed.

List of operations

- **SWITCH**
  This operation switches between normal display and detail display.

- **UPDATE**
  This operation updates information displayed.

- **STOP**
  This operation stops [SEARCH] operation.

- **SEARCH**
  This operation updates screen information so that a file specified by its file number is placed at the start of the list.

- **DELETE**
  This operation deletes a file held on the hard disk embedded to the host computer.

- **READ**
  This operation reads a file held on the hard disk embedded to the host computer to the CNC part program storage. This soft key is displayed only when 9 is set as the input/output device number of the CNC, and the CNC is placed in the EDIT mode.
This operation outputs a file held in the CNC part program storage to the hard disk embedded to the host computer. This soft key is displayed only when 9 is set as the input/output device number of the CNC, and the CNC is placed in the EDIT mode.

8.12.1.2 Host file search

When a list of the files held on the hard disk embedded to the host computer is displayed, a file can be placed at the start of the list by specifying its file number.

Procedure

1. Display the host file list screen.
2. Press the [SEARCH] soft key.
3. Type the file number of a file to be displayed at the start of the list with the MDI keys.
   [Input format]
   `<file–number>`
4. Press the [EXEC] soft key.
5. During search, “SEARCH” blinks in the lower–right corner of the screen.

8.12.1.3 Host file deletion

A file held on the hard disk embedded to the host computer can be deleted.

Procedure

1. Display the host file list screen.
2. Press the [DELETE] soft key.
3. Type the file number or file name of a file to be deleted, with the MDI keys.
   [Input format]
   `<file–number>`
   or
   `<file–name>`
4. Press the [EXEC] soft key.
5. During deletion, “DELETE” blinks in the lower–right corner of the screen.

NOTE

1. When a file number is used for deletion, only a file displayed on the host file list screen can be deleted.
2. The information displayed at the right end of the host file list (detail) screen is recognized as a file name. So, when deleting a host file from the host file list (detail) screen by specifying its file number, check that a file name is displayed at the right end of the screen, before specifying the file number.
8.12.1.4  
NC program input

A file (NC program) on the host computer can be read to the CNC memory.

For the host file list screen

**Procedure**

1. Place the CNC in the EDIT mode.
2. Display the host file list screen.
3. Press the [READ] soft key.
4. Type the file number or file name of an NC program to be input, with the MDI keys.
   
   **[Input format]**
   
   `<file–number>`
   
   or
   
   `<file–name>`

5. Press the [EXEC] soft key.
6. During input, “INPUT” blinks in the lower-right corner of the screen.

**CAUTION**

1. If the CNC memory holds an NC program that has the same O number as that of an NC program to be input, the NC program in the CNC memory is overwritten when bit 2 of parameter No. 3201 is set to 1.
2. If an NC program is input when bit 0 of parameter No. 3201 is set to 1, all NC programs in the CNC memory are automatically deleted before NC program input.

**[Example of use]**

When a file with the file name O0001.DAT held on the hard disk embedded to the host computer is to be input to the CNC memory, enter O001.DAT. Note, however, that the O number input to the CNC memory depends on the O number described in the file named O0001.DAT.

**NOTE**

When a file is input from this screen to the CNC memory, the O number described in the file is input.
For the program screen

Procedure

1. Place the CNC in the EDIT mode.
2. Press the function key [PROG].
3. Press the continuous menu key at the right end of the soft key display.
4. Press the [PRGRM] soft key. The program screen appears.
5. Press the [(OPRT)] soft key.
6. Press the continuous menu key at the right end of the soft key display.
7. Press the [READ] soft key.
8. Type the O number of an NC program to be input, with the MDI keys.
   [Input format]
   \(<O\text{-number}>\)
10. During input, “INPUT” blinks in the lower-right corner of the screen.

CAUTION

1. If the CNC memory holds an NC program that has the same O number as that of an NC program to be input, the NC program in the CNC memory is overwritten when bit 2 of parameter No. 3201 is set to 1.
2. If an NC program is input when bit 0 of parameter No. 3201 is set to 1, all NC programs in the CNC memory are automatically deleted before NC program input.

NOTE

The valid O number of a file to be input to the CNC memory is Oxxxx (with xxxx representing a number) only.
8.12.1.5 NC program output

A file (NC program) in the CNC memory can be output to the host computer.

For the host file list screen

Procedure

1. Place the CNC in the EDIT mode.
2. Display the host file list screen.
3. Press the [PUNCH] soft key.
4. Type the O number of an NC program to be output, with the MDI keys.
   [Input format]  
   <O-number>
5. Press the [EXEC] soft key.

[Example of use]
When an NC program (O0001) in the CNC memory is to be output to the hard disk embedded to the host computer, enter O0001.

NOTE
An outputted file name is Oxxxx.

For the program screen

Procedure

1. Place the CNC in the EDIT mode.
2. Press the function key [PRG].
3. Press the continuous menu key at the right end of the soft key display.
4. Press the [PRGRM] soft key. The program screen appears.
5. Press the [(OPRT)] soft key.
6. Press the continuous menu key at the right end of the soft key display.
7. Press the [PUNCH] soft key.
8. Type the O number of an NC program to be output, with the MDI keys.
   [Input format]  
   <O-number>
9 Press the [EXEC] soft key.

10 During output, “OUTPUT” blinks in the lower-right corner of the screen.

**NOTE**
An outputted file name is Oxxxx.

### 8.12.1.6 Input/output of various types of data

With the FTP file transfer function, the types of data listed below can be input/output. This subsection describes the input/output method.

- A) NC parameter
- B) Tool offset value
- C) Custom macro variable
- D) Workpiece origin offset value
- E) Pitch error compensation data
- F) M code group
- G) Operation history data

### Parameter input

The file (NC parameter) on the host computer can be input to the CNC memory.

**Procedure**

1 Place the CNC in the EDIT mode.

2 Press the function key `SYSTEM`.

3 Press the continuous menu key at the right end of the soft key display.

4 Press the [PARAM] soft key. The parameter screen appears.

5 Press the [(OPRT)] soft key.

6 Press the continuous menu key at the right end of the soft key display.

7 Press the [READ] soft key.

8 Press the [EXEC] soft key.

9 During input, “INPUT” blinks in the lower-right corner of the screen.

**File name**
The fixed file name PRAMETER is used.

**File format, restrictions**
Refer to the operator’s manual of each CNC.
Parameter output

The file (NC parameter) in the CNC memory can be output to the host computer.

Procedure

1. Place the CNC in the EDIT mode.
2. Press the function key [SYSTEM].
3. Press the continuous menu key at the right end of the soft key display.
5. Press the [(OPRT)] soft key.
6. Press the continuous menu key at the right end of the soft key display.
7. Press the [PUNCH] soft key.
8. Press the [EXEC] soft key.

File name

The fixed file name PRAMETER is used.

File format, restrictions

Refer to the operator’s manual of each CNC.

Tool offset value input

The file (tool offset value) on the host computer can be input to the CNC memory.

Procedure

1. Place the CNC in the EDIT mode.
2. Press the function key [OFFSET SETTING].
3. Press the continuous menu key at the right end of the soft key display.
5. Press the [(OPRT)] soft key.
6. Press the continuous menu key at the right end of the soft key display.
7. Press the [READ] soft key.
8. Press the [EXEC] soft key.

File name

The fixed file name TOOLOFS is used.

File format, restrictions

Refer to the operator’s manual of each CNC.
Tool offset value output

The file (tool offset value) in the CNC memory can be output to the host computer.

Procedure

1. Place the CNC in the EDIT mode.
2. Press the function key OFFSET SETTING.
3. Press the continuous menu key at the right end of the soft key display.
5. Press the [(OPRT)] soft key.
6. Press the continuous menu key at the right end of the soft key display.
7. Press the [PUNCH] soft key.
8. Press the [EXEC] soft key.

File name
The fixed file name TOOLOFS is used.

File format, restrictions
Refer to the operator’s manual of each CNC.

Workpiece origin offset value input

The file (workpiece origin offset value) on the host computer can be input to the CNC memory.

Procedure

1. Place the CNC in the EDIT mode.
2. Press the function key OFFSET SETTING.
3. Press the continuous menu key at the right end of the soft key display.
4. Press the [WORK] soft key. The workpiece coordinate system setting screen appears.
5. Press the [(OPRT)] soft key.
6. Press the continuous menu key at the right end of the soft key display.
7. Press the [READ] soft key.
8. Press the [EXEC] soft key.

File name
The fixed file name WORKOFS is used.

File format, restrictions
Refer to the operator’s manual of each CNC.
Workpiece origin offset value output

The file (workpiece origin offset value) in the CNC memory can be output to the host computer.

**Procedure**

1. Place the CNC in the EDIT mode.
2. Press the function key `OFFSET SETTING`.
3. Press the continuous menu key at the right end of the soft key display.
4. Press the [WROK] soft key. The workpiece coordinate system setting screen appears.
5. Press the [(OPRT)] soft key.
6. Press the continuous menu key at the right end of the soft key display.
7. Press the [PUNCH] soft key.
8. Press the [EXEC] soft key.

**File name**
The fixed file name WORKOFS is used.

**File format, restrictions**
Refer to the operator’s manual of each CNC.

Pitch error compensation input

The file (pitch error compensation) on the host computer can be input to the CNC memory.

**Procedure**

1. Place the CNC in the EDIT mode.
2. Press the function key `SYSTEM`.
3. Press the continuous menu key at the right end of the soft key display.
4. Press the [PITCH] soft key. The pitch error setting screen appears.
5. Press the [(OPRT)] soft key.
6. Press the continuous menu key at the right end of the soft key display.
7. Press the [READ] soft key.
8. Press the [EXEC] soft key.

**File name**
The fixed file name PITCH is used.

**File format, restrictions**
Refer to the operator’s manual of each CNC.
Pitch error compensation output

The file (pitch error compensation) in the CNC memory can be output to the host computer.

**Procedure**

1. Place the CNC in the EDIT mode.
2. Press the function key **SYSTEM**.
3. Press the continuous menu key at the right end of the soft key display.
4. Press the [PITCH] soft key. The pitch error setting screen appears.
5. Press the [(OPRT)] soft key.
6. Press the continuous menu key at the right end of the soft key display.
7. Press the [PUNCH] soft key.
8. Press the [EXEC] soft key.

**File name**
The fixed file name PITCH is used.

**File format, restrictions**
Refer to the operator’s manual of each CNC.

M code group input

The file (M code group) on the host computer can be input to the CNC memory.

**Procedure**

1. Place the CNC in the EDIT mode.
2. Press the function key **SYSTEM**.
3. Press the continuous menu key at the right end of the soft key display.
5. Press the [(OPRT)] soft key.
6. Press the continuous menu key at the right end of the soft key display.
7. Press the [READ] soft key.
8. Press the [EXEC] soft key.

**File name**
The fixed file name M–CODE is used.

**File format, restrictions**
Refer to the operator’s manual of each CNC.
M code group output

The file (M code group) in the CNC memory can be output to the host computer.

Procedure

1. Place the CNC in the EDIT mode.
2. Press the function key `SYSTEM`.
3. Press the continuous menu key at the right end of the soft key display.
5. Press the [(OPRT)] soft key.
6. Press the continuous menu key at the right end of the soft key display.
7. Press the [PUNCH] soft key.
8. Press the [EXEC] soft key.

File name

The fixed file name M–CODE is used.

File format, restrictions

Refer to the operator’s manual of each CNC.

Operation history data input

The file (operation history data) on the host computer can be input to the CNC memory.

Procedure

1. Place the CNC in the EDIT mode.
2. Press the function key `SYSTEM`.
3. Press the continuous menu key at the right end of the soft key display.
4. Press the [OPEHIS] soft key. The operation history screen appears.
5. Press the [(OPRT)] soft key.
6. Press the continuous menu key at the right end of the soft key display.
7. Press the [READ] soft key.
8. Press the [EXEC] soft key.

File name

The fixed file name HISTORY is used.

File format, restrictions

Refer to the operator’s manual of each CNC.
**Operation history data output**

The file (operation history data) in the CNC memory can be output to the host computer.

**Procedure**

1. Place the CNC in the EDIT mode.
2. Press the function key \( \text{SYSTEM} \).
3. Press the continuous menu key at the right end of the soft key display.
4. Press the \([\text{OPEHIS}]\) soft key. The operation history screen appears.
5. Press the \([\text{OPRT}]\) soft key.
6. Press the continuous menu key at the right end of the soft key display.
7. Press the \([\text{PUNCH}]\) soft key.
8. Press the \([\text{EXEC}]\) soft key.

**File name**
The fixed file name HISTORY is used.

**File format, restrictions**
Refer to the operator’s manual of each CNC.

---

8.12.1.7 **Checking and changing of the connection host**

The host computer to which the FTP file transfer function attempts to make a connection as the current communication destination can be checked.

**Procedure**

1. Press the function key \( \text{PROG} \).
2. Press the continuous menu key at the right end of the soft key display.
3. Press the \([\text{CONECT}]\) soft key. The connection host change screen appears. The Ethernet functions currently available are displayed.
The upper row displays the usable embedded Ethernet function device. The embedded port or PCMCIA card is displayed. The lower row displays the usable Ethernet option boards. When no option board is installed, no information is displayed.

4 When you press the [EMBEDD] soft key, a list of the connection host computers specified with the embedded Ethernet port is displayed. If the usable embedded Ethernet function device is the PCMCIA card, the [PCMCIA] soft key is displayed instead of the [EMBEDD] soft key. When you press the [PCMCIA] soft key, a list of the connection host computers specified with the PCMCIA Ethernet card is displayed.
The title of the host computer that is the current communication destination of the data server board is displayed in reverse video.

The connected host can be changed by pressing the [CON–1], [CON–2], or [CON–3] soft key.

Display items

- **Port number, IP address, user name, login DIR**
  Those values that are set on the Ethernet parameter setting screen are displayed.

List of operations

- **CON–1**
  This operation changes the connected host to host 1.
- **CON–2**
  This operation changes the connected host to host 2.
- **CON–3**
  This operation changes the connected host to host 3.
This chapter describes how to edit programs registered in the CNC. Editing includes the insertion, modification, deletion, and replacement of words. Editing also includes deletion of the entire program and automatic insertion of sequence numbers. The extended part program editing function can copy, move, and merge programs. This chapter also describes program number search, sequence number search, word search, and address search, which are performed before editing the program.

1) Program number search: See III–9.3.
2) Sequence number search: See III–9.4.
4) Address search: See III–9.1.1.
5) Inserting, altering, and deleting a word: See III–9.1.3 to 9.1.5.
6) Replacing words and addresses: See III–9.6.6.
8) Copying, moving, and merging programs: See III–9.6.1 and 9.6.5.
9) Deleting programs: See III–9.5.
This section outlines the procedure for inserting, modifying, and deleting a word in a program registered in memory.

9.1 INSERTING, ALTERING AND DELETING A WORD

Procedure for inserting, altering and deleting a word

1. Select **EDIT** mode.

2. Press **PROG**.

3. Select a program to be edited.
   - If a program to be edited is selected, perform the operation 4.
   - If a program to be edited is not selected, search for the program number.

4. Search for a word to be modified.
   - Scan method
   - Word search method

5. Perform an operation such as altering, inserting, or deleting a word.

Explanation

- **Concept of word and editing unit**

A word is an address followed by a number. With a custom macro, the concept of word is ambiguous.
So the editing unit is considered here.
The editing unit is a unit subject to alteration or deletion in one operation.
In one scan operation, the cursor indicates the start of an editing unit.
An insertion is made after an editing unit.
Definition of editing unit

(i) Program portion from an address to immediately before the next address

(ii) An address is an alphabet, **IF**, **WHILE**, **GOTO**, **END**, **DO**=, or **;** (EOB).
According to this definition, a word is an editing unit.

The word “word,” when used in the description of editing, means an editing unit according to the precise definition.

**WARNING**

The user cannot continue program execution after altering, inserting, or deleting data of the program by suspending machining in progress by means of an operation such as a single block stop or feed hold operation during program execution. If such a modification is made, the program may not be executed exactly according to the contents of the program displayed on the screen after machining is resumed. So, when the contents of memory are to be modified by part program editing, be sure to enter the reset state or reset the system upon completion of editing before executing the program.
9.1.1 Word Search

A word can be searched for by merely moving the cursor through the text (scanning), by word search, or by address search.

 Procedure for scanning a program

1. Press the cursor key \(\rightarrow\).  
The cursor moves forward word by word on the screen; the cursor is displayed at a selected word.

2. Press the cursor key \(\leftarrow\).  
The cursor moves backward word by word on the screen; the cursor is displayed at a selected word.

Example) When Z1250.0 is scanned

```
Program
O0050 ;
N01234 X100.0 Z1250.0 ;
S12 ;
N56789 M03 ;
M02 ;
%                  
```

3. Holding down the cursor key \(\rightarrow\) or \(\leftarrow\) scans words continuously.

4. The first word of the next block is searched for when the cursor key \(\downarrow\) is pressed.

5. The first word of the previous block is searched for when the cursor key \(\uparrow\) is pressed.

6. Holding down the cursor key \(\downarrow\) or \(\uparrow\) moves the cursor to the head of a block continuously.

7. Pressing the page key \(\downarrow\) displays the next page and searches for the first word of the page.

8. Pressing the page key \(\uparrow\) displays the previous page and searches for the first word of the page.

9. Holding down the page key \(\downarrow\) or \(\uparrow\) displays one page after another.
Procedure for searching a word

Example) of Searching for S12

Procedure for searching an address

Example) of Searching for M03

Alarm

<table>
<thead>
<tr>
<th>Alarm number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>71</td>
<td>The word or address being searched for was not found.</td>
</tr>
</tbody>
</table>
9.1.2 Heading a Program

The cursor can be jumped to the top of a program. This function is called heading the program pointer. This section describes the three methods for heading the program pointer.

Procedure for Heading a Program

Method 1
1. Press \textit{RESET} when the program screen is selected in EDIT mode. When the cursor has returned to the start of the program, the contents of the program are displayed from its start on the screen.

Method 2
Search for the program number.
1. Press address \texttt{O}, when a program screen is selected in the \texttt{MEMORY} or \texttt{EDIT} mode.
2. Input a program number.
3. Press the soft key [O SRH].

Method 3
2. Press \texttt{PROG}.
3. Press the [(OPRT)] key.
9.1.3 Inserting a Word

Procedure for inserting a word

1. Search for or scan the word immediately before a word to be inserted.
2. Key in an address to be inserted.
3. Key in data.
4. Press the \texttt{INSERT} key.

Example of Inserting T15

Procedure

1. Search for or scan Z1250.

```
Program
O0050 ;
N01234 X100.0 Z1250.0 ;
S12 ;
N56789 M03 ;
M02 ;
%
```

2. Key in \begin{array}{c}
T \end{array} 15 .

3. Press the \texttt{INSERT} key.

```
Program
O0050 ;
N01234 X100.0 Z1250.0 15 ;
S12 ;
N56789 M03 ;
M02 ;
%
```

Z1250.0 is searched for/ scanned.
T15 is inserted.
9.1.4 Altering a Word

Procedure for altering a word

1. Search for or scan a word to be altered.
2. Key in an address to be inserted.
3. Key in data.
4. Press the \textit{ALTER} key.

Example of changing T15 to M15

Procedure

1. Search for or scan T15.

\begin{verbatim}
Program O0050 N01234
0050 ;
N01234 X100.0 Z1250.0 \textbf{T15} ;
S12 ;
N56789 M03 ;
M02 ;
%
\end{verbatim}

2. Key in \textbf{M15}.

3. Press the \textit{ALTER} key.

\begin{verbatim}
Program O0050 N01234
0050 ;
N1234 X100.0 Z1250.0 \textbf{M15} ;
S12 ;
N5678 M03 ;
M02 ;
%
\end{verbatim}
9.1.5 Deleting a Word

Procedure for deleting a word

1. Search for or scan a word to be deleted.
2. Press the DELETE key.

Example of deleting X100.0

Procedure

1. Search for or scan X100.0.

```
Program: O0050
O050 ;
N01234  X100.0  Z1250.0  M15 ;
S12 ;
N56789  M03 ;
M02 ;
%
```

X100.0 is searched for/scanned.

2. Press the DELETE key.

```
Program: O0050
O050 ;
N01234  Z1250.0  M15 ;
S12 ;
N56789  M03 ;
M02 ;
%
```

X100.0 is deleted.
9.2 DELETING BLOCKS

A block or blocks can be deleted in a program.

9.2.1 Deleting a Block

The procedure below deletes a block up to its EOB code; the cursor advances to the address of the next word.

Procedure for deleting a block

1. Search for or scan address N for a block to be deleted.
2. Key in EOB.
3. Press the DELETE key.

Example of deleting a block of N01234

Procedure

1. Search for or scan N01234.

   Program
   O0050 N01234
   Z1250.0 M15 ;
   S12 ;
   N56789 M03 ;
   M02 ;
   %

   N01234 is searched for/scanned.

2. Key in EOB.

3. Press the DELETE key.

   Program
   O0050 N01234
   S12 ;
   N56789 M03 ;
   M02 ;
   %

   Block containing N01234 has been deleted.
The blocks from the currently displayed word to the block with a specified sequence number can be deleted.

### Procedure for deleting multiple blocks

1. Search for or scan a word in the first block of a portion to be deleted.
2. Key in address \( N \).
3. Key in the sequence number for the last block of the portion to be deleted.
4. Press the DELETE key.

#### Example of deleting blocks from a block containing N01234 to a block containing N56789

### Procedure

1. Search for or scan N01234.

   ![Program O0050 N01234](image)

   Program:
   
   ```
   O0050 ;
   N01234 Z1250.0 M15 ;
   S12 ;
   N56789 M03 ;
   M02 ;
   %
   ```

   N01234 is searched for/scanned.

2. Key in \( \boxed{N\ 5\ 6\ 7\ 8\ 9} \).

   ![Program O0050 N01234](image)

   Program:
   
   ```
   O0050 ;
   N01234 Z1250.0 M15 ;
   S12 ;
   N56789 M03 ;
   M02 ;
   %
   ```

   Underlined part is deleted.

3. Press the DELETE key.

   ![Program O0050 N01234](image)

   Program:
   
   ```
   O0050 ;
   M02 ;
   %
   ```

   Blocks from block containing N01234 to block containing N56789 have been deleted.
9.3 PROGRAM NUMBER SEARCH

When memory holds multiple programs, a program can be searched for. There are three methods as follows.

**Procedure for program number search**

<table>
<thead>
<tr>
<th>Method 1</th>
<th>1 Select EDIT or MEMORY mode.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2 Press [PROG] to display the program screen.</td>
</tr>
<tr>
<td></td>
<td>3 Key in address [O].</td>
</tr>
<tr>
<td></td>
<td>4 Key in a program number to be searched for.</td>
</tr>
<tr>
<td></td>
<td>5 Press the [O SRH] key.</td>
</tr>
<tr>
<td></td>
<td>6 Upon completion of search operation, the program number searched for is displayed in the upper-right corner of the CRT screen. If the program is not found, P/S alarm No. 71 occurs.</td>
</tr>
</tbody>
</table>

**Method 2**

1 Select EDIT or MEMORY mode.

2 Press [PROG] to display the program screen.

3 Press the [O SRH] key. In this case, the next program in the directory is searched for.

This method searches for the program number (0001 to 0015) corresponding to a signal on the machine tool side to start automatic operation. Refer to the relevant manual prepared by the machine tool builder for detailed information on operation.

**Method 3**

1 Select MEMORY mode.

2 Set the reset state(*1)

   - The reset state is the state where the LED for indicating that automatic operation is in progress is off. (Refer to the relevant manual of the machine tool builder.)

3 Set the program number selection signal on the machine tool side to a number from 01 to 15.

   - If the program corresponding to a signal on the machine tool side is not registered, P/S alarm (No. 059) is raised.

4 Press the cycle start button.

   - When the signal on the machine tool side represents 00, program number search operation is not performed.

**Alarm**

<table>
<thead>
<tr>
<th>No.</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>59</td>
<td>The program with the selected number cannot be searched during external program number search.</td>
</tr>
<tr>
<td>71</td>
<td>The specified program number was not found during program number search.</td>
</tr>
</tbody>
</table>
9.4 Sequence number search

Sequence number search operation is usually used to search for a sequence number in the middle of a program so that execution can be started or restarted at the block of the sequence number.

Example) Sequence number 02346 in a program (O0002) is searched for.

<table>
<thead>
<tr>
<th>Program</th>
<th>Target sequence number is found.</th>
</tr>
</thead>
<tbody>
<tr>
<td>O0001 ; N01234 X100.0 Z100.0 ; S12 ;</td>
<td></td>
</tr>
<tr>
<td>O0002 ; N02345 X20.0 Z20.0 ; N02346 X10.0 Y10.0 ; O0003 ;</td>
<td>This section is searched starting at the beginning. (Search operation is performed only within a program.)</td>
</tr>
</tbody>
</table>

Procedure for sequence number search

1. Select MEMORY mode.
2. Press [PROG].
3. If the program contains a sequence number to be searched for, perform the operations 4 to 7 below.
   - If the program does not contain a sequence number to be searched for, select the program number of the program that contains the sequence number to be searched for.
4. Key in address [N].
5. Key in a sequence number to be searched for.
7. Upon completion of search operation, the sequence number searched for is displayed in the upper–right corner of the CRT screen. If the specified sequence number is not found in the program currently selected, P/S alarm No. 060 occurs.
Explanations

• Operation during Search

Those blocks that are skipped do not affect the CNC. This means that the data in the skipped blocks such as coordinates and M, S, and T codes does not alter the CNC coordinates and modal values.
So, in the first block where execution is to be started or restarted by using a sequence number search command, be sure to enter required M, S, and T codes and coordinates. A block searched for by sequence number search usually represents a point of shifting from one process to another. When a block in the middle of a process must be searched for to restart execution at the block, specify M, S, and T codes, G codes, coordinates, and so forth as required from the MDI after closely checking the machine tool and NC states at that point.

• Checking during search

During search operation, the following checks are made:
  · Optional block skip
  · P/S alarm (No. 003 to 010)

Limitations

• Searching in sub–program

During sequence number search operation, M98Pxxxx (subprogram call) is not executed. So a P/S alarm (No.060) is raised if an attempt is made to search for a sequence number in a subprogram called by the program currently selected.

```
Main program Subprogram
O1234       O5678
N88888
M98 P5678 ;
M99 ;
```

If an attempt is made to search for N8888 in the example above, an alarm is raised.

Alarm

<table>
<thead>
<tr>
<th>Number</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>Command sequence number was not found in the sequence number search.</td>
</tr>
</tbody>
</table>
9.5 DELETING PROGRAMS

Programs registered in memory can be deleted, either one program by one program or all at once. Also, More than one program can be deleted by specifying a range.

9.5.1 Deleting One Program

A program registered in memory can be deleted.

Procedure for deleting one program

1. Select the EDIT mode.
2. Press PROG to display the program screen.
3. Key in address 0.
4. Key in a desired program number.
5. Press the DELETE key.
   The program with the entered program number is deleted.

9.5.2 Deleting All Programs

All programs registered in memory can be deleted.

Procedure for deleting all programs

1. Select the EDIT mode.
2. Press PROG to display the program screen.
3. Key in address 0.
5. Press edit key DELETE to delete all programs.
9.5.3 Deleting More than One Program by Specifying a Range

Programs within a specified range in memory are deleted.

Procedure for deleting more than one program by specifying a range

1. Select the EDIT mode.
2. Press \text{PROG} to display the program screen.
3. Enter the range of program numbers to be deleted with address and numeric keys in the following format: OXXXX,OYYYY
   where XXXX is the starting number of the programs to be deleted and YYYY is the ending number of the programs to be deleted.
4. Press edit key \text{DELETE} to delete programs No. XXXX to No. YYYY.
9.6 EXTENDED PART PROGRAM EDITING FUNCTION

With the extended part program editing function, the operations described below can be performed using soft keys for programs that have been registered in memory.

Following editing operations are available:

- All or part of a program can be copied or moved to another program.
- One program can be merged at free position into other programs.
- A specified word or address in a program can be replaced with another word or address.
A new program can be created by copying a program.

**Fig. 9.6.1 Copying an Entire Program**

In Fig. 9.6.1, the program with program number xxxx is copied to a newly created program with program number yyyy. The program created by copy operation is the same as the original program except the program number.

**Procedure of copying an entire program**

1. Enter the **EDIT** mode.

2. Press function key **PROG**.

3. Press soft key **[OPRT]**.

4. Press the continuous menu key.

5. Press soft key **[EX–EDT]**.

6. Check that the screen for the program to be copied is selected and press soft key **[COPY]**.

7. Press soft key **[ALL]**.

8. Enter the number of the new program (with only numeric keys) and press the **INPUT** key.

9. Press soft key **[EXEC]**.
9.6.2 Copying Part of a Program

A new program can be created by copying part of a program.

In Fig. 9.6.2, part B of the program with program number xxxx is copied to a newly created program with program number yyyy. The program for which an editing range is specified remains unchanged after copy operation.

Procedure for copying part of a program

1. Perform steps 1 to 6 in III-9.6.1.

2. Move the cursor to the start of the range to be copied and press soft key [CRSR~].

3. Move the cursor to the end of the range to be copied and press soft key [-CRSR] or [-BTTM] (in the latter case, the range to the end of the program is copied regardless of the position of the cursor).

4. Enter the number of the new program (with only numeric keys) and press the INPUT key.

5. Press soft key [EXEC].
9.6.3 Moving Part of a Program

A new program can be created by moving part of a program.

In Fig. 9.6.3, part B of the program with program number xxxx is moved to a newly created program with program number yyyy; part B is deleted from the program with program number xxxx.

Procedure for moving part of a program

1. Perform steps 1 to 5 in III–9.6.1.

2. Check that the screen for the program to be moved is selected and press soft key [MOVE].

3. Move the cursor to the start of the range to be moved and press soft key [CRSR~].

4. Move the cursor to the end of the range to be moved and press soft key [~CRSR] or [~BTM] (in the latter case, the range to the end of the program is copied regardless of the position of the cursor).

5. Enter the number of the new program (with only numeric keys) and press the [INPUT] key.

6. Press soft key [EXEC].
9.6.4 Merging a Program

Another program can be inserted at an arbitrary position in the current program.

In Fig. 9.6.4, the program with program number XXXX is merged with the program with program number YYYY. The OYYYY program remains unchanged after merge operation.

Procedure for merging a program

1. Perform steps 1 to 5 in III-9.6.1.
2. Check that the screen for the program to be edited is selected and press soft key [MERGE].
3. Move the cursor to the position at which another program is to be inserted and press soft key [\textasciitilde CRSR] or [\textasciitilde BTTM] (in the latter case, the end of the current program is displayed).
4. Enter the number of the program to be inserted (with only numeric keys) and press the [INPUT] key.
5. Press soft key [EXEC].

The program with the number specified in step 4 is inserted before the cursor positioned in step 3.
9.6.5 Supplementary Explanation for Copying, Moving and Merging

Explanations

- Setting an editing range
  The setting of an editing range start point with [CRSR~] can be changed freely until an editing range end point is set with [~CRSR] or [~BTTM]. If an editing range start point is set after an editing range end point, the editing range must be reset starting with a start point.
  The setting of an editing range start point and end point remains valid until an operation is performed to invalidate the setting.
  One of the following operations invalidates a setting:
  - An edit operation other than address search, word search/scan, and search for the start of a program is performed after a start point or end point is set.
  - Processing is returned to operation selection after a start point or end point is set.

- Without specifying a program number
  In copying program and moving program, if [EXEC] is pressed without specifying a program number after an editing range end point is set, a program with program number O0000 is registered as a work program.
  This O0000 program has the following features:
  - The program can be edited in the same way as a general program.
    (Do not run the program.)
  - If a copy or move operation is newly performed, the previous information is deleted at execution time, and newly set information (all or part of the program) is reregistered. (In merge operation, the previous information is not deleted.) However, the program, when selected for foreground operation, cannot be reregistered in the background. (A BP/S alarm No. 140 is raised.) When the program is reregistered, a free area is produced. Delete such a free area with the \[RESET\] key.
  - When the program becomes unnecessary, delete the program by a normal editing operation.

- Editing when the system waiting for a program number to be entered
  When the system is waiting for a program number to be entered, no edit operation can be performed.

Limitations

- Number of digits for program number
  If a program number is specified by 5 or more digits, a format error is generated.
Alarm

<table>
<thead>
<tr>
<th>Alarm no.</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>70</td>
<td>Memory became insufficient while copying or inserting a program. Copy or insertion is terminated.</td>
</tr>
<tr>
<td>101</td>
<td>The power was interrupted during copying, moving, or inserting a program and memory used for editing must be cleared. When this alarm occurs, press the key [\text{ RES}] while pressing function key [\text{ PROG }]. Only the program being edited is deleted.</td>
</tr>
</tbody>
</table>
9.6.6 Replacement of Words and Addresses

Replace one or more specified words. Replacement can be applied to all occurrences or just one occurrence of specified words or addresses in the program.

Procedure for change of words or addresses

1. Perform steps 1 to 5 in III–9.6.1.

2. Press soft key [CHANGE].

3. Enter the word or address to be replaced.

4. Press soft key [BEFORE].

5. Enter the new word or address.

6. Press soft key [AFTER].

7. Press soft key [EXEC] to replace all the specified words or addresses after the cursor. Press soft key [1–EXEC] to search for and replace the first occurrence of the specified word or address after the cursor. Press soft key [SKIP] to only search for the first occurrence of the specified word or address after the cursor.

Examples

- Replace X100 with Y200
  
  [CHANGE] X 1 0 0 [BEFORE] Y 2 0 0 [AFTER][EXEC]

- Replace X100Y200 with X30
  
  [CHANGE] X 1 0 0 Y 2 0 0 [BEFORE] X 3 0 [AFTER][EXEC]

- Replace IF with WHILE
  
  [CHANGE] I [BEFORE] W H I L E [AFTER][EXEC]

- Replace X with ,C10
  
  [CHANGE] X [BEFORE] , C 1 0 [AFTER][EXEC]
The following custom macro words are replaceable:
IF, WHILE, GOTO, END, DO, BPRNT, DPRINT, POPEN, PCLOS
The abbreviations of custom macro words can be specified.
When abbreviations are used, however, the screen displays the abbreviations as they are key input, even after soft key [BEFORE] and [AFTER] are pressed.

Up to 15 characters can be specified for words before or after replacement.
(Sixteen or more characters cannot be specified.)

Words before or after replacement must start with a character representing an address.(A format error occurs.)
9.7 EDITING OF CUSTOM MACROS

Unlike ordinary programs, custom macro programs are modified, inserted, or deleted based on editing units. Custom macro words can be entered in abbreviated form. Comments can be entered in a program. Refer to the III–10.1 for the comments of a program.

Explanations

• Editing unit

When editing a custom macro already entered, the user can move the cursor to each editing unit that starts with any of the following characters and symbols:

(a) Address
(b) # located at the start of the left side of a substitution statement
(c) /, (, =, and ;
(d) First character of IF, WHILE, GOTO, END, DO, POP Bryant, DPRNT, DPRNT, and PCLOS

On the screen, a blank is placed before each of the above characters and symbols.

(Example) Head positions where the cursor is placed

\[ \begin{align*}
N001 & \ X \ - \ #100; \\
N002 & \ /2 \ X \ [12/#3]; \\
N003 & \ X \ - \ SQRT[#3/3; [4+1]]; \\
N004 & \ X \ - \ #2 \ Z[1; \\
N005 & \ #5 \ = \ 1+2-#10; \\
IF[\#1NE0] & \ GOTO10; \\
WHILE[\#2LE5] & \ DO1; \\
#2 & \ = \ #2+1; \\
END \ & \\
\end{align*} \]

• Abbreviations of custom macro word

When a custom macro word is altered or inserted, the first two characters or more can replace the entire word.

Namely,

\[ \begin{align*}
WHILE & \rightarrow WH \quad GOTO & \rightarrow GO \quad XOR & \rightarrow XO \quad AND & \rightarrow AN \\
SIN & \rightarrow SI \quad ASIN & \rightarrow AS \quad COS & \rightarrow CO \quad ACOS & \rightarrow AC \\
TAN & \rightarrow TA \quad ATAN & \rightarrow AT \quad SQRT & \rightarrow SQ \quad ABS & \rightarrow AB \\
BCD & \rightarrow BC \quad BIN & \rightarrow BI \quad FIX & \rightarrow FI \quad FUP & \rightarrow FU \\
ROUN D & \rightarrow RO \quad END & \rightarrow EN \quad EXP & \rightarrow EX \quad THEN & \rightarrow TH \\
PO PEN & \rightarrow PO \quad BPRNT & \rightarrow BP \quad DPRNT & \rightarrow DP \quad PCLOS & \rightarrow PC \\
\end{align*} \]

(Example) Keying in


has the same effect as


The program is also displayed in this way.
9.8 BACKGROUND EDITING

Editing a program while executing another program is called background editing. The method of editing is the same as for ordinary editing (foreground editing).

A program edited in the background should be registered in foreground program memory by performing the following operation:

During background editing, all programs cannot be deleted at once.

Procedure for background editing

1. Enter EDIT or MEMORY mode.
   Memory mode is allowed even while the program is being executed.

2. Press function key [PROG].

3. Press soft key [(OPRT)], then press soft key [BG–EDT].
   The background editing screen is displayed (PROGRAM (BG–EDIT) is displayed at the top left of the screen).

4. Edit a program on the background editing screen in the same way as for ordinary program editing.

5. After editing is completed, press soft key [(OPRT)], then press soft key [BG–EDT]. The edited program is registered in foreground program memory.

Explanation

• Alarms during background editing

Alarms that may occur during background editing do not affect foreground operation. Conversely, alarms that may occur during foreground operation do not affect background editing. In background editing, if an attempt is made to edit a program selected for foreground operation, a BP/S alarm (No. 140) is raised. On the other hand, if an attempt is made to select a program subjected to background editing during foreground operation (by means of subprogram calling or program number search operation using an external signal), a P/S alarm (Nos. 059, 078) is raised in foreground operation. As with foreground program editing, P/S alarms occur in background editing. However, to distinguish these alarms from foreground alarms, BP/S is displayed in the data input line on the background editing screen.
The password function (bit 4 (NE9) of parameter No. 3202) can be locked using parameter No. 3210 (PASSWD) and parameter No. 3211 (KEYWD) to protect program Nos. 9000 to 9999. In the locked state, parameter NE9 cannot be set to 0. In this state, program Nos. 9000 to 9999 cannot be modified unless the correct keyword is set. A locked state means that the value set in the parameter PASSWD differs from the value set in the parameter KEYWD. The values set in these parameters are not displayed. The locked state is released when the value already set in the parameter PASSWD is also set in parameter KEYWD. When 0 is displayed in parameter PASSWD, parameter PASSWD is not set.

### Procedure for locking and unlocking

#### Locking

1. Set the MDI mode.
2. Enable parameter writing. At this time, P/S alarm No. 100 is issued on the CNC.
3. Set parameter No. 3210 (PASSWD). At this time, the locked state is set.
4. Disable parameter writing.
5. Press the \(\text{RESET}\) key to release the alarm state.

#### Unlocking

1. Set the MDI mode.
2. Enable parameter writing. At this time, P/S alarm No. 100 is issued on the CNC.
3. In parameter No. 3211 (KEYWD), set the same value as set in parameter No. 3210 (PASSWD) for locking. At this time, the locked state is released.
4. Set bit 4 (NE9) of parameter No. 3202 to 0.
5. Disable parameter writing.
6. Press the \(\text{RESET}\) key to release the alarm state.
7. Subprograms from program Nos. 9000 to 9999 can now be edited.

### Explanations

- **Setting parameter PASSWD**

  The locked state is set when a value is set in the parameter PASSWD. However, note that parameter PASSWD can be set only when the locked state is not set (when PASSWD = 0, or PASSWD = KEYWD). If an attempt is made to set parameter PASSWD in other cases, a warning is given to indicate that writing is disabled. When the locked state is set (when PASSWD = 0 and PASSWD = KEYWD), parameter NE9 is automatically set to 1. If an attempt is made to set NE9 to 0, a warning is given to indicate that writing is disabled.

- **Changing parameter PASSWD**

  Parameter PASSWD can be changed when the locked state is released (when PASSWD = 0, or PASSWD = KEYWD). After step 3 in the procedure for unlocking, a new value can be set in the parameter PASSWD. From that time on, this new value must be set in parameter KEYWD to release the locked state.
- **Setting 0 in parameter PASSWD**
  When 0 is set in the parameter PASSWD, the number 0 is displayed, and the password function is disabled. In other words, the password function can be disabled by either not setting parameter PASSWD at all, or by setting 0 in parameter PASSWD after step 3 of the procedure for unlocking. To ensure that the locked state is not entered, care must be taken not to set a value other than 0 in parameter PASSWD.

- **Re-locking**
  After the locked state has been released, it can be set again by setting a different value in parameter PASSWD, or by turning the power to the NC off then on again to reset parameter KEYWD.

**CAUTION**
Once the locked state is set, parameter NE9 cannot be set to 0 and parameter PASSWD cannot be changed until the locked state is released or the memory all-clear operation is performed. Special care must be taken in setting parameter PASSWD.
9.10 COPYING A PROGRAM BETWEEN TWO PATHS

For a 2–path control CNC, setting bit 0 (PCP) of parameter No. 3206 to 1 enables the copying of a specified machining program from one path to another. Single-program copy and specified–range copy are supported.

Procedure for copying a program between two paths

Procedure

1. Select EDIT mode for both paths.

2. Press function key [PROG].

3. Press soft key [(OPRT)].

4. Press soft key [P COPY].

The following soft keys appear:

---

**PROGRAM**

O1357 (HEAD–1 MAIN PROGRAM);
N010 G90 G00 X200.0 Z220.0 ;
N020 T0101 ;
N030 S30000 M03 ;
N040 G40 G00 X40.0 Z180.0 ;
N080 X100.0 Z80.0 ;
N090 Z60.0 ;
N100 X140.0 Z40.0 ;

>_

EDIT  ****  ***  ***  14:25:36  HEAD1

---

5. Press soft key [PATH1] or [PATH2] to select the path from which a program is to be copied.

(Example) Pressing soft key [PATH1] causes an operation guidance, shown below, to appear on the screen.

---

SOURCE : PATH1 =1357
DEST : PATH2 = REPLACE : OFF

>_

EDIT  ****  ***  ***  14:25:36  HEAD1

---

- First, the program currently selected for the copy source path is displayed as the program to be copied. If no program has been selected for the copy source path, "0000" is displayed.
6 Select one or more programs to be copied.

- Single-program copy
  (1) Enter the number of the program to be copied.
  \[
  \rightarrow \ "\times\times\times\times"
  \]
  (2) Press soft key [SOURCE] to set the number.
  \[
  \rightarrow \text{SOURCE:PATH=}\"\times\times\times\times\"
  \]

- Specified-range copy
  (1) Enter the range of the programs to be copied, as a number.
  \[
  \rightarrow \ "\times\times\times\times-\square\square\square\square"
  \]
  \[
  \begin{array}{c}
  \text{Range symbol} \\
  \text{[Entry format]} \times \times \times \times-\square\square\square\square \\
  \text{Range end (largest) number} \\
  \text{Range start (smallest) number}
  \end{array}
  \]
  (2) Press soft key [SOURCE] to set the number.
  \[
  \rightarrow \text{SOURCE:PATH=}\"\times\times\times\times-\square\square\square\square\"
  \]

- To cancel the selection of the program(s) to be copied, press [SOURCE] again.

7 Select the copy destination number.

The selected program(s) can be copied by assigning numbers other than their original numbers.

(1) Type the destination number.
  \[
  \rightarrow \ "\Delta\Delta\Delta\Delta"
  \]

(2) Press soft key [DEST] to set the number.
  \[
  \rightarrow \text{DEST:PATH=}\"\Delta\Delta\Delta\Delta\"
  \]

- Pressing [DEST] without entering any number causes the original program number(s) to be used as is.
- To cancel the set number, press [DEST] again.
- For specified-range copy, the set number is assigned to the first program of the specified range. The subsequent programs are assigned numbers obtained by repeatedly incrementing the set number by one.

8 Specify replacement.

If any number to be assigned to a program to be copied is already being used for a program registered for the destination path, specify whether the existing program is to be replaced with that to be copied.

If replacement is currently disabled, pressing soft key [REPLACE] enables replacement. Pressing [REPLACE] repeatedly toggles between replacement being enabled and disabled.

"REPLACE=ON" indicates that replacement is enabled.
"REPLACE=OFF" indicates that replacement is disabled.

9 Press soft key [EXEC] to start copying.
Explanations

- **Operation flow**

- **Background editing**

  Copying can also be performed during background editing.
• Major related alarms

<table>
<thead>
<tr>
<th>Alarm number</th>
<th>Description</th>
<th>Relevant path</th>
</tr>
</thead>
<tbody>
<tr>
<td>P/S 70,70 BP/S 0</td>
<td>Insufficient free memory</td>
<td>Copy destination</td>
</tr>
<tr>
<td>P/S 71,71 BP/S 0</td>
<td>Specified program not found</td>
<td>Copy source</td>
</tr>
<tr>
<td>P/S 72,72 BP/S 0</td>
<td>Too many programs</td>
<td>Copy destination</td>
</tr>
<tr>
<td>P/S 73,73 BP/S 0</td>
<td>Duplicate registration</td>
<td>Copy destination</td>
</tr>
<tr>
<td>P/S 75,75 BP/S 0</td>
<td>Protected program number</td>
<td>Copy source/destination</td>
</tr>
</tbody>
</table>

- BP/S indicates an alarm output during background editing.
- Each alarm is issued to the path for which the operation causing the alarm is being performed.

Restrictions

• Conditions under which copying cannot be performed

Copying is not performed under any of the following conditions:
- The data protection key for the copy destination path is set to OFF.
- The specified O number is protected.
- The specified O number is already being used for a program registered for the copy destination path (if replacement is disabled).
- The part program storage for the copy destination path does not have sufficient free space.
- The copy source or destination path is placed in the alarm state.

During background editing, however, only P/S alarms 000 and 101 disable copying.

• Specified–range copy

During specified–range copy, if the part program storage for the copy destination path becomes insufficient, if the maximum number of programs which can be registered for the destination path is exceeded, if a specified program number has already been registered for the destination path, or if a specified program number is protected, an alarm is issued immediately and copying is stopped.

<table>
<thead>
<tr>
<th>Copy destination</th>
<th>Copy source</th>
</tr>
</thead>
<tbody>
<tr>
<td>O0001 ← O0020 ← O2000</td>
<td>O0001 O0020 O2000 O1100</td>
</tr>
</tbody>
</table>

Insufficient storage, duplicate registration, protected number, or maximum number of programs exceeded

Alarm issued, copying stopped
• Replacement

Even if replacement is enabled, the program is not replaced if the part program storage for the copy destination path does not have sufficient free space. During background editing, copying by replacing the currently running program is not allowed.

CAUTION
Once the copying of a program between paths has been started, it cannot be canceled. Carefully confirm all the settings before starting copying.
Programs can be created using any of the following methods:

- MDI keyboard
- PROGRAMMING IN TEACH IN MODE
- CONVERSATIONAL PROGRAMMING INPUT WITH GRAPHIC FUNCTION
- CONVERSATIONAL AUTOMATIC PROGRAMMING FUNCTION
- AUTOMATIC PROGRAM PREPARATION DEVICE (FANUC SYSTEM P)

This chapter describes creating programs using the MDI panel, Teach IN mode, and conversational programming with graphic function. This chapter also describes the automatic insertion of sequence numbers.
10. CREATING PROGRAMS USING THE MDI PANEL

Programs can be created in the EDIT mode using the program editing functions described in III–9.

Procedure for Creating Programs Using the MDI Panel

**Procedure**

1. Enter the **EDIT** mode.
2. Press the **PROG** key.
3. Press address key **O** and enter the program number.
4. Press the **INSERT** key.
5. Create a program using the program editing functions described in III–9.

**Explanation**

- **Comments in a program**

Comments can be written in a program using the control in/out codes.

Example) 

```
O0001 (FANUC SERIES 16) ;
M08 (COOLANT ON) ;
```

- When the **INSERT** key is pressed after the control–out code “(”, comments, and control–in code “)” have been typed, the typed comments are registered.
- When the **INSERT** key is pressed midway through comments, to enter the rest of comments later, the data typed before the **INSERT** key is pressed may not be correctly registered (not entered, modified, or lost) because the data is subject to an entry check which is performed in normal editing.

Note the following to enter a comment:

- Control–in code “)” cannot be registered by itself.
- Comments entered after the **INSERT** key is pressed must not begin with a number, space, or address O.
- If an abbreviation for a macro is entered, the abbreviation is converted into a macro word and registered (see Section 9.7).
- Address O and subsequent numbers, or a space can be entered but are omitted when registered.
10.2 AUTOMATIC INSERTION OF SEQUENCE NUMBERS

Sequence numbers can be automatically inserted in each block when a program is created using the MDI keys in the EDIT mode. Set the increment for sequence numbers in parameter 3216.

Procedure for automatic insertion of sequence numbers

<table>
<thead>
<tr>
<th>Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Set 1 for SEQUENCE NO. (see III–11.4.3).</td>
</tr>
<tr>
<td>2. Enter the EDIT mode.</td>
</tr>
<tr>
<td>3. Press PROG to display the program screen.</td>
</tr>
<tr>
<td>4. Search for or register the number of a program to be edited and move the cursor to the EOB (;) of the block after which automatic insertion of sequence numbers is started. When a program number is registered and an EOB (;) is entered with the INSERT key, sequence numbers are automatically inserted starting with 0. Change the initial value, if required, according to step 10, then skip to step 7.</td>
</tr>
<tr>
<td>5. Press address key N and enter the initial value of N.</td>
</tr>
<tr>
<td>6. Press INSERT.</td>
</tr>
<tr>
<td>7. Enter each word of a block.</td>
</tr>
<tr>
<td>8. Press EOB.</td>
</tr>
</tbody>
</table>
9 Press \( \text{INSERT} \). The EOB is registered in memory and sequence numbers are automatically inserted. For example, if the initial value of \( N \) is 10 and the parameter for the increment is set to 2, \( N12 \) inserted and displayed below the line where a new block is specified.

\[
\text{PROGRAM} \quad \text{O0040 N00012} \\
\text{O0040 ;} \\
\text{N10 G92 X0 Y0 Z0 ;} \\
\text{N12} \\
\%
\]

\[
> \text{EDIT} \quad \text{LIB} \quad \text{(C.A.P) (OPRT)} \\
13 : 18 : 08
\]

10 • In the example above, if \( N12 \) is not necessary in the next block, pressing the \( \text{DELETE} \) key after \( N12 \) is displayed deletes \( N12 \).

• To insert \( N100 \) in the next block instead of \( N12 \), enter \( N100 \) and press \( \text{ALTER} \) after \( N12 \) is displayed. \( N100 \) is registered and initial value is changed to 100.
10.3 CREATING PROGRAMS IN TEACH IN MODE (PLAYBACK)

When the playback option is selected, the TEACH IN JOG mode and TEACH IN HANDLE mode are added. In these modes, a machine position along the X, Y, and Z axes obtained by manual operation is stored in memory as a program position to create a program.

The words other than X, Y, and Z, which include O, N, G, R, F, C, M, S, T, P, Q, and EOB, can be stored in memory in the same way as in EDIT mode.

Procedure for Creating Programs in TEACH IN Mode

Procedure

The procedure described below can be used to store a machine position along the X, Y, and Z axes.

1. Select the TEACH IN JOG mode or TEACH IN HANDLE mode.
2. Move the tool to the desired position with jog or handle.
3. Press the PROG key to display the program screen. Search for or register the number of a program to be edited and move the cursor to the position where the machine position along each axis is to be registered (inserted).
4. Key in address X.
5. Press the INSERT key. Then a machine position along the X axis is stored in memory.
   (Example) X10.521 Absolute position (for mm input)
   X10521 Data stored in memory
6. Similarly, key in Y, then press the INSERT key. Then a machine position along the Y axis is stored in memory. Further, key in Z, then press the INSERT key. Then a machine position along the Z axis is stored in memory.

All coordinates stored using this method are absolute coordinates.

Examples

```
O1234 ;
N1 G92 X10000 Y0 Z10000 ;
N2 G00 G90 X3025 Y23723 ;
N3 G01 Z–325 F300 ;
N4 M02 ;
```

![Diagram showing machine positions in 3D space with coordinates and program points labeled.]
1 Set the setting data SEQUENCE NO. to 1 (on). (The incremental value parameter (No. 3216) is assumed to be “1”.)

2 Select the TEACH IN HANDLE mode.

3 Make positioning at position P0 by the manual pulse generator.

4 Select the program screen.

5 Enter program number O1234 as follows:

   O 1 2 3 4

This operation registers program number O1234 in memory. Next, press the following keys:

   EOB  INSERT

An EOB (;) is entered after program number O1234. Because no number is specified after N, sequence numbers are automatically inserted for N0 and the first block (N1) is registered in memory.

6 Enter the P0 machine position for data of the first block as follows:

   G 9 2 INSERT  X INSERT  Y INSERT  Z

   INSERT  EOB  INSERT

This operation registers G92X10000Y0Z10000; in memory. The automatic sequence number insertion function registers N2 of the second block in memory.

7 Position the tool at P1 with the manual pulse generator.

8 Enter the P1 machine position for data of the second block as follows:

   G 0 0 INSERT  G 9 0 X INSERT  Y

   INSERT  EOB  INSERT

This operation registers G00G90X3025Z23723; in memory. The automatic sequence number insertion function registers N3 of the third block in memory.

9 Position the tool at P2 with the manual pulse generator.

10 Enter the P2 machine position for data of the third block as follows:

   G 0 1 INSERT  Z INSERT  F 3 0 0

   INSERT  EOB  INSERT

This operation registers G01Z –325F300; in memory. The automatic sequence number insertion function registers N4 of the fourth block in memory.

11 Register M02; in memory as follows:

   M 0 2 INSERT  EOB  INSERT

N5 indicating the fifth block is stored in memory using the automatic sequence number insertion function. Press the DELETE key to delete it.

This completes the registration of the sample program.
Explanations

- **Checking contents of the memory**
  The contents of memory can be checked in the TEACH IN mode by using the same procedure as in EDIT mode.

<table>
<thead>
<tr>
<th>PROGRAM</th>
<th>O1234  N00004</th>
</tr>
</thead>
<tbody>
<tr>
<td>(RELATIVE)</td>
<td>(ABSOLUTE)</td>
</tr>
<tr>
<td>X –6.975</td>
<td>X 3.025</td>
</tr>
<tr>
<td>Y 23.723</td>
<td>Y 23.723</td>
</tr>
<tr>
<td>Z –10.325</td>
<td>Z –0.325</td>
</tr>
</tbody>
</table>

O1234 ;
N1 G92 X10000 Y0 Z10000 ;
N2 G00 G90 X3025 Y23723 ;
N3 G01 Z–325 F300 ;
N4 M02 %

PRGRM

- **Registering a position with compensation**
  When a value is keyed in after keying in address $X$, $Y$, or $Z$, then the INSERT key is pressed, the value keyed in for a machine position is added for registration. This operation is useful to correct a machine position by key–in operation.

- **Registering commands other than position commands**
  Commands to be entered before and after a machine position must be entered before and after the machine position is registered, by using the same operation as program editing in EDIT mode.
10.4 CONVERSATIONAL PROGRAMMING WITH GRAPHIC FUNCTION

Programs can be created block after block on the conversational screen while displaying the G code menu. Blocks in a program can be modified, inserted, or deleted using the G code menu and conversational screen.

Procedure for Conversational Programming with Graphic Function

Procedure 1 Creating a program

1. Enter the EDIT mode.

2. Press PROG. If no program is registered, the following screen is displayed. If a program is registered, the program currently selected is displayed.

```
PROGRAM O0000 N0000

> EDIT  ********  11:59:46

[PRGRM] [LIB] [C.A.P] [OPRT]
```

3. Key in the program number of a program to be registered after keying in address O, then press INSERT. For example, when a program with program number 10 is to be registered, key in O10, then press INSERT. This registers a new program O0010.
4 Press the [C.A.P] soft key. The following G code menu is displayed on the screen.
If soft keys different from those shown in step 2 are displayed, press the menu return key to display the correct soft keys.

<table>
<thead>
<tr>
<th>PROGRAM</th>
<th>O1234 N00004</th>
</tr>
</thead>
<tbody>
<tr>
<td>G00 : POSITIONING</td>
<td></td>
</tr>
<tr>
<td>G01 : LINEAR IPL</td>
<td></td>
</tr>
<tr>
<td>G02 : CIRCULAR IPL, CW</td>
<td></td>
</tr>
<tr>
<td>G03 : CIRCULAR IPL, CCW</td>
<td></td>
</tr>
<tr>
<td>G04 : DELL</td>
<td></td>
</tr>
<tr>
<td>G09 : EXACT STOP CHECK</td>
<td></td>
</tr>
<tr>
<td>G10 : OFFSET&amp;TLC VALUE SETTING (0)</td>
<td></td>
</tr>
<tr>
<td>G17 : XY PLANE</td>
<td></td>
</tr>
<tr>
<td>G18 : ZX PLANE</td>
<td></td>
</tr>
<tr>
<td>G19 : YZ PLANE</td>
<td></td>
</tr>
<tr>
<td>G20 : INCH</td>
<td></td>
</tr>
<tr>
<td>G21 : METRIC</td>
<td></td>
</tr>
</tbody>
</table>

When no keys are pressed, the standard details screen is displayed.

5 Key in the G code corresponding to a function to be programmed. When the positioning function is desired, for example, the G code menu lists the function with the G code G00. So key in G00. If the screen does not indicate a function to be programmed, press the page key to display the next G code menu screen. Repeat this operation until a desired function appears. If a desired function is not a G code, key in no data.

6 Press the soft key [BLOCK] to display a detailed screen for a keyed in G code. The figure below shows an example of detailed screen for G00.

When no keys are pressed, the standard details screen is displayed.
7 Move the cursor to the block to be modified on the program screen. At this time, a data address with the cursor blinks.

8 Enter numeric data by pressing the numeric keys and press the [INPUT] soft key or INPUT key. This completes the input of one data item.

9 Repeat this operation until all data required for the entered G code is entered.

10 Press the INSERT key. This completes the registration of data of one block in program memory. On the screen, the G code menu screen is displayed, allowing the user to enter data for another block. Repeat the procedure starting with 5 as required.

11 After registering all programs, press the [PRGRM] soft key. The registered programs are converted to the conversational format and displayed.

12 Press the RESET key to return to the program head.

**Procedure 2**

**Modifying a block**

1 Move the cursor to the block to be modified on the program screen and press the [C.A.P] soft key. Or, press the [C.A.P] soft key first to display the conversational screen, then press the page key until the block to be modified is displayed.

2 When data other than a G code is to be altered, just move the cursor to the data and key in a desired value, then press the [INPUT] soft key or INPUT key.

3 When a G code is to be altered, press the menu return key (→) and the soft key [G.MENU]. Then the G code menu appears. Select a desired G code, then key in the value. For example, to specify a cutting feed, since the G code menu indicates G01, key in G01. Then press the soft key [BLOCK]. The detailed screen of the G code is displayed, so enter the data.
After data is changed completely, press the **ALTER** key. This operation replaces an entire block of a program.

1. On the conversational screen, display the block immediately before a new block is to be inserted, by using the page keys. On the program screen, move the cursor with the page keys and cursor keys to immediately before the point where a new block is to be inserted.

2. Press the soft key **[G.MENU]** to display the G code menu. Then enter new block data.

3. When input of one block of data is completed in step 2, press the **INSERT** key. This operation inserts a block of data.

4. On the conversational screen, display the contents of a block to be deleted, then press the **DELETE** key.

5. The contents of the block displayed are deleted from program memory. Then the contents of the next block are displayed on the conversational screen.
To operate a CNC machine tool, various data must be set on the MDI panel for the CNC. The operator can monitor the state of operation with data displayed during operation.

This chapter describes how to display and set data for each function.

The screen transition for when each function key on the MDI panel is pressed is shown below. The subsections referenced for each screen are also shown. See the appropriate subsection for details of each screen and the setting procedure on the screen. See other chapters for screens not described in this chapter.

See Chapter 7 for the screen that appears when function key \(\text{MESSAGE}\) is pressed. See Chapter 12 for the screen that appears when function key \(\text{GRAPH}\) is pressed. See Chapter 13 for the screen that appears when function key \(\text{HELP}\) is pressed. In general, function key \(\text{CUSTOM}\) is prepared by the machine tool builder and used for macros. Refer to the manual issued by the machine tool builder for the screen that appears when function key \(\text{CUSTOM}\) is pressed.

The machine may have a data protection key to protect part programs, tool compensation values, setting data, and custom macro variables. Refer to the manual issued by the machine tool builder for where the data protection key is located and how to use it.
POS

Current position screen

ABS  REL  ALL  HNDL (OPRT)

Position display of workpiece coordinate system
⇒ See III—11.1.1.

Position displays relative coordinate system
⇒ See III—11.1.2.

Total position display of each coordinate system
⇒ See III—11.1.3.

Manual handle interruption
⇒ See III—4.8.

Display of part count and run time
⇒ See III—11.1.6.

Display of actual speed
⇒ See III—11.1.5.

Setting of floating reference position
⇒ See III—11.1.7.

Setting of relative coordinate values
⇒ See III—11.1.2.

Current position screen

MONI (OPRT)

Display of operating monitor
⇒ See III—11.1.8.
Program screen

MEM
[PRGRM] [CHECK] [CURRNT] [NEXT] (OPRT)

Display of program contents
⇒ See III–11.2.1.

Display of program number and sequence number
⇒ See III–11.6.1.

[ABS]
Program being executed
Absolute coordinate value
Distance to go modal values
⇒ See III–11.2.4.

[REL]
Program being executed
Relative coordinate value
Distance to go modal values
⇒ See III–11.2.4.

Command for MDI operation
⇒ See III–11.2.3.
(Displayed in the MDI mode)

Program screen

MEM
[RSTR] [FL.SDL] [ ] [ ] [ ] (OPRT)

Program restart screen
⇒ See III–4.5.

[PRGRM] [DIR] [SCHEDUL]
Display of file directory
⇒ See III–4.6.
Setting of schedule
See III–4.8.

*: Displayed in MDI mode

Screen transition triggered by the function key in the MEMORY or MDI mode
11. SETTING AND DISPLAYING DATA

**PROGRAM SCREEN** Screen transition triggered by the function key in the EDIT mode

**EDIT**

- **PRGRM**
- **LIB**
- **C.A.P.**
- **(OPRT)**

↓

Program editing screen ⇒ See III–9
Program memory and program directory ⇒ See III–11.3.1.
Conversational programming screen ⇒ See III–10.4

↓

Program screen

**EDIT**

- **FLOPPY**
- **(OPRT)**

↓

File directory screen for floppy disks ⇒ See III–8.8
SYSTEM SCREEN

Screen transition triggered by the function key

Parameter screen

PARAM [ DGNOS ] [ PMC ] [ SYSTEM ] [ (OPRT) ]

Display of parameter screen
⇒ See III–11.5.1

Display of diagnosis screen
⇒ See III–7.3

Setting of parameter
⇒ See III–11.5.1

Parameter screen

PITCH [ SV.PRM ] [ SP.PRM ] [ (OPRT) ]

Display of pitch error data
⇒ See III–11.5.2.
### Setting screens

The table below lists the data set on each screen.

<table>
<thead>
<tr>
<th>No.</th>
<th>Setting screen</th>
<th>Contents of setting</th>
<th>Reference item</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tool offset value</td>
<td>Tool offset value&lt;br&gt;Tooth length offset value&lt;br&gt;Cutter compensation value</td>
<td>III–11.4.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tool length measurement</td>
<td>III–11.4.2</td>
</tr>
<tr>
<td>2</td>
<td>Setting data(handy)</td>
<td>Parameter write&lt;br&gt;TV check&lt;br&gt;Punch code&lt;br&gt;Input unit (mm/inch)&lt;br&gt;I/O channel&lt;br&gt;Automatic insert of Sequence No.&lt;br&gt;Conversion of tape format (F15)</td>
<td>III–11.4.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sequence number comparison and stop</td>
<td>III–11.4.4</td>
</tr>
<tr>
<td>3</td>
<td>Setting data (mirror image)</td>
<td>Mirror image</td>
<td>III–11.4.3</td>
</tr>
<tr>
<td>4</td>
<td>Setting data (timer)</td>
<td>Parts required</td>
<td>III–11.4.5</td>
</tr>
<tr>
<td>5</td>
<td>Macro variables</td>
<td>Custom macro common variables&lt;br&gt;(#100 to #149) or (#100 to #199)&lt;br&gt;(#500 to #531) or (#500 to #599)</td>
<td>III–11.4.8</td>
</tr>
<tr>
<td>6</td>
<td>Parameter</td>
<td>Parameter</td>
<td>III–11.5.1</td>
</tr>
<tr>
<td>7</td>
<td>Pitch error</td>
<td>Pitch error compensation data</td>
<td>III–11.5.2</td>
</tr>
<tr>
<td>8</td>
<td>software operator’s panel</td>
<td>Mode selection&lt;br&gt;Jog feed axis selection&lt;br&gt;Jog rapid traverse&lt;br&gt;Axix selection for Manual pulse generator&lt;br&gt;Multiplication for manual pulse generator&lt;br&gt;Jog feedrate&lt;br&gt;Feedrate override&lt;br&gt;Rapid traverse override&lt;br&gt;Optional block skip&lt;br&gt;Single block&lt;br&gt;Machine lock&lt;br&gt;Dry run&lt;br&gt;Protect key&lt;br&gt;Feed hold</td>
<td>III–11.4.10</td>
</tr>
<tr>
<td>9</td>
<td>Tool life data</td>
<td>Life count</td>
<td>III–11.4.11</td>
</tr>
<tr>
<td>10</td>
<td>Tool life data</td>
<td>Life count type (cycle or minute)&lt;br&gt;Life value&lt;br&gt;Life counter&lt;br&gt;Tool number&lt;br&gt;H code&lt;br&gt;D code&lt;br&gt;New tool group&lt;br&gt;New tool number&lt;br&gt;Skipping tool&lt;br&gt;Clearing tool</td>
<td>III–11.4.12</td>
</tr>
<tr>
<td>11</td>
<td>Work coordinate system setting</td>
<td>Work origin offset value</td>
<td>III–11.4.6</td>
</tr>
<tr>
<td>12</td>
<td>Current position display screen</td>
<td>Floating reference position</td>
<td>III–11.1.7</td>
</tr>
</tbody>
</table>
Press function key $\text{POS}$ to display the current position of the tool.

The following three screens are used to display the current position of the tool:
- Position display screen for the work coordinate system.
- Position display screen for the relative coordinate system.
- Overall position display screen.

The above screens can also display the feedrate, run time, and the number of parts. In addition, a floating reference position can be set on these screens.

Function key $\text{POS}$ can also be used to display the load on the servo motor and spindle motor and the rotation speed of the spindle motor (operating monitor display).

Function key $\text{POS}$ can also be used to display the screen for displaying the distance moved by handle interruption. See III–4.8 for details on this screen.
11.1.1

Position Display in the Work Coordinate System

Displays the current position of the tool in the workpiece coordinate system. The current position changes as the tool moves. The least input increment is used as the unit for numeric values. The title at the top of the screen indicates that absolute coordinates are used.

Display procedure for the current position screen in the workpiece coordinate system

1. Press function key [POS].
2. Press soft key [ABS].
3. Press the [ABS] soft key one more time to display the coordinates along axes other than the six standard axes.

- Display with one–path control

```
ACTUAL POSITION(ABSOLUTE) O1000 N00010
X 123.456
Y 363.233
Z 0.000
PART COUNT 5
RUN TIME 0H15M CYCLE TIME 0H 0M38S
ACT.F 3000 MM/M S 0 T0000
MEM STRT MTN *** 09:06:35 [ABS] [ REL ] [ ALL ] [ HNDL ] [ OPRT ]
```

- Display with two–path control

```
ACTUAL POSITION(ABSOLUTE) O1000 N00010
X1 100.000
Z1 200.000
X1 300.000
PART COUNT 5
RUN TIME 0H15M CYCLE TIME 0H 0M38S
ACT.F 3000 MM/M S 0 T0000
MEM STRT MTN *** 09:06:35 HEAD1 [ABS] [ REL ] [ ALL ] [ HNDL ] [(OPRT)]
```
11. SETTING AND DISPLAYING DATA

- Display with two–path control
  (12 soft keys display unit)

<table>
<thead>
<tr>
<th>ACTUAL POSITION</th>
<th>O1000 N100010</th>
<th>O2000 N200010</th>
</tr>
</thead>
<tbody>
<tr>
<td>(ACTUAL)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X₁ 100.000</td>
<td>X₂ 400.000</td>
<td></td>
</tr>
<tr>
<td>Y₁ 200.000</td>
<td>Y₂ 500.000</td>
<td></td>
</tr>
<tr>
<td>Z₁ 300.000</td>
<td>Z₂ 600.000</td>
<td></td>
</tr>
<tr>
<td>(ACTUAL SPEED)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F : 0MM/MIN</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S : 0RPM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(PARTS COUNT)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>114</td>
<td>114</td>
<td></td>
</tr>
<tr>
<td>(RUN TIME)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5H 3M</td>
<td>5H 3M</td>
<td></td>
</tr>
<tr>
<td>(CYCLE TIME)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0H 0M 6S</td>
<td>0H 0M 6S</td>
<td></td>
</tr>
<tr>
<td>MEM STOP *** ***</td>
<td>12:34:56</td>
<td></td>
</tr>
<tr>
<td>HEAD1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Explanations

- Display including compensation values
  Bits 6 and 7 of parameter 3104 (DAL, DAC) can be used to select whether the displayed values include tool length offset and cutter compensation.

- Displaying the sixth and subsequent axes
  Only the coordinates for the first to fifth axes are displayed initially whenever when there are six or more controlled axes. Pressing the [ABS] soft key displays the coordinates for the sixth and subsequent axes.
11.1.2 Position Display in the Relative Coordinate System

Displays the current position of the tool in a relative coordinate system based on the coordinates set by the operator. The current position changes as the tool moves. The increment system is used as the unit for numeric values. The title at the top of the screen indicates that relative coordinates are used.

Display procedure for the current position screen with the relative coordinate system

1. Press function key \( \text{POS} \).
2. Press soft key \( \text{[REL]} \).
3. Press the \( \text{[REL]} \) soft key one more time to display the coordinates along axes other than the six standard axes.

- Display with one–path control

<table>
<thead>
<tr>
<th>ACTUAL POSITION(RELATIVE)</th>
<th>O1000 N00010</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>123.456</td>
</tr>
<tr>
<td>Y</td>
<td>363.233</td>
</tr>
<tr>
<td>Z</td>
<td>0.000</td>
</tr>
</tbody>
</table>

MEM STRT MTN *** 09:06:35
[ ABS ] [ REL ] [ ALL ] [ HNDL ] [ OPRT ]

PART COUNT 5
CYCLE TIME 0H 0M38S
ACT.F 3000 MM/M
RUN TIME 0H15M

See Explanations for the procedure for setting the coordinates.

- Display with two–path control (7 soft keys display unit)

<table>
<thead>
<tr>
<th>ACTUAL POSITION(RELATIVE)</th>
<th>O1000 N00010</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>100.000</td>
</tr>
<tr>
<td>Y</td>
<td>200.000</td>
</tr>
<tr>
<td>Z</td>
<td>300.000</td>
</tr>
</tbody>
</table>

MEM STRT MTN *** 09:06:35
[ ABS ] [ REL ] [ ALL ] [ HNDL ] [ OPRT ]

PART COUNT 5
CYCLE TIME 0H 0M38S
ACT.F 3000 MM/M
RUN TIME 0H15M


- Display with two–path control
  (12 soft keys display unit)

Explanations

- Setting the relative coordinates
  The current position of the tool in the relative coordinate system can be reset to 0 or preset to a specified value as follows:

**Procedure to set the axis coordinate to a specified value**

**Procedure**

1. Enter an axis address (such as X or Y) on the screen for the relative coordinates. The indication for the specified axis blinks and the soft keys change as shown on the left.

2. To reset the coordinate to 0, press soft key [ORIGIN]. The relative coordinate for the blinking axis is reset to 0.

3. To preset the coordinate to a specified value, enter the value and press soft key [PRESET]. The relative coordinate for the blinking axis is set to the entered value.

**Procedure to reset all axes**

**Procedure**

1. Press soft key [(OPRT)].

2. Press soft key [ORIGIN].

3. Press soft key [ALLEXE].

The relative coordinates for all axes are reset to 0.
• **Display including compensation values**  
  Bits 6 and 7 of parameter 3104 (DRL, DRC) can be used to select whether the displayed values include tool length offset and cutter compensation.

• **Presetting by setting a coordinate system**  
  Bit 3 of parameter 3104 (PPD) is used to specify whether the displayed positions in the relative coordinate system are preset to the same values as in the workpiece coordinate system when a coordinate system is set by a G92 command or when the manual reference position return is made.

• **Displaying the sixth and subsequent axes**  
  Only the coordinates for the first to fifth axes are displayed initially whenever when there are six or more controlled axes. Pressing the [ABS] soft key displays the coordinates for the sixth and subsequent axes.
Displays the following positions on a screen: Current positions of the tool in the workpiece coordinate system, relative coordinate system, and machine coordinate system, and the remaining distance. The relative coordinates can also be set on this screen. See III–11.1.2 for the procedure.

Procedure for displaying overall position display screen

Procedure

1. Press function key [POS].

2. Press soft key [ALL].

- Display with one–path control

```
ACTUAL POSITION O1000 N00010
(RELATIVE) (ABSOLUTE)
X 246.912  X 123.456
Y 913.780  Y 456.890
Z 1578.246 Z 789.123

(MACHINE) (DISTANCE TO GO)
X 0.000 X 0.000
Y 0.000 Y 0.000
Z 0.000 Z 0.000

PART COUNT 5
RUN TIME 0H15M CYCLE TIME 0H 0M38S
ACT.F 3000 MM/M S 0 T0000
MEM **** ***** 09:06:35
[ ABS ] [ REL ] [ ALL ] [ HNDL ] [ OPRT ]
```

- Display with two–path control

```
ACTUAL POSITION O1000 N00010
(RELATIVE) (ABSOLUTE)
X1 100.000 X1 100.000
Y1 200.000 Y1 200.000
Z1 300.000 Z1 300.000

(MACHINE) (DISTANCE TO GO)
X1 100.000 X1 000.000
Y1 200.000 Y1 000.000
Z1 300.000 Z1 000.000
Z2 000.000

PART COUNT 5
RUN TIME 0H15M CYCLE TIME 0H 0M38S
ACT.F 3000 MM/M S 0 T0000
MEM **** ***** 09:06:35 HEAD1
[ ABS ] [ REL ] [ ALL ] [ HNDL ] [ OPRT ]
```
• Display with two-path control (12 soft keys display unit)

<table>
<thead>
<tr>
<th>ACTUAL POSITION</th>
<th>O1000 N10010</th>
<th>O2000 N20010</th>
</tr>
</thead>
<tbody>
<tr>
<td>(RELATIVE)</td>
<td>(ABSOLUTE)</td>
<td>(RELATIVE)</td>
</tr>
<tr>
<td>X1 100.000</td>
<td>X1 100.000</td>
<td>X1 100.000</td>
</tr>
<tr>
<td>Y1 100.000</td>
<td>Y1 100.000</td>
<td>Y1 100.000</td>
</tr>
<tr>
<td>Z1 300.000</td>
<td>Z1 300.000</td>
<td>Z1 300.000</td>
</tr>
<tr>
<td>(MACHINE)</td>
<td>(DISTANCE TO GO)</td>
<td>(MACHINE)</td>
</tr>
<tr>
<td>X1 100.000</td>
<td>X1 100.000</td>
<td>X1 100.000</td>
</tr>
<tr>
<td>Y1 100.000</td>
<td>Y1 100.000</td>
<td>Y1 100.000</td>
</tr>
<tr>
<td>Z1 300.000</td>
<td>Z1 300.000</td>
<td>Z1 300.000</td>
</tr>
<tr>
<td>(ACTUAL SPEED)</td>
<td>F : 0MM/Min</td>
<td>S : 0RPM</td>
</tr>
<tr>
<td>(PARTS COUNT)</td>
<td>1/4</td>
<td>1/4</td>
</tr>
<tr>
<td>(RUN TIME)</td>
<td>6H 3M</td>
<td>6H 3M</td>
</tr>
<tr>
<td>(CYCLE TIME)</td>
<td>0H 0M 6S</td>
<td>0H 0M 6S</td>
</tr>
<tr>
<td>MEM STOP *** ***</td>
<td>12:34:56</td>
<td>HEAD1</td>
</tr>
</tbody>
</table>

Explanations

• Coordinate display
  The current positions of the tool in the following coordinate systems are displayed at the same time:
  • Current position in the relative coordinate system (relative coordinate)
  • Current position in the work coordinate system (absolute coordinate)
  • Current position in the machine coordinate system (machine coordinate)
  • Distance to go (distance to go)

• Distance to go
  The distance remaining is displayed in the MEMORY or MDI mode. The distance the tool is yet to be moved in the current block is displayed.

• Machine coordinate system
  The least command increment is used as the unit for values displayed in the machine coordinate system. However, the least input increment can be used by setting bit 0 (MCN) of parameter 3104.

• Displaying the sixth and subsequent axes
  Only the coordinates for the first to fifth axes are displayed initially whenever there are six or more controlled axes. Pressing the [ALL] soft key displays the coordinates for the sixth and subsequent axes.

• Displaying the fifth and subsequent axes
  Relative coordinates cannot be displayed together with absolute coordinates whenever there are five or more controlled axes. Pressing the [ALL] soft key toggles the display between absolute and relative coordinates.

• Resetting the relative coordinates
  The total position display screen also supports the resetting of the relative coordinates to 0 or presetting of them to specified values. See the procedure for resetting the relative coordinates described in Subsection III–11.1.2.
A workpiece coordinate system shifted by an operation such as manual intervention can be preset using MDI operations to a pre-shift workpiece coordinate system. The latter coordinate system is displaced from the machine zero point by a workpiece zero point offset value. A command (G92.1) can be programmed to preset a workpiece coordinate system. (See II–7.2.4 in the section for programming.)

**Procedure for Presetting the Workpiece Coordinate System**

1. Press function key [POS].
2. Press soft key [(OPRT)].
3. When [WRK–CD] is not displayed, press the continuous menu key [].
4. Press soft key [WRK–CD].
5. Press soft key [ALLAXS] to preset all axes.
6. To preset a particular axis in step 5, enter the axis name (X, Y, ...) and [0], then press soft key [AXS–CD].

**Explanations**

- **Operation mode**
  This function can be executed when the reset state or automatic operation stop state is entered, regardless of the operation mode.

- **Presetting relative coordinates**
  As with absolute coordinates, bit 3 (PPD) of parameter No. 3104 is used to specify whether to preset relative coordinates (RELATIVE).
11. SETTING AND DISPLAYING DATA

11.1.5 Actual Feedrate Display

The actual feedrate on the machine (per minute) can be displayed on a current position display screen or program check screen by setting bit 0 (DPF) of parameter 3105. On the 12 soft keys display unit, the actual feedrate is always displayed.

Display procedure for the actual feedrate on the current position display screen

Procedure

1. Press function key \text{POS} to display a current position display screen.

```
ACTUAL POSITION (ABSOLUTE)     O1000 N00010
X    123.456
Y    363.233
Z    0.000
RUN TIME 0H15M CYCLE TIME 0H 0M38S
ACT.F  3000 MM/M     S   0 T0000
MEM STRT MTN *** 09:06:35
ABS [ REL ] [ ALL ] [ HNDL ] [ OPRT ]
```

Actual feedrate is displayed after ACT.F.

Explanations

The actual feedrate is displayed in units of millimeter/min or inch/min (depending on the specified least input increment) under the display of the current position.

- **Actual feedrate value**
  
  The actual rate is calculated by the following expression:

  \[ \text{Fact} = \sqrt{\sum_{i=1}^{n} (f_i)^2} \]

  where

  \( n \): Number of axes

  \( f_i \): Cutting feed rate in the tangential direction of each axis or rapid traverse rate

  \( \text{Fact} \): Actual feedrate displayed

  The display unit: \text{mm/min} (metric input).

  \text{inch/min} (Inch input, Two digits below the decimal point are displayed.)

  The feedrate along the PMC axis can be omitted by setting bit 1 (PCF) of parameter 3105.

- **Actual feedrate display of feed per revolution**

  In the case of feed per revolution and thread cutting, the actual feedrate displayed is the feed per minute rather than feed per revolution.
In the case of movement of rotary axis, the speed is displayed in units of deg/min but is displayed on the screen in units of input system at that time. For example, when the rotary axis moves at 50 deg/min, the following is displayed: 0.50 INCH/M

The program check screen also displays the actual feedrate.
11.1.6 Display of Run Time and Parts Count

The run time, cycle time, and the number of machined parts are displayed on the current position display screens.

Procedure for displaying run time and parts count on the current position display screen

Procedure

1. Press function key **POS** to display a current position display screen.

```
ACTUAL POSITION(RELATIVE) O1000 N00010
X 123.456
Y 363.233
Z 0.000

RUN TIME 0H15M PART COUNT 5
ACT.F 3000 MM/M CYCLE TIME 0H 0M38S
S 0 T0000
```

The number of machined parts (PART COUNT), run time (RUN TIME), and cycle time (CYCLE TIME) are displayed under the current position.

Explanations

- **PART COUNT**
  Indicates the number of machined parts. The number is incremented each time M02, M30, or an M code specified by parameter 6710 is executed.

- **RUN TIME**
  Indicates the total run time during automatic operation, excluding the stop and feed hold time.

- **CYCLE TIME**
  Indicates the run time of one automatic operation, excluding the stop and feed hold time. This is automatically preset to 0 when a cycle start is performed at reset state. It is preset to 0 even when power is removed.

- **Display on the other screen**
  Details of the run time and the number of machined parts are displayed on the setting screen. See III–11.4.5.

- **Parameter setting**
  The number of machined parts and run time cannot be set on current position display screens. They can be set by parameters No. 6711, 6751, and 6752 or on the setting screen.

- **Incrementing the number of machined parts**
  Bit 0 (PCM) of parameter 6700 is used to specify whether the number of machined parts is incremented each time M02, M30, or an M code specified by parameter 6710 is executed, or only each time an M code specified by parameter 6710 is executed.
11.1.7 Setting the Floating Reference Position

To perform floating reference position return with a G30.1 command, the floating reference position must be set beforehand.

**Procedure for setting the floating reference position**

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Press function key [POS] to display a screen used for displaying the current position.</td>
</tr>
<tr>
<td>2</td>
<td>Move the tool to the floating reference position by jogging.</td>
</tr>
<tr>
<td>3</td>
<td>Press soft key [(OPRT)].</td>
</tr>
<tr>
<td>4</td>
<td>Press soft key [SET FRP].</td>
</tr>
</tbody>
</table>
| 5 | To register the floating reference positions for all axes, press soft key [ALLEXE].
   To register the floating reference position of a specific axis, enter the name of the axis [X, Y, etc.], then press soft key [EXEC]. Two or more names can be entered consecutively (e.g., [X Y Z] [EXEC]).
   The above operation stores the floating reference position. It can be checked with parameter (no. 1244). |
| 6 | In step 4, the floating reference position along a specified axis can also be stored by entering the axis name (such as [X] or [Y]) and pressing soft key [SET FRP]. |

**Explanations**

- **Presetting the relative coordinate system**

By parameter FPC (bit 3 of parameter 1201), the relative position can be preset to 0 when a floating reference position is registered.
11. SETTING AND DISPLAYING DATA

11.1.8 Operating Monitor Display

The reading on the load meter can be displayed for each servo axis and the serial spindle by setting bit 5 (OPM) of parameter 3111 to 1. The reading on the speedometer can also be displayed for the serial spindle.

Procedure for displaying the operating monitor

**Procedure**

1. Press function key \[POS\] to display a current position display screen.
2. Press the continuous-menu key \[\rightarrow\].
3. Press soft key \[MONI\].

```
OPERATING MONITOR
(LOAD METER)

X : * * * 80%   S1 : 01%
Y : * * * * 0%   (SPEED METER RPM)
Z : * * * * 0%   S1 : 1500

RUN TIME   0H15M
ACT.F     3000 MM/M

MEM STRT MTN *** 09:06:35
PART COUNT    5
CYCLE TIME   0H 0M38S

LOAD METER

0001 N00001
```

**Explanations**

- **Display of the servo axes**
  The reading on the load meter can be displayed for up to eight servo axes by setting parameters 3151 to 3158. When all these parameters are set to 0, data is displayed only to the 3rd axis.

- **Display of the spindle axes**
  When serial spindles are used, the reading on the load meter and speedometer can be displayed only for the main serial spindle.

- **Unit of graph**
  The bar graph for the load meter shows load up to 200% (only a value is displayed for load exceeding 200%). The bar graph for the speedometer shows the ratio of the current spindle speed to the maximum spindle speed (100%).

- **Load meter**
  The reading on the load meter depends on servo parameter 2086 and spindle parameter 4127.
• **Speedometer**

Although the speedometer normally indicates the speed of the spindle motor, it can also be used to indicate the speed of the spindle by setting bit 6 (OPS) of parameter 3111 to 1.

The spindle speed to be displayed during operation monitoring is calculated from the speed of the spindle motor (see the formula below). The spindle speed can therefore be displayed, during operation monitoring, even when no position coder is used. To display the correct spindle speed, however, the maximum spindle speed for each gear (spindle speed at each gear ratio when the spindle motor rotates at the maximum speed) must be set in parameters No. 3741 to 3744.

The input of the clutch and gear signals for the first serial spindle is used to determine the gear which is currently selected. Control the input of the CTH1A and CTH2A signals according to the gear selection, by referring to the table below.

(Formula for calculating the spindle speed to be displayed)

\[
\text{Spindle speed displayed during operation monitoring} = \frac{\text{Speed of spindle motor}}{\text{Maximum speed of spindle motor}} \times \text{Maximum spindle speed with the gear being used}
\]

The following table lists the correspondence between clutch and gear selection signals CTH1A and CTH2A, used to determine the gear being used, and parameters:

<table>
<thead>
<tr>
<th>CTH1A</th>
<th>CTH2A</th>
<th>Parameter</th>
<th>Serial spindle spec</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>=No.3741 (Maximum spindle speed with gear 1)</td>
<td>HIGH</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>=No.3742 (Maximum spindle speed with gear 2)</td>
<td>MEDIUM</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>HIGH</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>=No.3743 (Maximum spindle speed with gear 3)</td>
<td>MEDIUM</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>LOW</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>=No.3744 (Maximum spindle speed with gear 4)</td>
<td>LOW</td>
</tr>
</tbody>
</table>

The speed of the spindle motor and spindle can be displayed, during operation monitoring, only for the first serial spindle and the spindle switching axis for the first serial spindle. It cannot be displayed for the second spindle.

• **Color of graph**

If the value of a load meter exceeds 100%, the bar graph turns purple.
11.2
SCREENS DISPLAYED BY FUNCTION KEY PROG (IN MEMORY MODE OR MDI MODE)

This section describes the screens displayed by pressing function key PROG in MEMORY or MDI mode. The first four of the following screens display the execution state for the program currently being executed in MEMORY or MDI mode and the last screen displays the command values for MDI operation in the MDI mode:

1. Program contents display screen
2. Current block display screen
3. Next block display screen
4. Program check screen
5. Program screen for MDI operation
6. Stamping the machining time

Function key PROG can also be pressed in MEMORY mode to display the program restart screen and scheduling screen. See III–4.5 for the program restart screen. See III–4.6 for the scheduling screen.
11.2.1 Program Contents Display

Displays the program currently being executed in MEMORY or MDI mode.

Procedure for displaying the program contents

1. Press function key [PROG] to display the program screen.

2. Press chapter selection soft key [PRGRM].

The cursor is positioned at the block currently being executed.

On the 12 soft keys display unit, the contents of the program are displayed on the right half of the screen or on the entire screen (switched each time soft key [PRGRM] is pressed).

Explanations

- 12 soft keys display unit

On the 12 soft keys display unit, the contents of the program are displayed on the right half of the screen or on the entire screen (switched each time soft key [PRGRM] is pressed).
11.2.2
Current Block Display Screen

Displays the block currently being executed and modal data in the MEMORY or MDI mode.

Procedure for displaying the current block display screen

Procedure

1. Press function key [PROG].

2. Press chapter selection soft key [CURRNT].
The block currently being executed and modal data are displayed. The screen displays up to 22 modal G codes and up to 11 G codes specified in the current block.

Explanations

- 12 soft keys display unit

The current block display screen is not provided for 12 soft keys display unit. Press soft key [PRGRM] to display the contents of the program on the right half of the screen. The block currently being executed is indicated by the cursor. Modal data is displayed on the left half of the screen. The screen displays up to 18 modal G codes.
11.2.3 Next Block Display Screen

Displays the block currently being executed and the block to be executed next in the MEMORY or MDI mode.

Procedure for displaying the next block display screen

Procedure

1. Press function key PROG.

2. Press chapter selection soft key [NEXT].
   The block currently being executed and the block to be executed next are displayed.
   The screen displays up to 11 G codes specified in the current block and up to 11 G codes specified in the next block.

```
PROGRAM O2000 N00130
           (CURRT)                      (NEXT)
   G01   X  17.500                     G39   I  -17.500
   G17   F  2000                       G42
   G41   H   2                         G42
   G80

>  S 0 T0000  MEM STRT
PRGRM | CHECK | CURRNT |  NEXT | OPRT |

16:05:59
```
**11.2.4 Program Check Screen**

Displays the program currently being executed, current position of the tool, and modal data in the MEMORY mode.

**Procedure for displaying the program check screen**

**Procedure**

1. Press function key [PROG].

2. Press chapter selection soft key [CHECK].

The program currently being executed, current position of the tool, and modal data are displayed.

- **Display with one–path control**  
  (7 soft keys display unit)

```
PROGRAM 02000 N00130
C0010:
G92 G90 X100. Y200. Z50. ;
G00 X0 Y0 Z0 ;
G01 Z250. F1000 ;
(ABSOLUTE)(DIST TO GO) G00 G94 G80
X 0.000 X 0.000 G17 G21 G98
Y 0.000 Y 0.000 G90 G40 G50
Z 0.000 Z 0.000 G22 G49 G67
B
H M
T D
F S
MEM STRT *** 16:05:59
[PRGRM] [CHECK] [CURRNT] [NEXT] [(OPRT)]
```

- **Display with two–path control**  
  (7 soft keys display unit)

```
PROGRAM 02000 N00130
C0010:
G92 G90 X100. Y200. Z50. ;
G00 X0 Y0 Z0 ;
G01 Z250. F1000 ;
(ABSOLUTE)(DIST TO GO) G00 G94 G80
X1 0.000 X1 0.000 G17 G21 G98
Y1 0.000 Y1 0.000 G90 G40 G50
Z1 0.000 Z1 0.000 G22 G49 G67
B
H M
T D
F S
MEM STRT *** 16:05:59 HEAD1
[PRGRM] [CHECK] [CURRNT] [NEXT] [(OPRT)]
```
Display with two–path control (12 soft keys display unit)

Explanations

• Program display

The screen displays up to four blocks of the current program, starting from the block currently being executed. The block currently being executed is displayed in reverse video. During DNC operation, however, only three blocks can be displayed.

• Current position display

The position in the workpiece coordinate system or relative coordinate system and the remaining distance are displayed. The absolute positions and relative positions are switched by soft keys [ABS] and [REL]. When there are six or more controlled axes, pressing the [ABS] soft key toggles the display between the absolute coordinates for the first to fifth axes and those for the sixth to eighth axes. Pressing the [REL] soft key toggles the relative coordinate display in the same way.

• Modal G codes

Up to 12 modal G codes are displayed.

• Display during automatic operation

During automatic operation, the actual speed, SACT, and repeat count are displayed. The key input prompt (>_) is displayed otherwise.

• T codes

Then bit 2 (PCT) of parameter No. 3108 is set to 1, the T codes specified with the PMC (HD.T/NX.T) are displayed instead of those specified in the program. Refer to the FANUC PMC Programming Manual (B–61863E) for details of HD.T/NX.T.
The program check screen is not provided for 12 soft keys display unit. Press soft key [PRGRM] to display the contents of the program on the right half of the screen. The block currently being executed is indicated by the cursor. The current position of the tool and modal data are displayed on the left half of the screen.

Up to 18 modal G codes are displayed.
11.2.5 Program Screen for MDI Operation

Displays the program input from the MDI and modal data in the MDI mode.

Procedure for displaying the program screen for MDI operation

**Procedure**

1. Press function key **PROG**.
2. Press chapter selection soft key **[MDI]**. The program input from the MDI and modal data are displayed.

**Explanations**

- **MDI operation**
  See III–4.2 for MDI operation.

- **Modal information**
  The modal data is displayed when bit 7 (MDL) of parameter 3107 is set to 1. Up to 16 modal G codes are displayed. On the 12 soft keys display unit, however, the contents of the program are displayed on the right half of the screen and the modal data is displayed on the left half of the screen, regardless of this parameter.

- **Displaying during automatic operation**
  During automatic operation, the actual speed, SACT, and repeat count are displayed. The key input prompt (> _) is displayed otherwise.
11.2.6 Stamping the Machining Time

When a machining program is executed, the machining time of the main program is displayed on the program machining time display screen. The machining times of up to ten main programs are displayed in hours/minutes/seconds. When more than ten programs are executed, data for the oldest programs is discarded.

Procedure for Stamping Machining Time

Procedure 1

Machining time calculation and display

1. Select the memory operation mode, then press the [RESET] key.
2. Select the program screen, then select a program whose machining time is to be calculated.
3. Execute the program to perform actual machining.
4. When the [RESET] key is pressed, or M02 or M30 is executed, the machining time count operation stops. When the machining time display screen is selected, the program number of the stopped main program and its machining time are displayed.

To display the machining time display screen, use the procedure below. (Machining time data can be displayed in any mode and during background editing.)

- Press the function key [PROG].
- Press the rightmost soft key once or twice to display soft key [TIME].
- Press soft key [TIME]. The machining time display screen appears.

Machining time display screen

<table>
<thead>
<tr>
<th>PROGRAM (TIME)</th>
<th>O0010 N00002</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO.</td>
<td>TIME</td>
</tr>
<tr>
<td>O0020</td>
<td>12H48M02S</td>
</tr>
</tbody>
</table>

> EDIT **** *** ***        16:52:13

[TIME] [ ] [ ] [ ] [ ] [OPRT]
To calculate the machining times of additional programs, repeat the above procedure. The machining time display screen displays the executed main program numbers and their machining times sequentially.

Note, that machining time data cannot be displayed for more than ten main programs. When more than ten programs are executed, data for the oldest programs is discarded. The screens below show how the screen display changes from the initial state where the machining times of ten main programs (O0020, O0040, ..., and O0200) are displayed to the state where the machining time of the main program O0220 is calculated.

<table>
<thead>
<tr>
<th>PROGRAM (TIME)</th>
<th>O0000</th>
<th>N00000</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO.</td>
<td>TIME</td>
<td></td>
</tr>
<tr>
<td>O0020</td>
<td>12H48M01S</td>
<td></td>
</tr>
<tr>
<td>O0040</td>
<td>0H48M01S</td>
<td></td>
</tr>
<tr>
<td>O0060</td>
<td>4H16M01S</td>
<td></td>
</tr>
<tr>
<td>O0080</td>
<td>0H16M01S</td>
<td></td>
</tr>
<tr>
<td>O0100</td>
<td>1H20M01S</td>
<td></td>
</tr>
<tr>
<td>O0120</td>
<td>2H08M02S</td>
<td></td>
</tr>
<tr>
<td>O0140</td>
<td>2H32M01S</td>
<td></td>
</tr>
<tr>
<td>O0160</td>
<td>0H51M01S</td>
<td></td>
</tr>
<tr>
<td>O0180</td>
<td>15H04M01S</td>
<td></td>
</tr>
<tr>
<td>O0200</td>
<td>0H56M01S</td>
<td></td>
</tr>
</tbody>
</table>

**EDIT  **** *** ***  16:52:13**

![Screen shot showing the machining time display screen before calculating O0220's machining time]

<table>
<thead>
<tr>
<th>PROGRAM (TIME)</th>
<th>O0000</th>
<th>N00000</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO.</td>
<td>TIME</td>
<td></td>
</tr>
<tr>
<td>O0040</td>
<td>0H48M01S</td>
<td></td>
</tr>
<tr>
<td>O0060</td>
<td>4H16M01S</td>
<td></td>
</tr>
<tr>
<td>O0080</td>
<td>0H16M01S</td>
<td></td>
</tr>
<tr>
<td>O0100</td>
<td>1H20M01S</td>
<td></td>
</tr>
<tr>
<td>O0120</td>
<td>2H08M02S</td>
<td></td>
</tr>
<tr>
<td>O0140</td>
<td>2H32M01S</td>
<td></td>
</tr>
<tr>
<td>O0160</td>
<td>0H51M01S</td>
<td></td>
</tr>
<tr>
<td>O0180</td>
<td>15H04M01S</td>
<td></td>
</tr>
<tr>
<td>O0200</td>
<td>0H56M01S</td>
<td></td>
</tr>
<tr>
<td>O0220</td>
<td>0H03M01S</td>
<td></td>
</tr>
</tbody>
</table>

**EDIT  **** *** ***  16:52:20**
Procedure 2
Stamping machining time

1 To insert the calculated machining time of a program in a program as a comment, the machining time of the program must be displayed on the machining time display screen. Before stamping the machining time of the program, check that the machining time display screen shows the program number.

2 Set the part program storage and edit mode or background edit state and select the program screen. Then select the program whose machining time is to be inserted.

3 Suppose that the machining time of O0100 is displayed on the machining time display screen. Press soft key [(OPRT)] to display the operation soft keys. Then, hold down the rightmost soft key until soft key [TIME–INSERT] appears. When soft key [TIME–INSERT] is pressed, the cursor moves to the start of the program, and the machining time of the program is inserted after the program number.

```
PROGRAM O0100 N00000
O0100 ;
N10 G92 X100. Z10. ;
N20 S1500 M03 ;
N30 G00 X20.5 Z5. T0101 ;
N40 G01 X–10. F25. ;
N50 G02 X–16.5 Z–12. R2. ;
N60 G01 X40. ;
N70 X42. Z–13. ;
N80 Z–50. ;
N90 X44. Z–51. ;
N100 X80. ;
```

```
EDIT  *** *** ***      16:05:59
[  INS–TM  ][         ][        ][        ][        ]
```

```
PROGRAM O0100 N00000
O0100 [001H20M01S] ;
N10 G92 X100. Z10. ;
N20 S1500 M03 ;
N30 G00 X20.5 Z5. T0101 ;
N40 G01 Z–10. F25. ;
N50 G02 X16.5 Z–12. R2. ;
N60 G01 X40. ;
N70 X42. Z–13. ;
N80 Z–50. ;
N90 X44. Z–51. ;
N100 X80. ;
```

```
EDIT  *** *** ***      16:05:59
[  INS–TM  ][         ][        ][        ][        ]
```
If a comment already exists in the block containing the program number of a program whose machining time is to be inserted, the machining time is inserted after the existing comment.

The machining time of a program inserted as a comment can be displayed after an existing program comment on the program directory screen.
Explanations

• Machining time

Machining time is counted from the initial start after a reset in memory operation mode to the next reset. If a reset does not occur during operation, machining time is counted from the start to M03 (or M30). However, note that the time during which operation is held is not counted, but the time used to wait for completion of M, S, T, and/or B functions is counted.

• Stamping the machining time

The displayed machining time can be inserted (stamped) as a comment in a program stored in memory. Machining time is inserted as a comment after the program number.

• Program directory

The machining time inserted after a program number can be displayed on the program directory screen by setting bit 0 (NAM) of parameter No. 3107 to 1. This lets the user know the machining time of each program. This information is useful as reference data when planning processing.

Limitations

• Alarm

When program execution is terminated by an alarm during the machining time count, the machining time until the alarm is released is counted.

• M02

If the user specifies that M02 does not reset the CNC but returns completion signal FIN to the CNC to restart the program from the beginning successively (with bit 5 (M02) of parameter No. 3404 set to 0), the machining time count stops when M02 returns completion signal FIN.

• Stamping the machining time

When the machining time of a program to be stamped is not displayed on the machining time display screen, the machining time cannot be inserted into the program even if soft key [INS–TM] is pressed.
**Program directory**

When the machining time inserted into a program is displayed on the program directory screen and the comment after the program number consists of only machining time data, the machining time is displayed in both the program name display field and machining time display field.

If machining time data is inserted into a program as shown below, the program directory screen does not display the data or displays only part of the data.

**Example 1: Program directory screen when a program name longer than 16 characters**

```plaintext
PROGRAM DIRECTORY

<table>
<thead>
<tr>
<th>PROGRAM (NUM.)</th>
<th>MEMORY (CHAR.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>USED: 60</td>
<td>3321</td>
</tr>
<tr>
<td>FREE: 2</td>
<td>429</td>
</tr>
</tbody>
</table>

| O0240 (SHAFT XSF301 ) : ( ) |
```

All characters after the first 16 characters of the program comment are discarded and the machining time display field is left blank.
Example 2: Program directory screen when two or more machining times are stamped.

Program directory screen when two or more machining times are stamped.

Only the first machining time is displayed.

Example 2: Program directory screen when two or more machining times are stamped.

Program directory screen when two or more machining times are stamped.

Only the first machining time is displayed.
Example 3: Program directory screen when inserted machining time data does not conform to the format hhhHmMssS (3-digit number followed by H, 2-digit number followed by M, and 2-digit number followed by S, in this order)

```
PROGRAM
O0280 (SHAFT XSF303) : H10M59S
N10 G92 X100. Z10. ;
N20 S1500 M03 ;
N30 G00 X20.5 Z5. T0101 ;
N40 G01 Z-10. F25. ;
N50 G02 X16.5 Z-12. R2. ;
N60 G01 X40. ;
N70 X42. Z-13. ;
N80 Z-50. ;
N90 X44. Z-51. ;
N100 X80. ;
```

The machining time display field is blank.

```
PROGRAM DIRECTORY
PROGRAM (NUM.) MEMORY (CHAR.)
USED: 60 3321
FREE: 2 429

O0260 (SHAFT XSF302) : (001H15M59S)
O0280 (SHAFT XSF303 ) : (      )
```

**Correcting the machining time**

If an incorrect machining time is calculated (such as when a reset occurs during program execution), reexecute the program to calculate the correct machining time. If the machining time display screen displays multiple programs with the same program number, select the machining time of the latest program number for insertion into the program.
11.3 SCREENS DISPLAYED BY FUNCTION KEY \text{PROG} (IN THE EDIT MODE)

This section describes the screens displayed by pressing function key \text{PROG} in the EDIT mode. Function key \text{PROG} in the EDIT mode can display the program editing screen and the program list screen (displays memory used and a list of programs). Pressing function key \text{PROG} in the EDIT mode can also display the conversational graphics programming screen and the floppy file directory screen. See III–9 and 10 for the program editing screen and conversational graphics programming screen. See III–8 for the floppy file directory screen.

11.3.1 Displaying Memory Used and a List of Programs

Displays the number of registered programs, memory used, and a list of registered programs.

Procedure for displaying memory used and a list of programs

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Select the EDIT mode.</td>
</tr>
<tr>
<td>2</td>
<td>Press function key \text{PROG}.</td>
</tr>
<tr>
<td>3</td>
<td>Press chapter selection soft key [\text{DIR}].</td>
</tr>
</tbody>
</table>

![Screen Displaying Memory Used and a List of Programs](image)
Explanations

- **Details of memory used**
  - **PROGRAM NO. USED**
    - *PROGRAM NO. USED*: The number of the programs registered (including the subprograms).
    - *FREE*: The number of programs which can be registered additionally.
  - **MEMORY AREA USED**
    - *MEMORY AREA USED*: The capacity of the program memory in which data is registered (indicated by the number of characters).
    - *FREE*: The capacity of the program memory which can be used additionally (indicated by the number of characters).

- **Program library list**
  - Program Nos. registered are indicated.
  - Also, the program name can be displayed in the program table by setting parameter NAM (No. 3107#0) to 1.

```
PROGRAM DIRECTORY
O0001 N00010
  PROGRAM (NUM.) MEMORY (CHAR.)
  USED: 60 3321
  FREE: 2 429
  O0001 (MACRO–GCODE.MAIN)
  O0002 (MACRO–GCODE.SUB1)
  O0010 (TEST–PROGRAM.ARITHMETIC NO.1)
  O0020 (TEST–PROGRAM.F10–MACRO)
  O0040 (TEST–PROGRAM.OFFSET)
  O0050
  O0100 (INCH/MM CONVERT CHECK NO.1)
  O0200 (MACRO–M CODE.MAIN)
```

- **Program name**
  - Always enter a program name between the control out and control in codes immediately after the program number.
  - Up to 31 characters can be used for naming a program within the parentheses. If 31 characters are exceeded, the exceeded characters are not displayed.
  - Only program number is displayed for the program without any program name.

- **Order in which programs are displayed in the program library list**
  - Programs are displayed in the same order that they are registered in the program library list. However, if bit 4 (SOR) of parameter 3107 is set to 1, programs are displayed in the order of program number starting from the smallest one.
• **Order in which programs are registered**

When no program has been deleted from the list, each program is registered at the end of the list.

If some programs in the list were deleted, then a new program is registered, the new program is inserted in the empty location in the list created by the deleted programs.

**Example**) When bit 4 (SOR) of parameter 3107 is 0

1. After clearing all programs, register programs O0001, O0002, O0003, O0004, and O0005 in this order. The program library list displays the programs in the following order:
   - O0001, O0002, O0003, O0004, O0005

2. Delete O0002 and O0004. The program library list displays the programs in the following order:
   - O0001, O0003, O0005

3. Register O0009. The program library list displays the programs in the following order:
   - O0001, O0009, O0003, O0005
11.3.2 Displaying a Program List for a Specified Group

In addition to the normal listing of the numbers and names of CNC programs stored in memory, programs can be listed in units of groups, according to the product to be machined, for example.

To assign CNC programs to the same group, assign names to those programs, beginning each name with the same character string.

By searching through the program names for a specified character string, the program numbers and names of all the programs having names including that string are listed.

Procedure for Displaying a Program List for a Specified Group

Procedure

1. Enter EDIT or background editing mode.
2. Press the PROG function key.
3. Press the PROG function key or [DIR] soft key to display the program list.
4. Press the [(OPRT)] operation soft key.
5. Press the [GROUP] operation soft key.
7. Enter the character string corresponding to the group for which a search is to be made, using the MDI keys. No restrictions are imposed on the length of a program name. Note, however, that search is made based on only the first 32 characters.

Example: To search for those CNC programs having names that begin with character string “GEAR–1000,” enter the following:

>GEAR–1000*
8 Pressing the [EXEC] operation soft key displays the group–unit program list screen, listing all those programs whose name includes the specified character string.

```
PROGRAM DIRECTORY (GROUP) O0001 N00010
PROGRAM (NUM.) MEMORY (CHAR.)
USED: 60 3321
FREE: 2 429
O0020 (GEAR–1000 MAIN)
O0040 (GEAR–1000 SUB–1)
O0200 (GEAR–1000 SUB–2)
O2000 (GEAR–1000 SUB–3)
```

When the program list consists of two or more pages, the pages can be changed by using a page key.

**Explanations**

- * and ?

In the above example, the asterisk (*) must not be omitted. The asterisk indicates an arbitrary character string (wild card specification).

“GEAR–1000*” indicates that the first nine characters of the target program names must be “GEAR–1000,” followed by an arbitrary character string. If only “GEAR–1000” is entered, a search is made only for those CNC programs having the nine–character name “GEAR–1000.”

A question mark (?) can be used to specify a single arbitrary character. For example, entering “????–1000” enables a search to be made for programs having names which start with four arbitrary characters, followed by “–1000”.

---

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[Example of using wild cards]

(Entered character string) (Group for which the search will be made)
(a) "*" CNC programs having any name
(b) "*ABC" CNC programs having names which end with “ABC”
(c) "ABC*" CNC programs having names which start with “ABC”
(d) "*ABC*" CNC programs having names which include “ABC”
(e) "?A?C" CNC programs having four-character names, the second and fourth characters of which are A and C, respectively
(f) "??A?C" CNC programs having five-character names, the third and fifth characters of which are A and C, respectively
(g) "123*456" CNC programs having names which start with “123” and which end with “456”

• When the specified character string cannot be found
   If no program is located as a result of a search for an entered character string, warning message “DATA NOT FOUND” is displayed on the program list screen.

• Holding the group for which a search is made
   A group–unit program list, generated by a search, is held until the power is turned off or until another search is performed.

• Group for which previous search was made
   After changing the screen from the group–unit program list to another screen, pressing the [PR–GRP] operation soft key (displayed in step 6) redispays the group–unit program list screen, on which the program names for the previously searched group are listed. Using this soft key eliminates the need to enter the relevant character string again to redisplay the search results after changing the screen.

Examples

Assume that the main programs and subprograms for machining gear part number 1000 all have names which include character string “GEAR–1000.” The numbers and names of those programs can be listed by searching through the names of all CNC programs for character string “GEAR–1000.” This function facilitates the management of the CNC programs stored in large–capacity memory.
Press function key to display or set tool compensation values and other data.

This section describes how to display or set the following data:

1. Tool offset value  
2. Settings  
3. Run time and part count  
4. Workpiece origin offset value  
5. Custom macro common variables  
6. Pattern menu and pattern data  
7. Software operator’s panel  
8. Tool life management data  
9. Chopping data  
10. Rotary table dynamic fixture offset data

This section also describes measurement of tool length and the sequence number comparison and stop function.

The pattern menu, pattern data, software operator’s panel, and tool life management data depend on the specifications of the machine tool builder. See the manual issued by the machine tool builder for details.
11.4.1 Setting and Displaying the Tool Offset Value

Tool offset values, tool length offset values, and cutter compensation values are specified by D codes or H codes in a program. Compensation values corresponding to D codes or H codes are displayed or set on the screen.

Procedure for setting and displaying the tool offset value

Procedure

1. Press function key [OFFSET].

   For the two-path control, select the tool post for which tool compensation values are to be displayed with the tool post selection switch.

2. Press chapter selection soft key [OFFSET] or press [OFFSET] several times until the tool compensation screen is displayed. The screen varies according to the type of tool offset memory.

   Tool offset memory A

<table>
<thead>
<tr>
<th>OFFSET</th>
<th>O0001 N00000</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO.</td>
<td>DATA</td>
</tr>
<tr>
<td>001</td>
<td>0.000</td>
</tr>
<tr>
<td>002</td>
<td>-2.000</td>
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<tr>
<td>003</td>
<td>0.000</td>
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<tr>
<td>004</td>
<td>5.000</td>
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<td>005</td>
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<tr>
<td>006</td>
<td>0.000</td>
</tr>
<tr>
<td>007</td>
<td>0.000</td>
</tr>
<tr>
<td>008</td>
<td>0.000</td>
</tr>
</tbody>
</table>

   ACTUAL POSITION (RELATIVE)
   - X: 0.000
   - Y: 0.000
   - Z: 0.000

   MDI **** *** ***      16:05:59
   [OFFSET] [SETTING] [WORK] [ ] (OPRT)

   Tool offset memory C

<table>
<thead>
<tr>
<th>OFFSET</th>
<th>O0001 N00000</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO.</td>
<td>GEOM(H)</td>
</tr>
<tr>
<td>001</td>
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</tr>
<tr>
<td>002</td>
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<td>20.000</td>
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<tr>
<td>005</td>
<td>0.000</td>
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<td>006</td>
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</tr>
<tr>
<td>007</td>
<td>0.000</td>
</tr>
<tr>
<td>008</td>
<td>0.000</td>
</tr>
</tbody>
</table>

   ACTUAL POSITION (RELATIVE)
   - X: 0.000
   - Y: 0.000
   - Z: 0.000

   MDI **** *** ***      16:05:59
   [OFFSET] [SETTING] [WORK] [ ] (OPRT)
3 Move the cursor to the compensation value to be set or changed using page keys and cursor keys, or enter the compensation number for the compensation value to be set or changed and press soft key [NO.SRH].

4 To set a compensation value, enter a value and press soft key [INPUT]. To change the compensation value, enter a value to add to the current value (a negative value to reduce the current value) and press soft key [+INPUT]. Or, enter a new value and press soft key [INPUT].

Explanations

• Decimal point input
A decimal point can be used when entering a compensation value.

• Other setting method
An external input/output device can be used to input or output a tool offset value. See III–8. A tool length offset value can be set by measuring the tool length as described in the next subsection.

• Tool offset memory
There are tool offset memories A, B, and C, which are classified as follows:

  **Tool offset memory A**
  D codes and H codes are treated the same. Tool geometry compensation and tool wear compensation are treated the same.

  **Tool offset memory B**
  D codes and H codes are treated the same. Tool geometry compensation and tool wear compensation are treated differently.

  **Tool offset memory C**
  D codes and H codes are treated differently. Tool geometry compensation and tool wear compensation are treated differently.

• Disabling entry of compensation values
The entry of compensation values may be disabled by setting bit 0 (WOF) and bit 1 (GOF) of parameter 3290 (not applied to tool offset memory A). And then, the input of tool compensation values from the MDI can be inhibited for a specified range of offset numbers. The first offset number for which the input of a value is inhibited is set in parameter No. 3294. The number of offset numbers, starting from the specified first number, for which the input of a value is inhibited is set in parameter No. 3295. Consecutive input values are set as follows:

1) When values are input for offset numbers, starting from one for which input is not inhibited to one for which input is inhibited, a warning is issued and values are set only for those offset numbers for which input is not inhibited.

2) When values are input for offset numbers, starting from one for which input is inhibited to one for which input is not inhibited, a warning is issued and no values are set.
### 11. SETTING AND DISPLAYING DATA

- **12 soft keys display unit**

**OFFSET**

<table>
<thead>
<tr>
<th>NO.</th>
<th>DATA</th>
<th>NO.</th>
<th>DATA</th>
<th>ACTUAL POSITION (RELATIVE)</th>
</tr>
</thead>
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<td>0.000</td>
<td>017</td>
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<td>018</td>
<td>0.000</td>
<td>Y–12345.678</td>
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<td>003</td>
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<td>019</td>
<td>0.000</td>
<td>Z–12345.678</td>
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<td>C–12345.678</td>
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<td>8–12345.678</td>
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<tr>
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<td>025</td>
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>_<MDI **** *** *** 20:45:00

#### Tool offset memory A

**OFFSET**

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<th>ACTUAL POSITION (RELATIVE)</th>
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</thead>
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<td>X 0.000</td>
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<tr>
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<td>0.000</td>
<td>0.000</td>
<td>Y 0.000</td>
</tr>
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<td></td>
</tr>
<tr>
<td>016</td>
<td>0.000</td>
<td>0.000</td>
<td></td>
</tr>
</tbody>
</table>

>_<MDI **** *** *** 20:45:00

#### Tool offset memory C
11.4.2 Tool Length Measurement

The length of the tool can be measured and registered as the tool length offset value by moving the reference tool and the tool to be measured until they touch the specified position on the machine. The tool length can be measured along the X-, Y-, or Z-axis.

Procedure for tool length measurement

**Procedure**

1. Use manual operation to move the reference tool until it touches the specified position on the machine (or workpiece.)

2. Press function key \[\text{POS}\] several times until the current position display screen with relative coordinates is displayed.

3. Reset the relative coordinate for the Z-axis to 0 (see III–11.1.2 for details).

4. Press function key \[\text{OFFSET SETTING}\] several times until the tool compensation screen is displayed.

5. Use manual operation to move the tool to be measured until it touches the same specified position. The difference between the length of the reference tool and the tool to be measured is displayed in the relative coordinates on the screen.

6. Move the cursor to the compensation number for the target tool (the cursor can be moved in the same way as for setting tool compensation values).

7. Press the address key \[\text{Z}\].

If either \[\text{X}\] or \[\text{Y}\] key is depressed instead of \[\text{Z}\] key, the X or Y axis relative coordinate value is input as an tool length compensation value.
8 Press the soft key [INP.C.]. The Z axis relative coordinate value is input and displayed as an tool length offset value.
11. SETTING AND DISPLAYING DATA

11.4.3 Displaying and Entering Setting Data

Data such as the TV check flag and punch code is set on the setting data screen. On this screen, the operator can also enable/disable parameter writing, enable/disable the automatic insertion of sequence numbers in program editing, and perform settings for the sequence number comparison and stop function.

See III–10.2 for automatic insertion of sequence numbers.
See III–11.4.4 for the sequence number comparison and stop function.

This subsection describes how to set data.

Procedure for setting the setting data

Procedure

1. Select the MDI mode.

2. Press function key [OFFSET SETING].

3. Press soft key [SETTING] to display the setting data screen. This screen consists of several pages.

   Press page key [PAGE] or [PAGE] until the desired screen is displayed.

An example of the setting data screen is shown below.

```
SETTING (HANDY) O0001 N00000
PARAMETER WRITE = 1:DISABLE 1:ENABLE)
TV CHECK = 0:OFF 1:ON)
PUNCH CODE = 1:EIA 1:ISO)
INPUT UNIT = 0:MM 1:INCH)
I/O CHANNEL = 0:0–3:CHANNEL NO.)
SEQUENCE NO. = 0:OFF 1:ON)
TAPE FORMAT = 0:NO CNV 1:F15)
SEQUENCE STOP = 0:PROGRAM NO.)
SEQUENCE STOP = 0:SEQUENCE NO.)
> _ MDI **** *** *** 16:05:59
[ OFFSET ] [ SETING ] [ WORK ] [ ] [ (OPRT) ]
```

```
SETTING (HANDY) O0001 N00000
MIRROR IMAGE X = 0:OFF 1:ON)
MIRROR IMAGE Y = 0:OFF 1:ON)
MIRROR IMAGE Z = 0:OFF 1:ON)
> _ MDI **** *** *** 16:05:59
[ OFFSET ] [ SETING ] [ WORK ] [ ] [ (OPRT) ]
```
4. Move the cursor to the item to be changed by pressing cursor keys \( \uparrow \), \( \downarrow \), \( \leftarrow \), or \( \rightarrow \).

5. Enter a new value and press soft key [INPUT].

**Contents of settings**

- **PARAMETER WRITE**
  Setting whether parameter writing is enabled or disabled.
  - 0: Disabled
  - 1: Enabled

- **TV CHECK**
  Setting to perform TV check.
  - 0: No TV check
  - 1: Perform TV check

- **PUNCH CODE**
  Setting code when data is output through reader puncher interface.
  - 0: EIA code output
  - 1: ISO code output

- **INPUT UNIT**
  Setting a program input unit, inch or metric system
  - 0: Metric
  - 1: Inch

- **I/O CHANNEL**
  Using channel of reader/puncher interface.
  - 0: Channel 0
  - 1: Channel 1
  - 2: Channel 2
  - 3: Channel 3

- **SEQUENCE STOP**
  Setting of whether to perform automatic insertion of the sequence number or not at program edit in the EDIT mode.
  - 0: Does not perform automatic sequence number insertion.
  - 1: Perform automatic sequence number insertion.

- **TAPE FORMAT**
  Setting the F15 tape format conversion.
  - 0: Tape format is not converted.
  - 1: Tape format is converted.
  See II. PROGRAMMING for the F15 tape format.

- **SEQUENCE STOP**
  Setting the sequence number with which the operation stops for the sequence number comparison and stop function and the number of the program to which the sequence number belongs

- **MIRROR IMAGE**
  Setting of mirror image ON/OFF for each axes.
  - 0: Mirror image off
  - 1: Mirror image on

- **Others**
  Page key \( \text{PAGE} \) or \( \text{PAGE} \) can also be pressed to display the SETTING (TIMER) screen. See III–11.4.5 for this screen.
11. SETTING AND DISPLAYING DATA

11. SETTING AND DISPLAYING DATA

11.4.4 Sequence Number Comparison and Stop

If a block containing a specified sequence number appears in the program being executed, operation enters single block mode after the block is executed.

Procedure for sequence number comparison and stop

Procedure

1. Select the MDI mode.
2. Press function key OFFSET SETING.
3. Press chapter selection soft key [SETTING].
4. Press page key PAGE or PAGE several times until the following screen is displayed.

```
SETTING (HANDY) O0001N00000
PARAMETER WRITE = 1 (0:DISABLE 1:ENABLE)
TV CHECK = 0 (0:OFF 1:ON)
PUNCH CODE = 1 (0:EIA 1:ISO)
INPUT UNIT = 0 (0:MM 1:INCH)
I/O CHANNEL = 0 (0-3:CHANNEL NO.)
SEQUENCE NO. = 0 (0:OFF 1:ON)
TAPE FORMAT = 0 (0:NO CNV 1:F10/11)
SEQUENCE STOP = 0 (PROGRAM NO.)
SEQUENCE STOP = 11 (SEQUENCE NO.)

> MDI **** *** *** 16:05:59
[OFFSET] [SETTING] [ WORK ] [ ] [(OPRT)]
```

5. Enter in (PROGRAM NO.) for SEQUENCE STOP the number (1 to 9999) of the program containing the sequence number with which operation stops.
6. Enter in (SEQUENCE NO.) for SEQUENCE STOP (with five or less digits) the sequence number with which operation is stopped.
7. When automatic operation is executed, operation enters single block mode at the block containing the sequence number which has been set.
Explanations

• Sequence number after the program is executed
  After the specified sequence number is found during the execution of the program, the sequence number set for sequence number compensation and stop is decremented by one. When the power is turned on, the setting of the sequence number is 0.

• Exceptional blocks
  If the predetermined sequence number is found in a block in which all commands are those to be processed within the CNC control unit, the execution does not stop at that block.
  
  Example
  
  N1 #1=1 ;
  N2 IF [#1 EQ 1] GOTO 08 ;
  N3 GOTO 09 ;
  N4 M98 P1000 ;
  N5 M99 ;
  
  In the example shown above, if the predetermined sequence number is found, the execution of the program does not stop.

• Stop in the canned cycle
  If the predetermined sequence number is found in a block which has a canned-cycle command, the execution of the program stops after the return operation is completed.

• When the same sequence number is found several times in the program
  If the predetermined sequence number appears twice or more in a program, the execution of the program stops after the block in which the predetermined sequence number is found for the first time is executed.

• Block to be repeated a specified number of times
  If the predetermined sequence number is found in a block which is to be executed repeatedly, the execution of the program stops after the block is executed specified times.
11. SETTING AND DISPLAYING DATA

11.4.5 Displaying and Setting Run Time, Parts Count, and Time

Various run times, the total number of machined parts, number of parts required, and number of machined parts can be displayed. This data can be set by parameters or on this screen (except for the total number of machined parts and the time during which the power is on, which can be set only by parameters). This screen can also display the clock time. The time can be set on the screen.

Procedure for Displaying and Setting Run Time, Parts Count and Time

**Procedure**

1. Select the MDI mode.
2. Press function key [OFFSET SETING].
3. Press chapter selection soft key [SETTING].
4. Press page key [PAGE] or several times until the following screen is displayed.

```
PARTS TOTAL = 14
PARTS REQUIRED = 0
PARTS COUNT = 23
POWER ON = 4H 31M
OPERATING TIME = 0H 0M 0S
CUTTING TIME = 0H 37M 5S
FREE PURPOSE = 0H 0M 0S
CYCLE TIME = 0H 0M 0S
DATE = 2001/07/05
TIME = 11:32:52

> _
MDI **** *** *** 16:05:59
[ OFFSET ] [ SETING ] [ WORK ] [ ] [ (OPRT) ]
```

5. To set the number of parts required, move the cursor to PARTS REQUIRED and enter the number of parts to be machined.
6. To set the clock, move the cursor to DATE or TIME, enter a new date or time, then press soft key [INPUT].

**Display items**

- **PARTS TOTAL**
  
  This value is incremented by one when M02, M30, or an M code specified by parameter 6710 is executed. This value cannot be set on this screen. Set the value in parameter 6712.

- **PARTS REQUIRED**
  
  It is used for setting the number of machined parts required. When the “0” is set to it, there is no limitation to the number of parts. Also, its setting can be made by the parameter (NO. 6713).
• **PARTS COUNT**

This value is incremented by one when M02, M30, or an M code specified by parameter 6710 is executed. The value can also be set by parameter 6711. In general, this value is reset when it reaches the number of parts required. Refer to the manual issued by the machine tool builder for details.

• **POWER ON**

Displays the total time which the power is on. This value cannot be set on this screen but can be preset in parameter 6750.

• **OPERATING TIME**

Indicates the total run time during automatic operation, excluding the stop and feed hold time. This value can be preset in parameter 6751 or 6752.

• **CUTTING TIME**

Displays the total time taken by cutting that involves cutting feed such as linear interpolation (G01) and circular interpolation (G02 or G03). This value can be preset in parameter 6753 or 6754.

• **FREE PURPOSE**

This value can be used, for example, as the total time during which coolant flows. Refer to the manual issued by the machine tool builder for details.

• **CYCLE TIME**

Indicates the run time of one automatic operation, excluding the stop and feed hold time. This is automatically preset to 0 when a cycle start is performed at reset state. It is preset to 0 even when power is removed.

• **DATA and TIME**

Displays the current date and time. The date and time can be set on this screen.

**Limitations**

**• Usage**

When the command of M02 or M30 is executed, the total number of machined parts and the number of machined parts are incremented by one. Therefore, create the program so that M02 or M30 is executed every time the processing of one part is completed. Furthermore, if an M code set to the parameter (NO. 6710) is executed, counting is made in the similar manner. Also, it is possible to disable counting even if M02 or M30 is executed (parameter PCM (No. 6700#0) is set to 1). For details, see the manual issued by machine tool builders.

**Restrictions**

**• Run time and part count settings**

Negative value cannot be set. Also, the setting of “M” and “S” of run time is valid from 0 to 59.

Negative value may not be set to the total number of machined parts.

**• Time settings**

Neither negative value nor the value exceeding the value in the following table can be set.

<table>
<thead>
<tr>
<th>Item</th>
<th>Maximum value</th>
<th>Item</th>
<th>Maximum value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
<td>2085</td>
<td>Hour</td>
<td>23</td>
</tr>
<tr>
<td>Month</td>
<td>12</td>
<td>Minute</td>
<td>59</td>
</tr>
<tr>
<td>Day</td>
<td>31</td>
<td>Second</td>
<td>59</td>
</tr>
</tbody>
</table>
11. SETTING AND DISPLAYING DATA

11.4.6 Displaying and Setting the Workpiece Origin Offset Value

Displays the workpiece origin offset for each workpiece coordinate system (G54 to G59, G54.1 P1 to G54.1 P48 and G54.1 P1 to G54.1 P300) and external workpiece origin offset. The workpiece origin offset and external workpiece origin offset can be set on this screen.

Procedure for Displaying and Setting the Workpiece Origin Offset Value

Procedure

1. Press function key [OFFSET SETTING].

2. Press chapter selection soft key [WORK].
The workpiece coordinate system setting screen is displayed.

<table>
<thead>
<tr>
<th>WORK COORDINATES</th>
<th>00001 N00000</th>
</tr>
</thead>
<tbody>
<tr>
<td>(G54) 00 X 0.000</td>
<td>(G54) 02 X 152.580</td>
</tr>
<tr>
<td>(EXT) 00 Y 0.000</td>
<td>(G55) 02 Y 234.000</td>
</tr>
<tr>
<td></td>
<td>Z 0.000</td>
</tr>
<tr>
<td></td>
<td>Z 112.000</td>
</tr>
<tr>
<td>01 (G54) X 20.000</td>
<td>03 (G56) X 300.000</td>
</tr>
<tr>
<td></td>
<td>Y 50.000</td>
</tr>
<tr>
<td></td>
<td>Z 30.000</td>
</tr>
<tr>
<td></td>
<td>Y 200.000</td>
</tr>
<tr>
<td></td>
<td>Z 189.000</td>
</tr>
</tbody>
</table>

> S 0 T0000
MDI **** *** *** 16:05:59
[OFFSET] [SETTING] [WORK] [ (OPRT) ]

3. The screen for displaying the workpiece origin offset values consists of two or more pages. Display a desired page in either of the following two ways:
   - Press the page up or page down key.
   - Enter the workpiece coordinate system number (0 : external workpiece origin offset, 1 to 6: workpiece coordinate systems G54 to G59, P1 to P48 : workpiece coordinate systems G54.1 P1 to G54.1 P48, P1 to P300 : workpiece coordinate systems G54.1 P1 to G54.1 P300) and press operation selection soft key [NO.SRH].

4. Turn off the data protection key to enable writing.

5. Move the cursor to the workpiece origin offset to be changed.

6. Enter a desired value by pressing numeric keys, then press soft key [INPUT]. The entered value is specified in the the workpiece origin offset value. Or, by entering a desired value with numeric keys and pressing soft key [+INPUT], the entered value can be added to the previous offset value.

7. Repeat 5 and 6 to change other offset values.

8. Turn on the data protection key to disable writing.
11.4.7 Direct Input of Measured Workpiece Origin Offsets

This function is used to compensate for the difference between the programmed workpiece coordinate system and the actual workpiece coordinate system. The measured offset for the origin of the workpiece coordinate system can be input on the screen such that the command values match the actual dimensions. Selecting the new coordinate system matches the programmed coordinate system with the actual coordinate system.

Procedure for Direct Inputting of Measured Workpiece Origin Offsets

Procedure

1. When the workpiece is shaped as shown above, position the reference tool manually until it touches surface A of the workpiece.
2. Retract the tool without changing the Y coordinate.
3. Measure distance $\alpha$ between surface A and the programmed origin of the workpiece coordinate system as shown above.
4. Press function key $\text{OFFSET SETTING}$.
5. To display the workpiece origin offset setting screen, press the chapter selection soft key [WORK].

<table>
<thead>
<tr>
<th>NO.</th>
<th>DATA</th>
<th>NO.</th>
<th>DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>X 0.000</td>
<td>02</td>
<td>X 0.000</td>
</tr>
<tr>
<td>(EXT)</td>
<td>Y 0.000</td>
<td>(G55)</td>
<td>Y 0.000</td>
</tr>
<tr>
<td></td>
<td>Z 0.000</td>
<td></td>
<td>Z 0.000</td>
</tr>
<tr>
<td>01</td>
<td>X 0.000</td>
<td>03</td>
<td>X 0.000</td>
</tr>
<tr>
<td>(G54)</td>
<td>Y 0.000</td>
<td>(G56)</td>
<td>Y 0.000</td>
</tr>
<tr>
<td></td>
<td>Z 0.000</td>
<td></td>
<td>Z 0.000</td>
</tr>
</tbody>
</table>

6. Position the cursor to the workpiece origin offset value to be set.

7. Press the address key for the axis along which the offset is to be set (Y-axis in this example).

8. Enter the measured value ($\alpha$) then press the [MEASUR] soft key.

9. Move the reference tool manually until it touches surface B of the workpiece.

10. Retract the tool without changing the X coordinate.

11. Measure distance $\beta$ then enter the distance at X on the screen in the same way as in steps 7 and 8.

**Limitations**

- **Consecutive input**: Offsets for two or more axes cannot be input at the same time.
- **During program execution**: This function cannot be used while a program is being executed.
11.4.8 Displaying and Setting Custom Macro Common Variables

Displays common variables (#100 to #149 or #100 to #199, and #500 to #531 or #500 to #999) on the CRT. When the absolute value for a common variable exceeds 99999999, ******** is displayed. The values for variables can be set on this screen. Relative coordinates can also be set to variables.

Procedure for displaying and setting custom macro common variables

Procedure

1. Press function key [OFFSET SETTING].

2. Press the continuous menu key [MACRO], then press chapter selection soft key [MACRO]. The following screen is displayed:

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>O0001 N00000</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO.</td>
<td>DATA</td>
</tr>
<tr>
<td>100</td>
<td>1000.000</td>
</tr>
<tr>
<td>101</td>
<td>0.000</td>
</tr>
<tr>
<td>102</td>
<td>-50000.000</td>
</tr>
<tr>
<td>103</td>
<td>0.000</td>
</tr>
<tr>
<td>104</td>
<td>1238501.0</td>
</tr>
<tr>
<td>105</td>
<td>0.000</td>
</tr>
<tr>
<td>106</td>
<td>0.000</td>
</tr>
<tr>
<td>107</td>
<td>0.000</td>
</tr>
</tbody>
</table>

   ACTUAL POSITION (RELATIVE)
   X 0.000    Y 0.000    Z 0.000

   > _  S 0 T0000
   MDI **** *** *** 16:05:59
   [NO.SRH] [ ] [ INP.C. ] [ ] [ INPUT ]

3. Move the cursor to the variable number to set using either of the following methods:
   - Enter the variable number and press soft key [NO.SRH].
   - Move the cursor to the variable number to set by pressing page keys [PAGE] and/or [PAGE] and cursor keys [↑], [↓], [←], and/or [→].

4. Enter data with numeric keys and press soft key [INPUT].

5. To set a relative coordinate in a variable, press address key [X], [Y], or [Z], then press soft key [INP.C.].

6. To set a blank in a variable, just press soft key [INPUT]. The value field for the variable becomes blank.
11. SETTING AND DISPLAYING DATA

11.4.9 Displaying Pattern Data and Pattern Menu

This subsection uses an example to describe how to display or set machining menus (pattern menus) created by the machine tool builder. Refer to the manual issued by the machine tool builder for the actual pattern menus and pattern data. See II. PROGRAMMING for the pattern data entry function.

Procedure for displaying the pattern data and the pattern menu

Procedure

1. Press function key SETTING.

2. Press the continuous menu key MENU, then press chapter selection soft keyMENU.
The following screen (pattern menu screen) is displayed:

```
MENU : HOLE PATTERN  O0000 N00000
1. TAPPING
2. DRILLING
3. BORING
4. POCKET
5. BOLT HOLE
6. LINE ANGLE
7. GRID
8. PECK
9.
10.
```

3. Enter a pattern number and press soft key SELECT.
In this example, press 5, then press SELECT.
The following screen (pattern data screen) is displayed:

```
VAR. : BOLT HOLE  O0001 N00000
NO.  NAME  DATA  COMMENT
500  TOOL  0.000
501  STANDARD X  0.000  *BOLT HOLE
502  STANDARD Y  0.000  CIRCLE*
503  RADIUS  0.000  SET PATTERN
504  S. ANGL  0.000  DATA TO VAR.
505  HOLES NO  0.000  NO.500–505.
506  0.000
507  0.000

ACTUAL POSITION (RELATIVE)
X  0.000  Y  0.000
> Z  0.000
```

--- 1046 ---
4 Enter necessary pattern data and press \textbf{INPUT}.

5 After entering all necessary data, enter the \textbf{MEMORY} mode and press the cycle start button to start machining.

\textbf{Explanations}

\begin{itemize}
  \item \textbf{Explanation of the pattern menu screen}
    \begin{itemize}
      \item \textbf{HOLE PATTERN} : Menu title
        An optional character string can be displayed within 12 characters.
      \end{itemize}
    \end{itemize}

\begin{itemize}
  \item \textbf{BOLE HOLE} : Pattern name
    An optional character string can be displayed within 10 characters.
  \end{itemize}

The machine tool builder should program character strings of menu title and pattern name by custom macro, and load them into the program memory.

\begin{itemize}
  \item \textbf{BOLT HOLE} : Pattern data title
    An optional character string can be displayed within 12 characters.
  \end{itemize}

\begin{itemize}
  \item \textbf{TOOL} : Variable name
    An optional character string can be displayed within 10 characters.
  \end{itemize}

\begin{itemize}
  \item \textbf{BOLT HOLE CIRCLE} : Comment statement
    An optional character string comment can be displayed up to 12 characters/line by 8 lines.
  \end{itemize}

The machine tool builder should program the character strings of variable name and comment statement by custom macro, and load them into the program memory.
With this function, functions of the switches on the machine operator’s panel can be controlled from the CRT/MDI panel. Jog feed can be performed using numeric keys.

**Procedure for displaying and setting the software operator’s panel**

1. Press function key `OFFSET SETTING`.

2. Press the continuous menu key `MOPR`, then press chapter selection soft key `[OPR]`.

3. The screen consists of several pages. Press page key `↑` or `↓` until the desired screen is displayed.

<table>
<thead>
<tr>
<th>OPERATOR’S PANEL</th>
<th>O0000 N00000</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MODE</strong>: MDI MEM EDIT HNDL JOG REF</td>
<td></td>
</tr>
<tr>
<td><strong>STEP MULTI.</strong>: *1 *10 *100</td>
<td></td>
</tr>
<tr>
<td><strong>RAPID OVRD.</strong>: 100% 50% 25% F0</td>
<td></td>
</tr>
<tr>
<td><strong>JOG FEED</strong>: 2.0% ***************</td>
<td></td>
</tr>
<tr>
<td><strong>FEED OVRD.</strong>: 100% ***</td>
<td></td>
</tr>
<tr>
<td><strong>ACTUAL POSITION (ABSOLUTE)</strong></td>
<td></td>
</tr>
<tr>
<td>X 0.000 Y 0.000 Z 0.000</td>
<td></td>
</tr>
<tr>
<td>&gt; MDI ***** ***** 16:05:59</td>
<td></td>
</tr>
<tr>
<td>[ MACRO ] [ ] [ OPR ] [TOOLLF] [ (OPRT) ]</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>OPERATOR’S PANEL</th>
<th>O0000 N00000</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BLOCK SKIP</strong> : OFF ON</td>
<td></td>
</tr>
<tr>
<td><strong>SINGLE BLOCK</strong> : OFF ON</td>
<td></td>
</tr>
<tr>
<td><strong>MACHINE LOCK</strong> : OFF ON</td>
<td></td>
</tr>
<tr>
<td><strong>PROTECT KEY</strong> : PROTECT RELEASE</td>
<td></td>
</tr>
<tr>
<td><strong>FEED HOLD</strong> : OFF</td>
<td></td>
</tr>
<tr>
<td><strong>ACTUAL POSITION (ABSOLUTE)</strong></td>
<td></td>
</tr>
<tr>
<td>X 0.000 Y 0.000 Z 0.000</td>
<td></td>
</tr>
<tr>
<td>&gt; S 0 T0000 MDI ***** ***** 16:05:59</td>
<td></td>
</tr>
<tr>
<td>[ MACRO ] [ ] [ OPR ] [TOOLLF] [ (OPRT) ]</td>
<td></td>
</tr>
</tbody>
</table>
4 Move the cursor to the desired switch by pressing cursor key \( \uparrow \) or \( \downarrow \).

5 Push the cursor move key \( \leftarrow \) or \( \rightarrow \) to match the mark \( \square \) to an arbitrary position and set the desired condition.

6 Press one of the following arrow keys to perform jog feed. Press the \( 5 \) key together with an arrow key to perform jog rapid traverse.

\[
\begin{array}{cccc}
7 & 8 & 9 \\
4 & 5 & 6 \\
1 & 2 & 3 \\
\end{array}
\]

**Explanations**

- **Valid operations**
  
  The valid operations on the software operator’s panel are shown below. Whether to use the CRT/MDI panel or machine operator’s panel for each group of operations can be selected by parameter 7200.

  - Group1 : Mode selection
  - Group2 : Selection of jog feed axis, jog rapid traverse
  - Group3 : Selection of manual pulse generator feed axis, selection of manual pulse magnification x1, x10, x100
  - Group4 : Jog federate, federate override, rapid traverse override
  - Group5 : Optional block skip, single block, machine lock, dry run
  - Group6 : Protect key
  - Group7 : Feed hold

- **Display**

  The groups for which the machine operator’s panel is selected by parameter 7200 are not displayed on the software operator’s panel.

- **Screens on which jog feed is valid**

  When the CRT indicates other than the software operator’s panel screen and diagnostic screen, jog feed is not conducted even if the arrow key is pushed.

- **Jog feed and arrow keys**

  The feed axis and direction corresponding to the arrow keys can be set with parameters (Nos. 7210 to 7217).

- **General purpose switches**

  Eight optionally definable switches are added as an extended function of the software operator’s panel. The name of these switches can be set by parameters (Nos. 7220 to 7283) as character strings of max. 8 characters. For the meanings of these switches, refer to the manual issued by machine tool builder.
Tool life data can be displayed to inform the operator of the current state of tool life management. Groups which require tool changes are also displayed. The tool life counter for each group can be preset to an arbitrary value. Tool data (execution data) can be reset or cleared. To register or modify tool life management data, a program must be created and executed. See Explanations in this section for details.

When bit 6 (EXT) of parameter 6801 is 1, extended tool life management applies. See III–11.4.12.

**Procedure for display and setting the tool life management data**

1. Press function key OFFSET SETTING.
2. Press the continuous menu key to display chapter selection soft key [TOOLLF].
3. Press softkey [TOOLLF].
4. One page displays data on two groups. Pressing page key successively displays data on the following groups. Up to four group Nos., for which the Tool Change signal is being issued, are displayed at the bottom of each page. An arrow shown in the figure is displayed for five or more groups, if exists.

```
TOOL LIFE DATA : O3000 N00060
SELECTED GROUP 000
GROUP 001 : LIFE 0150 COUNT 0000
  0034 0078 0012 0056
  0090 0035 0026 0061
  0000 0000 0000 0000
  0000 0000 0000 0000
GROUP 002 : LIFE 1400 COUNT 0000
  0062 0024 0044 0074
  0000 0000 0000 0000
  0000 0000 0000 0000
  0000 0000 0000 0000
TO BE CHANGED : 003 004 005 006
> MEM **** **** 16:05:59 [ MACRO ] [ OPR ] [ TOOLLF ] [ (OPRT) ]
```
5 To display the page containing the data for a group, enter the group number and press soft key [NO.SRH].
   The cursor can be moved to an arbitrary group by pressing cursor key \( \uparrow \) or \( \downarrow \).

6 To change the value in the life counter for a group, move the cursor to the group, enter a new value (four digits), and press [INPUT]. The life counter for the group indicated by the cursor is preset to the entered value. Other data for the group is not changed.

7 To reset the tool data, move the cursor on the group to reset, then press the [OPRT], [CLEAR], and [EXEC] soft keys in this order. All execution data for the group indicated by the cursor is cleared together with the marks (@, #, or *).
Explanations

- **Display contents**

```
TOOL LIFE DATA : O3000 N00060

SELECTED GROUP 000

GROUP 001 : LIFE 0150 COUNT 0007
          * 0034 #0078 @ 0012 0056
          0090 0035 0026 0061
          0000 0000 0000 0000
          0000 0000 0000 0000

GROUP 002 : LIFE 1400 COUNT 0000
          0062 0024 0044 0074
          0000 0000 0000 0000
          0000 0000 0000 0000
          0000 0000 0000 0000

TO BE CHANGED : 003 004 005 006

MEM ***** *** 16:05:59
[ MACRO ][ ] [ OPR ][ TOOLLF (OPRT) ]
```

- The first line is the title line.
- In the second line the group number of the current command is displayed. When there is no group number of the current command, 0 is displayed.
- In lines 3 to 7 the tool life data of the group is displayed. The third line displays group number, life and the count used. The life count is chosen by parameter LTM (No. 6800#2) as either minutes (or hours) or number of times used. In lines 4 to 5, tool numbers are displayed. In this case, the tool is selected in the order, 0034 → 0078 → 0012 → 056 → 0090 ...
  The meaning of each mark before the tool numbers is:
  * : Shows the life has finished.
  # : Shows that the skip command has been accepted.
  @ : Shows that the tool is currently being used.

- Lines 8 to 12 are next group life data to the group displayed in lines 3 to 7.
- In the thirteenth line the group number when the tool change signal is being emitted is displayed. The group number display appears in ascending order. When it cannot be completely displayed, “——>” is displayed.
11.4.12 Displaying and Setting Extended Tool Life Management

The extended tool life management function provides more detailed data display and more data editing functions than the ordinary tool life management function. Moreover, if the tool life is specified in units of time, the time which has been set can be increased or reduced (life count override). When bit 6 (EXT) of parameter 6801 is set to 0, the ordinary tool life management function applies. See III–11.4.11.

Procedure for displaying and setting extended tool life management

Procedure

1. Press function key \[ \text{OFFSET SETTING} \].
2. Press the continuous menu key \[ \rightarrow \] to display chapter selection soft key \[ \text{TOOLLF} \].
3. Press soft key \[ \text{TOOLLF} \] to display the tool life management data screen. On this screen, place the cursor on a group of items to be edited.
4. Press soft key \[ \text{(OPRT)} \].
5. Press soft key \[ \text{EDIT} \]. The extended tool life management data editing screen for the group indicated by the cursor is the displayed.

<table>
<thead>
<tr>
<th>( \text{NO.} )</th>
<th>( \text{STATE} )</th>
<th>( \text{T-CODE} )</th>
<th>( \text{H-CODE} )</th>
<th>( \text{D-CODE} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>*</td>
<td>0034</td>
<td>011</td>
<td>005</td>
</tr>
<tr>
<td>02</td>
<td>#</td>
<td>0078</td>
<td>000</td>
<td>033</td>
</tr>
<tr>
<td>03</td>
<td>@</td>
<td>0012</td>
<td>004</td>
<td>018</td>
</tr>
<tr>
<td>04</td>
<td>*</td>
<td>0056</td>
<td>000</td>
<td>000</td>
</tr>
<tr>
<td>05</td>
<td>*</td>
<td>0090</td>
<td>000</td>
<td>000</td>
</tr>
<tr>
<td>06</td>
<td>*</td>
<td>0076</td>
<td>023</td>
<td>( \text{012} )</td>
</tr>
</tbody>
</table>

MDI **** *** *** 16:05:59
[ INSERT ] [ DELETE ] [ STATE ] [ END ] [ INPUT ]

Tool life management data can be edited as follows:

6. Select the MDI mode.

7. Stop, pause, or reset the CNC by the feed hold, single block stop, or reset operation (tool life management data cannot be edited while data is set by a program.).

The following editing can be performed. See each step for details:

- Setting the life count type, life value, current life count, and tool data (T, H, or D code) : 7–1
- Adding a tool group : 7–2
- Adding a tool number (T code) : 7–3
Deleting a tool group : 7-4
Deleting tool data (T, H, or D code) : 7-5
Skipping a tool : 7-6
Clearing the life count (resetting the life) : 7-7

7–1 Setting the life count type, life value, current life count, and tool data (T, H, or D code)

(1) Position the cursor on the data item to be changed.
(2) Enter a desired value.
(3) Press the softkey [INPUT].

7–2 Adding a tool group

(1) In step 3, select a group for which no data is set and display the editing screen.
(2) Enter tool numbers.
(3) Press soft key [INSERT].

- In this case, the type of the life counter is determined by the setting of LTM (No. 6800#2), and 0 is set in both the life expectancy and life counter.
- 0 is set in both the H code and D code.
- The cursor remains on the tool number until the T code is specified.

7–3 Adding a tool number

(1) Move the cursor to the tool data (T, H, or D code) after which a new number is to be added.
(2) Enter the tool number.
(3) Press soft key [INSERT].

Example), Inserting tool No. 1500 between No. 1 and No. 2.

<table>
<thead>
<tr>
<th>NO.</th>
<th>STATE</th>
<th>T–CODE</th>
<th>H–CODE</th>
<th>D–CODE</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>*</td>
<td>0034</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>02</td>
<td>#</td>
<td>0078</td>
<td>0</td>
<td>33</td>
</tr>
</tbody>
</table>

Move the cursor to 5 in D–CODE column and press soft key [INSERT].

<table>
<thead>
<tr>
<th>NO.</th>
<th>STATE</th>
<th>T–CODE</th>
<th>H–CODE</th>
<th>D–CODE</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>*</td>
<td>0034</td>
<td>11</td>
<td>5</td>
</tr>
<tr>
<td>02</td>
<td>#</td>
<td>1500</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>03</td>
<td>#</td>
<td>0078</td>
<td>0</td>
<td>33</td>
</tr>
</tbody>
</table>
7–4 Deleting a tool group

(1) In step 3, position the cursor on a group to be deleted and display the editing screen.

(2) Press soft key [DELETE].

(3) Press soft key [GROUP].

(4) Press soft key [EXEC].

7–5 Deleting tool data (T, H, or D code)

(1) Position the cursor on the data item (T, H, or D code) to be deleted.

(2) Press soft key [DELETE].

(3) Press soft key [<CRSR>].

- The line containing the cursor is deleted.
- When a tool with mark @ (being used) is deleted, mark @ shifts to the tool whose life has expired most recently or which has been skipped. In this case, marks * and # are displayed in reverse video.

7–6 Skipping a tool

(1) Position the cursor on the data item (T, H, or D code) for the tool to be skipped.

(2) Press soft key [STATE].

(3) Press soft key [SKIP].

7–7 Clearing the life count (resetting the life)

(1) Position the cursor on the data item (T, H, or D code) of the tool to be cleared.

(2) Press soft key [STATE].

(3) Press soft key [CLEAR].

8 To complete the edit operation, press soft key [END].
The tool life management screen is displayed again.
11. SETTING AND DISPLAYING DATA

Explanations

- Displays

<table>
<thead>
<tr>
<th>No.</th>
<th>State</th>
<th>T-Code</th>
<th>H-Code</th>
<th>D-Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>*</td>
<td>0034</td>
<td>011</td>
<td>005</td>
</tr>
<tr>
<td>02</td>
<td>#</td>
<td>0078</td>
<td>000</td>
<td>033</td>
</tr>
<tr>
<td>03</td>
<td>@</td>
<td>0012</td>
<td>004</td>
<td>018</td>
</tr>
<tr>
<td>04</td>
<td>*</td>
<td>0056</td>
<td>000</td>
<td>000</td>
</tr>
<tr>
<td>05</td>
<td></td>
<td>0090</td>
<td>000</td>
<td>000</td>
</tr>
<tr>
<td>06</td>
<td>*</td>
<td>0076</td>
<td>023</td>
<td>012</td>
</tr>
</tbody>
</table>

>  

MDI  16:05:59  
[ INSERT ] [ DELETE ] [ STATE ] [ END ] [ INPUT ]

NEXT GROUP:
Number of the tool group whose life is to be calculated by the next M06 command.

USE GROUP:
Number of the tool group whose life is being calculated.

SELECTED GROUP:
Number of the tool group whose life is being calculated or was calculated last.

TYPE: 1: Life count is represented in units of cycles.
TYPE: 2: Life count is represented in units of minutes.
LIFE: Life expectancy
COUNT: Life counter
STATE: State of the tool

<table>
<thead>
<tr>
<th>Tool state</th>
<th>In use</th>
<th>Not in use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Available</td>
<td>@</td>
<td>_(Space)</td>
</tr>
<tr>
<td>Skip</td>
<td></td>
<td>#</td>
</tr>
<tr>
<td>Skipped</td>
<td>#</td>
<td></td>
</tr>
</tbody>
</table>

NOTE
When bit 3 (EMD) of parameter 6801 is set to 0, @ is displayed until the next tool is selected.

T-CODE: Tool number
H-CODE: H code
D-CODE: D code
• Tool life management screen

When the extended tool life management function is provided, the following items are added to the tool life management screen:

- **NEXT**: Tool group to be used next
- **USE**: Tool group in use
- **Life counter type for each tool group (C: Cycles, M: Minutes)

```
GROUP 001: C LIFE 9800 COUNT 6501
GROUP 002: C LIFE 9800 COUNT 1001
```

**TO BE CHANGED**: 006 012 013 014

The tool life count can be overridden provided that the life counter is indicated in units of minutes and LFV (bit 2 of parameter 6801) is 1. Override values can be specified using the override switch on the operator’s panel within the range from 0 to 99.9. If 0 is specified, tool life is not counted. If the count of actual cutting time is less than 4 seconds, the override value is invalid.

**Example**

When cutting is performed for 10 minutes with an override of 0.1, the tool life counter counts one minute.

• Life count override

The tool life count can be overridden provided that the life counter is indicated in units of minutes and LFV (bit 2 of parameter 6801) is 1. Override values can be specified using the override switch on the operator’s panel within the range from 0 to 99.9. If 0 is specified, tool life is not counted. If the count of actual cutting time is less than 4 seconds, the override value is invalid.

**Example**

When cutting is performed for 10 minutes with an override of 0.1, the tool life counter counts one minute.

• Display of the mark indicating that the life of a tool has expired

The symbol * for indicating that the life of a tool has expired can be displayed either when the machine starts using the next tool or when the life of the tool actually expires. Either of these methods can be selected using EMD (bit 3 of parameter 6801).

• Influence of changes in data

- Modification of the life expectancy or life counter does not affect the tool states or tool change signal.
- When the type of the life counter is changed, be sure to change the life expectancy and life count as well.
11.4.13 Displaying and Setting Chopping Data

Chopping data, including the reference point (R point), upper dead point, lower dead point, and chopping feedrate, can be displayed and set by using the chopping screen.

Procedure for displaying and setting chopping data

Procedure

1. Press the \textit{OFFSET SETTING} function key.
2. Press the continuous menu key several times until [CHOP] is displayed.
3. Press the [CHOP] soft key.

The following chopping screen appears:

\begin{center}
\begin{tabular}{|l|c|}
\hline
CHOPPING PARAMETER & O1000 N10000 \\
R (REFERENCE) POINT & 50.000 \\
UPPER DEAD POINT & 40.000 \\
LOWER DEAD POINT & 10.000 \\
CHOPPING FEED RATE & 2000 \\
\hline
\end{tabular}
\end{center}

Explanations

- **Numerical input**
  - Position the cursor to the item to be set.
  - Enter data, then press the [INPUT] soft key.
  - To append the entered data to the current data, press the [+INPUT] soft key.

  The set data is displayed.

- **Teaching the position**
  - The reference point (R point), upper dead point, and lower dead point can be set by teaching the current position (absolute coordinates).
  - Move the current position (absolute coordinates) along the chopping axis to the position to be taught.
  - Position the cursor to the item to be set.
  - Press the [TEACH] soft key, then the [EXEC] soft key.

  The current position (absolute coordinates) is set for that item.

- **G81.1**
  - The data for each item displayed on the chopping screen can also be changed by executing a G81.1 command.
Limitations

- **Chopping feedrate**
  If bit 7 (CHPX) of parameter No. 8360 is set to 1, the chopping feedrate cannot be set by using the chopping screen.

- **Data setting conditions**
  The chopping screen can be used to set chopping data regardless of the current mode, even during automatic or manual operation that includes chopping. If the level of memory protection signal KEY2 (G046#4) is currently low, however, chopping data cannot be set.

### 11.4.14 Tool Length/Workpiece Origin Measurement B

To enable measurement of the tool length, the following functions are supported: automatic measurement of the tool length by using a program command (G37) (automatic tool length measurement, described in Section II.14.2) and measurement of the tool length by manually moving the tool until it touches a reference position, such as the workpiece top surface (tool length measurement, described in Subsection III.11.4.2). In addition to these functions, tool length/workpiece origin measurement B is supported to simplify the tool length measurement procedure, thus facilitating and reducing the time required for machining setup. This function also facilitates the measurement of the workpiece origin offsets. This function allows the operator to specify T/M code commands or reference position return, by means of a manual numeric command, while the tool length offset measurement screen is displayed.

### Procedure for measuring the tool length offset value

The tool length offset value can be measured by manually moving the tool until it touches the workpiece or a reference block. For details of this operation, refer to the manual supplied by the machine tool builder.

1. Move the tool to the tool change position by means of manual reference position return, for example.
2. Press mode selection switch HANDLE or JOG.
3. Set the tool offset value measurement mode switch on the machine operator’s panel to ON. The tool length offset measurement screen, shown below, appears and "OFST" blinks in the status display at the bottom of the screen.

The tool length offset measurement screen varies slightly depending on whether tool length offset memory A, B (geometry compensation and wear compensation are treated differently), or C (geometry compensation and wear compensation are treated differently, and cutter compensation and tool length compensation are treated differently) is used.
### 11. SETTING AND DISPLAYING DATA

#### OPERATION

OFFSET 01234 N12345

<table>
<thead>
<tr>
<th>No.</th>
<th>GEOMETRY</th>
<th>WEAR</th>
<th>LENGTH (MACHINE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>001</td>
<td>100.000</td>
<td>100.000</td>
<td>X–12345.678</td>
</tr>
<tr>
<td>002</td>
<td>200.000</td>
<td>200.000</td>
<td>Y–12345.678</td>
</tr>
<tr>
<td>003</td>
<td>300.000</td>
<td>300.000</td>
<td>Z–12345.678</td>
</tr>
<tr>
<td>004</td>
<td>400.000</td>
<td>400.000</td>
<td>A–12345.678</td>
</tr>
<tr>
<td>005</td>
<td>500.000</td>
<td>500.000</td>
<td>B–12345.678</td>
</tr>
<tr>
<td>006</td>
<td>600.000</td>
<td>600.000</td>
<td>C–12345.678</td>
</tr>
<tr>
<td>007</td>
<td>700.000</td>
<td>700.000</td>
<td>U–12345.678</td>
</tr>
<tr>
<td>008</td>
<td>800.000</td>
<td>800.000</td>
<td>V–12345.678</td>
</tr>
<tr>
<td>009</td>
<td>900.000</td>
<td>900.000</td>
<td>(T) 12345678</td>
</tr>
<tr>
<td>010</td>
<td>–999.999</td>
<td>–999.999</td>
<td>(M) 12345678</td>
</tr>
</tbody>
</table>

> JOG **** **** ALM 13:14:15 OFST

[ OFFSET ][SETTING][WORK][OPRT]

Tool length offset measurement screen for tool offset memory A

OFFSET 01234 N12345

<table>
<thead>
<tr>
<th>No.</th>
<th>GEOMETRY</th>
<th>WEAR</th>
<th>LENGTH (MACHINE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>001</td>
<td>100.000</td>
<td>100.000</td>
<td>X–12345.678</td>
</tr>
<tr>
<td>002</td>
<td>200.000</td>
<td>200.000</td>
<td>Y–12345.678</td>
</tr>
<tr>
<td>003</td>
<td>300.000</td>
<td>300.000</td>
<td>Z–12345.678</td>
</tr>
<tr>
<td>004</td>
<td>400.000</td>
<td>400.000</td>
<td>A–12345.678</td>
</tr>
<tr>
<td>005</td>
<td>500.000</td>
<td>500.000</td>
<td>B–12345.678</td>
</tr>
<tr>
<td>006</td>
<td>600.000</td>
<td>600.000</td>
<td>C–12345.678</td>
</tr>
<tr>
<td>007</td>
<td>700.000</td>
<td>700.000</td>
<td>U–12345.678</td>
</tr>
<tr>
<td>008</td>
<td>800.000</td>
<td>800.000</td>
<td>V–12345.678</td>
</tr>
<tr>
<td>009</td>
<td>900.000</td>
<td>900.000</td>
<td>(T) 12345678</td>
</tr>
<tr>
<td>010</td>
<td>–999.999</td>
<td>–999.999</td>
<td>(M) 12345678</td>
</tr>
</tbody>
</table>

> JOG **** **** ALM 13:14:15 OFST

[ OFFSET ][SETTING][WORK][OPRT]

Tool length offset measurement screen for tool offset memory B

OFFSET 01234 N12345

<table>
<thead>
<tr>
<th>No.</th>
<th>GEOMETRY</th>
<th>WEAR</th>
<th>LENGTH (MACHINE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>001</td>
<td>100.000</td>
<td>100.000</td>
<td>X–12345.678</td>
</tr>
<tr>
<td>002</td>
<td>200.000</td>
<td>200.000</td>
<td>Y–12345.678</td>
</tr>
<tr>
<td>003</td>
<td>300.000</td>
<td>300.000</td>
<td>Z–12345.678</td>
</tr>
<tr>
<td>004</td>
<td>400.000</td>
<td>400.000</td>
<td>A–12345.678</td>
</tr>
<tr>
<td>005</td>
<td>500.000</td>
<td>500.000</td>
<td>B–12345.678</td>
</tr>
<tr>
<td>006</td>
<td>600.000</td>
<td>600.000</td>
<td>C–12345.678</td>
</tr>
<tr>
<td>007</td>
<td>700.000</td>
<td>700.000</td>
<td>U–12345.678</td>
</tr>
<tr>
<td>008</td>
<td>800.000</td>
<td>800.000</td>
<td>V–12345.678</td>
</tr>
<tr>
<td>009</td>
<td>900.000</td>
<td>900.000</td>
<td>(T) 12345678</td>
</tr>
<tr>
<td>010</td>
<td>–999.999</td>
<td>–999.999</td>
<td>(M) 12345678</td>
</tr>
</tbody>
</table>

> JOG **** **** ALM 13:14:15 OFST

[ OFFSET ][SETTING][WORK][OPRT]

Tool length offset measurement screen for tool offset memory C
NOTE
Pressing the [RESET] key resets the displayed T and M addresses to 0. Once MEM or MDI mode has been selected, however, the modal T and M codes are displayed.

4 Use the numeric keys to enter the distance from the base measurement surface to the measurement surface, then press soft key [HM INPUT] to set the distance. For details of the measurement surface and base measurement surface, see Explanations, below.

5 Select the tool for which the tool length offset value is to be measured. While "OFST" is blinking at the bottom of the tool length offset measurement screen, a T code or M code can be specified in manual handle feed or jog feed mode (manual numeric command). First, enter Tttt (where tttt is a T code number), then press the cycle start button on the machine operator’s panel or MDI panel. The Tttt command is executed, thus selecting the tool to be measured. Then, usually, enter the M06 command to move the tool to the spindle position. Once the tool for which the tool length offset is to be measured has been selected at the spindle position, position the cursor to the tool offset number with which the tool length offset for the selected tool is to be stored. The positioning of the cursor to the offset number is usually done by the operator. Some machines, however, automatically position the cursor to an appropriate tool offset number upon the completion of tool selection, if bit 5 (QNI) of parameter No. 5005 is set to 1.

6 Perform manual handle feed or jog feed to move the tool until it touches the measurement surface of the workpiece or reference block.

7 Press soft key [MEASURE B]. The tool length offset is stored in the tool offset memory. If tool offset memory B or C is being used, the tool length offset is set as the tool geometry value, while 0 is set as the tool wear offset. The cursor remains positioned to the set tool offset number. To automatically advance the cursor to the next tool offset number upon the completion of the setting an offset, press soft key [MEASURE B+], instead of [MEASURE B].

8 Once the tool length offset has been set, the tool is automatically moved to the tool change position.

9 This completes tool length offset measurement for a single tool. To measure the tool length offsets of other tools, repeat steps 5 to 8.

10 Once the tool length offsets of all tools have been measured, set the tool offset measurement mode switch on the machine operator’s panel to OFF. The "OFST" blinking indication is cleared from the bottom of the screen.
In general, the tool length offset value can be defined in either of the following two ways. Both methods are based on the same concept: The difference between the tip position of the tool and that of a reference tool is used as the tool offset.

(1) Definition 1

The first method involves using the actual tool length as the tool length offset. In this case, the reference tool is an imaginary tool which has its tip at the machine zero point when the machine is positioned to the Z-axis machine zero point. The difference between the tip position of the tool to be measured and that of the reference tool, that is, the distance along the Z-axis from the machine zero point to the tip of the tool when the machine is positioned to the Z-axis machine zero point, is defined as the tool length offset.

Also, with this function, the tool is manually moved by means of jog feed until its tip touches the top surface of the workpiece or reference block. This surface is called the measurement surface. Assume that the top surface of the machines table is set as the measurement surface, although this is actually not allowed because the machine would be damaged. In such a case, distance L from the machine zero point to the machine table top surface is specific to that machine. Set distance L in a parameter (No. 5022). Assume Zt to be the machine coordinate of the tool at the position where it would touch the machine table top surface if that surface were set as the measurement surface. The tool length offset (OFSL) can then be easily calculated from L and Zt. Because the machine table top surface cannot actually be used as the measurement surface, however, that surface is defined as the base measurement surface and the distance from the base measurement surface to the actual measurement surface, that is, the height of the workpiece or reference block (Hm) must be set. The tool length offset value (OFSL) can thus be obtained from the formula shown below.
L : Distance from the reference tool tip position to the base measurement surface (machine coordinate of the measurement surface)
Hm : Distance from the base measurement surface to the actual measurement surface
Zm : Distance from the tip of the tool to be measured to the measurement surface when the tool is positioned to the machine zero point
(Zt : Distance from the tip of the tool to be measured to the base measurement surface when the tool is positioned to the machine zero point)
OFSL : Tool length offset value (OFSL = Zm – Hm – L)

Defining the actual tool length as the tool length offset has the advantage of eliminating the need for remeasuring, even if the workpiece is changed, provided the tool is not worn. Another advantage is that the tool length offset need not be re-set when multiple workpieces are machined. In this case, assign a workpiece coordinate system to each workpiece, using G54 to G59, and set the workpiece origin offset for each workpiece. For an explanation of how to measure the workpiece origin offset, see "Measuring the workpiece origin offset", below.
(2) Definition 2

In the second definition method, the tool length offset is the distance from the tool tip position to the workpiece coordinate system origin when the machine is positioned to the Z-axis zero point. A tool length offset defined in this way will be equal to the difference between the length of the tool to be measured and that of the reference tool, in the same way as with definition 1. The reference tool for definition 2 is, however, an imaginary tool which has a tip at the workpiece coordinate system origin when the machine is positioned to the Z-axis zero point.

OFSL01 : Tool length offset for tool T01
OFSL02 : Tool length offset for tool T02
OFSL03 : Tool length offset for tool T03
The base measurement surface for this definition is located at the workpiece coordinate system origin. Because the tip of the reference tool is also located at the workpiece coordinate system origin, distance L from the reference tool tip position to the base measurement surface is 0. Set, therefore, 0 in the parameter for distance L (No. 5022). The actual measurement surface is usually the same as the base measurement surface, located at the workpiece coordinate system origin. If, however, the measurement surface is the top surface of the reference block, or if the workpiece coordinate system origin is located on other than the top surface of the workpiece (for example, when the origin is shifted from the workpiece top surface by an amount equal to the cutting allowance), set the distance from the base measurement surface to the actual measurement surface as Hm, such that the tool length offset (OFSL) can be calculated using the same formula as that used for definition 1.

\[
L \quad : \quad \text{Distance from the reference tool tip position to the base measurement surface} \ (= 0) \\
Hm \quad : \quad \text{Distance from the base measurement surface to the actual measurement surface} \\
Zm \quad : \quad \text{Distance from the tip of the tool to be measured to the measurement surface when the tool is positioned to the machine zero point} \\
\text{OFSL} \quad : \quad \text{Tool length offset} \ (\text{OFSL} = Zm - Hm - L)
\]
The reference tool for definition 2 has a tip at the workpiece coordinate system origin when the machine is positioned to the Z-axis zero point. Whenever the workpiece is changed, therefore, the tool length offset must be remeasured. Remeasuring is not, however, necessary if the difference between the workpiece coordinate system origin for a new workpiece and that when the tool length offset value was measured is set as the new workpiece origin offset (any of G54 to G59). In such a case, the tool length offset need not be modified, even when the workpiece is changed.

Taking a different point of view, definition 2 can be thought of as setting the workpiece origin offset as the tool length offset for each tool.

Because the tool is usually mounted in parallel with the Z-axis, the tool length offset is measured by moving the tool along the Z-axis. Some machines, however, have their W-axis in parallel with the Z-axis, making it necessary to measure the tool length offset by moving the tool along the W-axis. Moreover, some machines, when fitted with an attachment, support the mounting of the tool in parallel with an axis other than the Z-axis. For such a machine, the tool length offset can be measured along a specified axis by setting bit 2 (TMA) of parameter No. 5007 to 1. To measure the tool length offset along an axis other than the Z-axis, first set distance L from the reference tool tip position to the base measurement surface, for each of the axes along which the tool length offset may be measured, in parameter No. 5022, in addition to distance L along the Z-axis. Next, set distance Hm from the base measurement surface to the actual measurement surface for the axis along which the tool length offset is to be measured (see Explanations, below). Finally, move the tool along that axis until it touches the workpiece or reference block, then enter the name of that axis before pressing soft key [MEASURE B] or [MEASURE B+]. When the tool offset is measured along the W-axis, for example, enter W then press soft key [MEASURE B] or [MEASURE B+].

The tool change position must be set beforehand, using bits 1 (TC3) and 0 (TC2) of parameter No. 5007.

<table>
<thead>
<tr>
<th>TC3</th>
<th>TC2</th>
<th>Meaning</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>The tool change position is the first reference position (G28)</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>The tool change position is the second reference position (G30 P2)</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>The tool change position is the third reference position (G30 P3)</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>The tool change position is the fourth reference position (G30 P4)</td>
<td></td>
</tr>
</tbody>
</table>
Procedure for measuring the workpiece origin offset

In addition to the workpiece origin offset along the tool lengthwise axis, that is, the Z–axis, the workpiece origin offsets along the X– and Y–axes, on a plane perpendicular to the Z–axis, can also be measured easily. The workpiece origin offsets along the X– and Y–axes can be measured regardless of whether the workpiece origin is located on a surface of the workpiece or at the center of a hole to be machined. For details of this measurement, refer to the manual supplied by the machine tool builder.

1 Select a tool using an MDI command, then move it to the spindle position (see the explanation of the procedure for measuring the tool length offset). The tool length offset for the selected tool must be measured beforehand.

2 Press mode selection switch HANDLE or JOG.

3 Set the workpiece origin offset measurement mode switch on the machine operator’s panel to ON. The workpiece origin offset screen appears and “WOFS” blinks in the status display at the bottom of the screen.

4 Enter the tool length offset for the selected tool. Enter the offset using numeric keys then press soft key [TL INPUT].

5 Position the cursor to the workpiece origin offset number to be used to store the offset (any of G54 to G59). No problem will arise even if the cursor is positioned to the offset for other than the Z–axis.

6 Move the tool by means of manual handle feed or jog feed until it touches the top surface of the workpiece.

7 Enter the axis name, Z, press soft key [MEASURE B], then press soft key [INPUT]. The Z–axis workpiece origin offset value is set and the cursor is positioned to the set Z–axis workpiece origin offset. There is no need to enter Z provided the parameter has been set so that only the Z–axis workpiece origin offset is to be measured (bit 3 (WMA) of No. 5007 = 0).
To set the workpiece origin on other than the workpiece top surface (for example, when the origin is shifted from the workpiece top surface by an amount equal to the cutting allowance), enter the amount of shift (S in the following figure) using the numeric keys, press soft key [MEASURE B], then press soft key [INPUT].

![Diagram showing workpiece origin offset](image)

8 To measure any subsequent workpiece origins, retract the tool from the workpiece, then repeat steps 5 to 7.

**Measuring the X-/Y-axis workpiece origin offset based on a reference surface**

To set the X– or Y–axis workpiece origin offset on a specified surface of the workpiece, set bit 3 (WMA) of parameter No. 5007 to 1, then follow the same procedure as that for measuring the Z–axis workpiece origin offset. In step 4, however, enter the cutter compensation value for the selected tool, instead of the tool length offset. After entering the cutter compensation value with the numeric keys, press soft key [TL INPUT].

**NOTE**

When entering the cutter compensation value, ensure that its sign is entered correctly.
- When the measurement surface is located in the positive (+) direction relative to the tool, enter a minus (−) sign.
- When the measurement surface is located in the negative (−) direction relative to the tool, enter a plus (+) sign.

**Measuring the X-/Y-axis workpiece origin offset based on a reference hole**

1 Connect a measurement probe, fitted with a sensor, to the spindle.
2 Press mode selection switch HANDLE or JOG.
3 Set the workpiece origin offset measurement mode switch on the machine operator’s panel to ON. The workpiece origin offset screen appears and “WOFS” blinks in the status display at the bottom of the screen, indicating that the preparation required prior to measuring the workpiece origin offset has been completed.
4 Position the cursor to the workpiece origin offset number to be used to store the offset (any of G54 to G59). No problem will arise even if the cursor is positioned to the offset for other than the X– or Y–axis.
5 Move the tool by means of manual handle feed or jog feed until the measurement probe touches the circumference of the hole. Do not move the tool along more than one axis at any one time.
As soon as the sensor detects contact with the circumference, input a skip signal to the machine, thus stopping the axial movement of manual handle feed or jog feed. Simultaneously, the position at which feed stopped is stored as the first measurement point. The machine coordinates of the stored measurement point are displayed at the bottom right of the screen, as follows:

<table>
<thead>
<tr>
<th>WORK COORDINATES</th>
<th>01234 N12345</th>
</tr>
</thead>
<tbody>
<tr>
<td>(G54) No.</td>
<td>(TL)</td>
</tr>
<tr>
<td>00</td>
<td>−12345.678</td>
</tr>
<tr>
<td>(EXT) X</td>
<td>−12345.678</td>
</tr>
<tr>
<td>Y</td>
<td>−12345.678</td>
</tr>
<tr>
<td>Z</td>
<td>−12345.678</td>
</tr>
<tr>
<td>A</td>
<td>−12345.678</td>
</tr>
<tr>
<td>(HOLE MEASURED)</td>
<td></td>
</tr>
<tr>
<td>#1 X</td>
<td>X−12345.678</td>
</tr>
<tr>
<td>Y</td>
<td>Y−12345.678</td>
</tr>
<tr>
<td>#2 X</td>
<td>X−12345.678</td>
</tr>
<tr>
<td>Z</td>
<td>Y−12345.678</td>
</tr>
<tr>
<td>A</td>
<td>Z−12345.678</td>
</tr>
<tr>
<td>(HOLE MEASURED)</td>
<td></td>
</tr>
<tr>
<td>#3 X</td>
<td>X−12345.678</td>
</tr>
<tr>
<td>Y</td>
<td>Y−12345.678</td>
</tr>
</tbody>
</table>

Move the measurement probe to the second measurement point. At this time, the CNC interlocks the machine to prevent the probe from moving in the direction in which it was moved so as to touch the current measurement point. For example, when the probe touched the measurement point after being moved in the +X direction, movement of the probe to the next measurement point is allowed only in the −X direction. Movement in the +X, +Y, or −Y direction is interlocked until the skip signal is set to 0. Once the probe touches the second measurement point, follow the same procedure as that for storing the first measurement point.

Once the probe has touched the third measurement point, press soft key [MEASURE B], then [CENTER]. This calculates the center of the hole from the coordinates of the three measured points, then sets the X– and Y–axis workpiece origin offsets. To cancel and restart measurement at any point, press the [RESET] key. Pressing the [RESET] key clears the coordinates of all stored measurement points.

**Explanations**

- **Z–axis workpiece origin offset**

  Definitions 1 and 2, described in "Definition of tool length offset" in Explanations for measuring the tool length offset, also apply to the general concept of the Z–axis workpiece origin offset, as follows:

  (1) Definition 1

  In definition 1, the Z–axis workpiece origin offset is defined as the distance from the machine zero point to the origin of the workpiece coordinate system.
As can be seen from the above figure, the Z-axis workpiece origin offset can be calculated from the following formula:

\[
\text{OFSW} = Zm - \text{OFSL}
\]

where

- **OFSW**: Workpiece origin offset
- **OFSL**: Tool length offset for the tool used to measure the workpiece origin offset
- **Zm**: Amount of movement from the machine zero point to the workpiece origin when measured with a tool having a length of OFSL
(2) Definition 2

The tool length offset in definition 2 equals the Z-axis workpiece origin offset, as described above. Usually in this case, therefore, the workpiece origin offset need not be set. If, however, the workpiece is changed after its tool length offset has been measured, or if multiple workpieces are machined, the workpiece origin coordinates can be set as follows when assigning workpiece coordinate systems to G54 to G59, thus eliminating the need to remeasure the tool length offset.

For definition 2, the workpiece origin offset can be calculated using the same formula as that used for definition 1:

\[
\text{OFSW} = \text{Zm} - \text{OFSL}
\]

where

- \text{OFSW} : Workpiece origin offset
- \text{OFSL} : Tool length offset for the tool used to measure the workpiece origin offset
- \text{Zm} : Amount of movement from the machine zero point to the workpiece origin when measured with a tool having a length of \text{OFSL}
The X– and Y–axis workpiece origin offsets can be measured regardless of whether the workpiece origin is located on a surface of the workpiece or at the center of a hole to be machined.

(1) When the workpiece origin is located on a surface

In the above case, the workpiece origin is located on a side surface of the workpiece. The measurement of the X–/Y–axis workpiece origin offset when the origin is located on a surface of the workpiece is the same as that for the Z–axis workpiece origin offset, but with the following exception: The tool length offset for the tool used to measure the offset is used to calculate the Z–axis workpiece origin offset, while the cutter compensation value for the tool is used to calculate the X–/Y–axis workpiece origin offset.
As can be seen from the above figure, the workpiece origin offset can be calculated from the following formula:

\[ \text{OFSW} = \text{Xm} - \text{OFSR} \]

Pay particularly careful attention, however, to the sign of the cutter compensation value OFSR:

The sign of OFSR is \(-\) when the measurement surface is located in the positive (+) direction relative to the tool center.

The sign of OFSR is + when the measurement surface is located in the negative (−) direction relative to the tool center.
(2) When the workpiece origin is located at the center of a hole.

In the above case, the workpiece origin is located at the center of a hole in the workpiece. A measurement probe having a sensor at its tip is used to measure the positions of three arbitrary points on the circumference of the hole. The three points prescribe a unique circle, the center of which is set as the X–Y–axis workpiece origin. Set bit 4 (WMH) of parameter No. 5007 to 1 before starting the measurement.
**Using a skip signal**

A measurement probe, fitted with a sensor, can also be used to measure the Z-axis workpiece origin offset or measure the X–Y-axis workpiece origin offset based on a surface, in the same way as when measuring the X–Y-axis workpiece origin offset based on a hole. By inputting a skip signal as soon as the probe touches the workpiece surface, feed is automatically stopped. Subsequently, apply the same procedure as that for each measurement.

---

### 11.4.15 Displaying and Setting Rotary Table Dynamic Fixture Offset

There are the following screens for the fixture offset function: Screen for checking the currently selected fixture offset value (fixture offset (ACT) screen) and screen for setting and checking eight groups of fixture offset values (fixture offset screen).

**Procedure for displaying the fixture offset (ACT) screen**

**Procedure**

1. Press function key \`

\`

2. Press continuous menu key \`

\`

several times until \`

\`

appears.

3. Press soft key \`

\`

The following fixture offset (ACT) screen appears:

**FIXTURE OFFSET (ACT)**

| P=01 | X 0.000 | Y 0.000 | Z 0.000 | C 0.000 | B 0.000 | A 0.000 |

Explanations

This screen displays the currently selected fixture offset number (P) and fixture offset vector data.
Procedure for displaying the fixture offset screen and setting data on the screen

**Procedure**

1. Press function key \[OFFSET\].
2. Press continuous menu key \[\text{\textarrow{}}\] several times until \[F-OF\] appears.
3. Press soft key \[F-OF\].

The following fixture offset screen appears:

```
F OFFSET
NO. 01  NO. 02
X  0.000  X  0.000
Y  0.000  Y  0.000
Z  0.000  Z  0.000
C  0.000  C  0.000
B  0.000  B  0.000
A  0.000  A  0.000

[NO.SRH] [ ] [PUNCH] [+INPUT] [ INPUT ]
```

**Explanations**

On this screen, eight groups of fixture offset values can be set and checked.
Press soft key \[(OPRT)\] to display the above operation soft keys.

- **Entering numeric values**
  - Use the page and cursor keys, and soft key \[NO. SRH\] to place the cursor at a desired item to be set.
  - Enter data, then press soft key \[INPUT\].
  - To add a value to already set data, press soft key \[+INPUT\].

The displayed data is now changed to the set data.
Data can also be set using the INPUT MDI key.

- **Number of groups of fixture offset values**
  NO. 01 to NO. 08 indicates the number of a group of fixture offset values. There are eight groups. Soft key \[NO. SRH\] can be used to search for a desired group number.

- **Outputting fixture offset values**
  Soft key \[PUNCH\] can be used to output fixture offset values to an external device. For details of the output format and how to input data, see Section II.14.14, “ROTARY TABLE DYNAMIC FIXTURE OFFSET,” in this manual.
When the CNC and machine are connected, parameters must be set to determine the specifications and functions of the machine in order to fully utilize the characteristics of the servo motor or other parts. This chapter describes how to set parameters on the MDI panel. Parameters can also be set with external input/output devices such as the Handy File (see III–8). In addition, pitch error compensation data used for improving the precision in positioning with the ball screw on the machine can be set or displayed by the operations under function key \textit{SYSTEM}. See III–7 for the diagnostic screens displayed by pressing function key \textit{SYSTEM}. 

When the CNC and machine are connected, parameters are set to determine the specifications and functions of the machine in order to fully utilize the characteristics of the servo motor. The setting of parameters depends on the machine. Refer to the parameter list prepared by the machine tool builder. Normally, the user need not change parameter setting.

### Procedure for displaying and setting parameters

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Set 1 for \textbf{PARAMETER WRITE} to enable writing. See the procedure for enabling/disabling parameter writing described below.</td>
</tr>
<tr>
<td>2</td>
<td>Press function key \textit{SYSTEM}.</td>
</tr>
<tr>
<td>3</td>
<td>Press chapter selection soft key \textbf{PARAM} to display the parameter screen.</td>
</tr>
<tr>
<td></td>
<td><img src="image" alt="Parameter Screen" /></td>
</tr>
<tr>
<td>4</td>
<td>Move the cursor to the parameter number to be set or displayed in either of the following ways:</td>
</tr>
<tr>
<td></td>
<td>- Enter the parameter number and press soft key \textbf{NO.SRH}.</td>
</tr>
</tbody>
</table>
1. SETTING AND DISPLAYING DATA

- Move the cursor to the parameter number using the page keys, 
  \( \uparrow \) and \( \downarrow \), and cursor keys, \( \uparrow \), \( \downarrow \), \( \leftarrow \), and \( \rightarrow \).

5. To set the parameter, enter a new value with numeric keys and press soft key [INPUT]. The parameter is set to the entered value and the value is displayed.

6. Set 0 for **PARAMETER WRITE** to disable writing.

---

**Procedure for enabling/displaying parameter writing**

1. Select the **MDI** mode or enter state emergency stop.

2. Press function key [OFFSET SETING].

3. Press soft key [SETTING] to display the setting screen.

   ![Setting Screen](image)

   - **SETTING (HANDY)**
   - **PARAMETER WRITE** = 1 (0:DISABLE 1:ENABLE)
   - TV CHECK = 0 (0:OFF 1:ON)
   - PUNCH CODE = 1 (0:EIA 1:ISO)
   - INPUT UNIT = 0 (0:MM 1:INCH)
   - I/O CHANNEL = 0 (0–3:CHANNEL NO.)
   - SEQUENCE NO. = 0 (0:OFF 1:ON)
   - TAPE FORMAT = 0 (0:NO CVN 1:F10/11)
   - SEQUENCE STOP = 0 (PROGRAM NO.)
   - SEQUENCE STOP = 11(SEQUENCE NO.)

4. Move the cursor to **PARAMETER WRITE** using cursor keys.

5. Press soft key [([OPRT]), then press [ON :1] to enable parameter writing. 
   At this time, the CNC enters the P/S alarm state (No. 100).

6. After setting parameters, return to the setting screen. Move the cursor to **PARAMETER WRITE** and press soft key [([OPRT]), then press [OFF :0].

7. Depress the [RESET] key to release the alarm condition. If P/S alarm No. 000 has occurred, however, turn off the power supply and then turn it on, otherwise the P/S alarm is not released.

---

**Explanations**

- Setting parameters with external input/output devices
  See III–8 for setting parameters with external input/output devices such as the Handy File.
11. SETTING AND DISPLAYING DATA

- **Parameters that require turning off the power**
  Some parameters are not effective until the power is turned off and on again after they are set. Setting such parameters causes P/S alarm 000. In this case, turn off the power, then turn it on again.

- **Parameter list**
  Refer to the Parameter Manual (B–63530EN) for the parameter list.

- **Setting data**
  Some parameters can be set on the setting screen if the parameter list indicates "Setting entry is acceptable". Setting 1 for **PARAMETER WRITE** is not necessary when three parameters are set on the setting screen.

11.5.2 Displaying and Setting Pitch Error Compensation Data

If pitch error compensation data is specified, pitch errors of each axis can be compensated in detection unit per axis.

Pitch error compensation data is set for each compensation point at the intervals specified for each axis. The origin of compensation is the reference position to which the tool is returned.

The pitch error compensation data is set according to the characteristics of the machine connected to the NC. The content of this data varies according to the machine model. If it is changed, the machine accuracy is reduced.

In principle, the end user must not alter this data.

Pitch error compensation data can be set with external devices such as the Handy File (see Chapter III–8). Compensation data can also be written directly with the MDI panel.

The following parameters must be set for pitch error compensation. Set the pitch error compensation value for each pitch error compensation point number set by these parameters.

In the following example, 33 is set for the pitch error compensation point at the reference position.

<table>
<thead>
<tr>
<th>Compensation position number</th>
<th>31</th>
<th>32</th>
<th>33</th>
<th>34</th>
<th>35</th>
<th>36</th>
<th>37</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compensation value to be set</td>
<td>+3</td>
<td>-1</td>
<td>-1</td>
<td>+1</td>
<td>+2</td>
<td>-1</td>
<td>-3</td>
</tr>
</tbody>
</table>

- **Reference position**
- **Compensation number parameter for the reference position (No. 3620)**
- **Compensation number parameter for the compensation point having the largest value (No. 3622)**
- **Compensation number parameter for the compensation point having the smallest value (No. 3621)**
- **Compensation interval parameter (No. 3624)**
- **Pitch error compensation value (absolute value)**

- **Number of the pitch error compensation point at the reference position (for each axis):** Parameter 3620
- **Number of the pitch error compensation point having the smallest value (for each axis):** Parameter 3621
Bidirectional pitch error compensation

The bidirectional pitch error compensation function allows independent pitch error compensation in different travel directions. (When the movement is reversed, compensation is automatically carried out as in a backlash.)

To use this function, specify pitch error compensation for each travel direction, that is, separately for the positive and negative directions of a movement.

When using bidirectional pitch error compensation (setting the BDP bit (bit 0 of parameter 3605) to 1), specify the following parameters in addition to the pitch error compensation parameter.

- Number of the pitch error compensation point at the negative end (for travel in the positive direction, for each axis): Parameter 3620
- Number of the pitch error compensation point at the positive end (for travel in the positive direction, for each axis): Parameter 3621
- Number of the pitch error compensation point at the negative end (for travel in the negative direction, for each axis): Parameter 3626
- Number of the pitch error compensation point at the positive end (for travel in the negative direction, for each axis): Parameter 3627

Procedure for displaying and setting the pitch error compensation data

1. Set the following parameters:
   - Number of the pitch error compensation point at the reference position (for each axis): Parameter 3620
   - Number of the pitch error compensation point having the smallest value (for each axis): Parameter 3621
   - Number of the pitch error compensation point having the largest value (for each axis): Parameter 3622
   - Pitch error compensation magnification (for each axis): Parameter 3623
   - Interval of the pitch error compensation points (for each axis): Parameter 3624
   - Travel distance per revolution of pitch error compensation of the rotary axis type (for each axis): Parameter 3625

When using bidirectional pitch error compensation (setting the BDP bit (bit 0 of parameter 3605) to 1), specify the following parameters in addition to the pitch error compensation parameter.

- Number of the pitch error compensation point at the negative end (for travel in the positive direction, for each axis): Parameter 3620
11. SETTING AND DISPLAYING DATA

- Number of the pitch error compensation point at the positive end (for travel in the positive direction, for each axis): Parameter 3621
- Number of the pitch error compensation point at the negative end (for travel in the negative direction, for each axis): Parameter 3626
- Number of the pitch error compensation point at the positive end (for travel in the negative direction, for each axis): Parameter 3627

2. Press function key \( \text{SYSTEM} \).

3. Press the continuous menu key \( \rightarrow \), then press chapter selection soft key [PITCH].

The following screen is displayed:

![Continuous menu key](image)

4. Move the cursor to the compensation point number to be set in either of the following ways:
   - Enter the compensation point number and press the \([\text{NO.SRH}]\) soft key.
   - Move the cursor to the compensation point number using the page keys, \( \text{PAGE} \) and \( \text{PAGE} \), and cursor keys, \( \uparrow \), \( \downarrow \), \( \leftarrow \), and \( \rightarrow \).

5. Enter a value with numeric keys and press the \([\text{INPUT}]\) soft key.
11.6 DISPLAYING THE PROGRAM NUMBER, SEQUENCE NUMBER, AND STATUS, AND WARNING MESSAGES FOR DATA SETTING OR INPUT/OUTPUT OPERATION

The program number, sequence number, and current CNC status are always displayed on the screen except when the power is turned on, a system alarm occurs, or the PMC screen is displayed. If data setting or the input/output operation is incorrect, the CNC does not accept the operation and displays a warning message. This section describes the display of the program number, sequence number, and status, and warning messages displayed for incorrect data setting or input/output operation.

11.6.1 Displaying the Program Number and Sequence Number

The program number and sequence number are displayed at the top right on the screen as shown below.

```
> __EDIT **** *** ***  16:05:59
  [ PRGRM ] [ CHECK ] [ CURRNT ] [ NEXT ] [ (OPRT) ]
```

The program number and sequence number displayed depend on the screen and are given below:

- **On the program screen in the EDIT mode on Background edit screen:**
  The program No. being edited and the sequence number just prior to the cursor are indicated.

- **Other than above screens:**
  The program No. and the sequence No. executed last are indicated.

- **Immediately after program number search or sequence number search:**
  Immediately after the program No. search and sequence No. search, the program No. and the sequence No. searched are indicated.
11.6.2
Displaying the Status and Warning for Data Setting or Input/Output Operation

Explanations
Description of each display

| (1) Current mode | MDI : Manual data input, MDI operation |
|                  | MEM : Automatic operation (memory operation) |
|                  | RMT : Automatic operation (DNC operation, or such like) |
|                  | EDIT : Memory editing |
|                  | HND : Manual handle feed |
|                  | JOG : Jog feed |
|                  | TJOG : TEACH IN JOG |
|                  | THND : TEACH IN HANDLE |
|                  | INC : Manual incremental feed |
|                  | REF : Manual reference position return |

| (2) Automatic operation status | **** : Reset (When the power is turned on or the state in which program execution has terminated and automatic operation has terminated.) |
|                              | STOP : Automatic operation stop (The state in which one block has been executed and automatic operation is stopped.) |
|                              | HOLD : Feed hold (The state in which execution of one block has been interrupted and automatic operation is stopped.) |
|                              | STRT : Automatic operation start–up (The state in which the system operates automatically) |

| (3) Axis moving status/dwell status | MTN : Indicates that the axis is moving. |
|                                     | DWL : Indicates the dwell state. |
|                                     | *** : Indicates a state other than the above. |

| (4) State in which an auxiliary function is being executed | FIN : Indicates the state in which an auxiliary function is being executed. (Waiting for the complete signal from the PMC) |
|                                                           | *** : Indicates a state other than the above. |
(5) Emergency stop or reset status

- EMG : Indicates emergency stop. (Blinks in reversed display.)
- RESET : Indicates that the reset signal is being received.

(6) Alarm status

- ALM : Indicates that an alarm is issued. (Blinks in reversed display.)
- BAT : Indicates that the battery is low. (Blinks in reversed display.)

Space : Indicates a state other than the above.

(7) Current time

hh:mm:ss – Hours, minutes, and seconds

(8) Program editing status

INPUT : Indicates that data is being input.
OUTPUT : Indicates that data is being output.
SRCH : Indicates that a search is being performed.
EDIT : Indicates that another editing operation is being performed
(insertion, modification, etc.)
LSK : Indicates that labels are skipped when data is input.
RSTR : Indicates that the program is being restarted
Space : Indicates that no editing operation is being performed.

(9) Warning for data setting or input/output operation

When invalid data is entered (wrong format, value out of range, etc.),
when input is disabled (wrong mode, write disabled, etc.), or when
input/output operation is incorrect (wrong mode, etc.), a warning message
is displayed. In this case, the CNC does not accept the setting or
input/output operation (retry the operation according to the message).
The following are examples of warning messages:

Example 1)
When a parameter is entered

> 1
EDIT  WRONG MODE
(Display soft keys)

Example 2)
When a parameter is entered

> 999999999
MDI  TOO MANY DIGITS
(Display soft keys)

Example 3)
When a parameter is output to an external input/output device

> 
MEM  WRONG MODE
(Display soft keys)

(10) Tool post name (for the two-path control)

PATH1 : Tool post 1 is selected.
PATH2 : Tool post 2 is selected.
Other names can be used depending on the settings of parameters 3141
to 3147.
The tool post name is displayed at the position where (8) is now displayed.
While the program is edited, (8) is displayed.
11.7 SCREENS DISPLAYED BY FUNCTION KEY

By pressing the function key , data such as alarms, alarm history data, and external messages can be displayed. For information relating to alarm display, see Section III.7.1. For information relating to alarm history display, see Section III.7.2. For information relating to external message display, see the relevant manual supplied by the machine tool builder.

11.7.1 External Operator Message History Display

External operator messages can be preserved as history data. Preserved history data can be displayed on the external operator message history screen.

Procedure for external operator message history display

<table>
<thead>
<tr>
<th>Procedure</th>
<th>1 Press the function key.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2 Press the continuous menu key , then press the chapter selection soft key [MSGHIS]. The screen shown below appears.</td>
</tr>
</tbody>
</table>

![Screen shot](image)

**NOTE**

Up to 255 characters can be specified for an external operator message. By setting MS1 and MS0 (bits 7 and 6 of parameter No. 3113), however, the number of characters that can be preserved as external operator message history data can be restricted, and the number of history data items selected.

**Explanations**

- **Updating external operator message history data**

  When an external operator message number is specified, updating of the external operator message history data is started; this updating is continued until a new external operator message number is specified or deletion of the external operator message history data is specified.
• **Clearing external operator message history data**

  To clear external operator message history data, press the [CLEAR] soft key. This clears all external operator message history data. (Set MSGCR (bit 0 of parameter No. 3113) to 1.)

  Note that when MS1 and MS0 (bits 7 and 6 of parameter No. 3113), used to specify the number of external operator message history data items to be displayed, are changed, all existing external operator message history data is cleared.

**Limitations**

• **Two–path control**

  When two–path control is exercised, the external operator messages for system 1 are displayed. (The external operator messages for system 2 are not displayed.)

• **Option**

  Before this function can be used, the external data input function or optional external message function must be selected.
When screen indication isn’t necessary, the life of the back light for LCD can be put off by turning off the back light. The screen can be cleared by pressing specific keys. It is also possible to specify the automatic clearing of the screen if no keys are pressed during a period specified with a parameter. But, the life of the back light may be contracted all the more when the clearing of screen and re-indication of screen are repeated beyond the necessity. This effect can be expected when a screen is cleared for more than one hour.

Holding down the \textbf{CAN} key and pressing an arbitrary function key clears the screen.

\textbf{Procedure for erase screen display}

\begin{itemize}
  \item \textbf{Clearing the screen} \hspace{1cm} Hold down the \textbf{CAN} key and press an arbitrary function key (such as \textbf{POS} and \textbf{PROG}).
  \item \textbf{Restoring the screen} \hspace{1cm} Press an arbitrary function key.
  \item \textbf{Limitations} \hspace{1cm} Erase screen screen display function can not be used with the 160i/180i/160is/180is.
11.8.2
Automatic Erase Screen Display

The CNC screen is automatically cleared if no keys are pressed during the period (in minutes) specified with a parameter. The screen is restored by pressing any key.

Procedure for automatic erase screen display

- **Clearing the screen**
  The CNC screen is cleared once the period (minutes) specified with parameter No. 3123 has elapsed, provided the following conditions are satisfied:

  **Conditions for clearing the CNC screen**
  - Parameter No. 3123 is set to other than 0.
  - None of the following keys have been pressed:
    - MDI keys
    - Soft keys
    - External input keys
  - No alarm has been issued.

- **Restoring the screen**
  The cleared CNC screen is restored once at least one of the following conditions is satisfied:

  **Conditions for restoring the CNC screen**
  - Any of the following keys has been pressed:
    - MDI keys
    - Soft keys
    - Externally input keys
  - An alarm has been issued.

Some machines feature a special key for restoring the screen. For an explanation of the location and use of this key, refer to the corresponding manual, supplied by the machine tool builder.

Explanations

- **Clearing the screen using CAN + function key**
  If parameter No. 3123 is set to 0, clearing of the screen using the CAN key and a function key (III–11.8.1) is disabled.

- **Specified period**
  The period specified with parameter No. 3123 is valid only for tool post 1.

- **Alarm for another path**
  The screen is not cleared if an alarm is issued for tool post 1 or 2 or the loader before the specified period elapses.

**CAUTION**

Pressing any key while the screen is being cleared restores the screen. In such a case, however, the function assigned to the pressed key is initiated. Do not press the DELETE, EDIT, or ALTER key to restore the screen, therefore.
• **Limitations**

Automatic erase screen display function cannot be used with the 160i/180i/160is/180is.
Two graphic functions are available. One is a graphic display function, and the other is a dynamic graphic display function.

The graphic display function can draw the tool path specified by a program being executed on a screen. The graphic display function also allows enlargement and reduction of the display.

The dynamic graphic display function can draw a tool path and machining profile.

In tool path drawing, automatic scaling and solid drawing are possible.

In machining profile drawing, the status of machining in progress can be drawn through simulation. Blank figures can also be drawn.

The background drawing function enables drawing to be performed by one program while machining is performed by another program.

This chapter mainly explains drawing procedures and drawing parameters for the following:

1. Drawing the tool path specified by a program being executed, with the graphic display function
2. Drawing the tool path with the dynamic graphic display function
3. Drawing the machining profile with the dynamic graphic display function
4. Background drawing procedure
12.1
GRAPHICS DISPLAY

It is possible to draw the programmed tool path on the screen, which makes it possible to check the progress of machining, while observing the path on the screen. In addition, it is also possible to enlarge/reduce the screen. Before drawing, graphic parameters must be set. When the dynamic graphics function is used, the graphics function described in this section cannot be used. See Section 12.2 for the dynamic graphics function.

Graphics display procedure

Procedure


   The graphic parameter screen shown below appears. (If this screen does not appear, press soft key [PARAM].)

   ![Graphic Parameter Screen]

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>AXES</td>
<td>4</td>
</tr>
<tr>
<td>RANGE (MAX.)</td>
<td>X: 115000 Y: 150000 Z: 0</td>
</tr>
<tr>
<td>RANGE (MIN.)</td>
<td>X: 0 Y: 0 Z: 0</td>
</tr>
<tr>
<td>SCALE</td>
<td>K: 70</td>
</tr>
<tr>
<td>GRAPHIC CENTER</td>
<td>X: 57500 Y: 75000 Z: 0</td>
</tr>
<tr>
<td>PROGRAM STOP</td>
<td>N: 0</td>
</tr>
<tr>
<td>AUTO ERASE</td>
<td>A: 1</td>
</tr>
</tbody>
</table>

   MDI  • • •  • • •  14 : 23 : 54

2. Move the cursor with the cursor keys to a parameter to set.

3. Enter data, then press the [INPUT] key.

4. Repeat steps 2 and 3 until all required parameters are specified.

5. Press soft key [GRAPH].
6 Automatic operation is started and machine movement is drawn on the screen.

**Explanation**

- **RANGE**  
  *(Actual graphic range)*

  The size of the graphic screen will be as follows:

  ![Graphic Screen Diagram](image)

  **Fig. 12.1 (a) Graphic range**

  As shown in Fig.12.1 (a), the maximum graphics range is an area of approx. 144 mm (width) $\times$ 90 mm (height) for 7.2”/8.4” LCD and approx. 240 mm (width) $\times$ 150 mm (height) for 9.5”/10.4” LCD.

  To draw a section of the program within the actual graphics range, set the graphics range using one of the following two methods:

  1. Set the center coordinates of the range and the magnification.
  2. Set the maximum and minimum coordinates for the range in the program.

  Whether 1 or 2 is used depends on which parameters are set last. A graphics range which has been set is retained when the power is turned off.
Set the center of the graphic range to the center of the screen. If the drawing range in the program can be contained in the above actual graphics range, set the magnification to 1 (actual value set is 100).

When the drawing range is larger than the maximum graphics range or much smaller than the maximum graphics range, the graphics magnification should be changed. The graphics magnification is 0.01 to 100.00 times, which is usually determined as follows:

Graphics magnification \( \mathbf{H} \), or graphics magnifications \( \mathbf{V} \), whichever is smaller

\[
\text{Graphics magnification } \mathbf{H} = \frac{\alpha}{\text{(length on program to horizontal direction axis)}}
\]

\[
\text{Graphics magnification } \mathbf{V} = \frac{\beta}{\text{(length on program to vertical direction axis)}}
\]

\( \alpha \): 144mm (for seven soft key type)

\( \beta \): 90mm (for twelve soft key type)

\( \alpha \): 240mm (for seven soft key type)

\( \beta \): 150mm (for twelve soft key type)

The graphics magnification is always based on the center of the screen.

**Fig. 12.1 (b) Applying graphics magnification (Example of enlargement)**
2. Setting the maximum and minimum coordinates for the drawing range in the program

When the actual tool path is not near the center of the screen, method 1 will cause the tool path to be drawn out of the graphics range if graphics magnification is not set properly. To avoid such cases, the following six graphic parameters are prepared:

- Graphic range (Max.) X
- Graphic range (Max.) Y
- Graphic range (Max.) Z
- Graphic range (Min.) X
- Graphic range (Min.) Y
- Graphic range (Min.) Z

With the above parameters, the center of screen (Gcx, Gcy, Gcz) is determined by the CNC as follows:

\[
Gcx = \frac{(X_{\text{MAX.}} + X_{\text{MIN.}})}{2} \\
Gcy = \frac{(Y_{\text{MAX.}} + Y_{\text{MIN.}})}{2} \\
Gcz = \frac{(Z_{\text{MAX.}} + Z_{\text{MIN.}})}{2}
\]

The unit of the value will be 0.001 mm or 0.0001 inch depending on the input unit.

Graphics magnification is applied automatically. When the graphics range is specified, the center coordinates and magnification do not need to be calculated.

The graphic origin and graphic center point will not be changed even if the workpiece coordinate origin is changed.

In other words, the workpiece coordinate origin is always consistent with the graphic origin.

---

**Work coordinate system and graphics**

The graphic origin and graphic center point will not be changed even if the workpiece coordinate origin is changed.

In other words, the workpiece coordinate origin is always consistent with the graphic origin.

---

As shown in the above example, when the command of G92 is specified, the drawing is moved as indicated by the arrow. The position of the graphics origin or graphics center does not change.

![Fig. 12.1 (c) Workpiece coordinate origin and graphics origin](image-url)
• **Graphics parameter**  

  **AXES**  
  Specify the plane to use for drawing. The user can choose from the following six coordinate systems.  
  With two-path control, a different drawing coordinate system can be selected for each tool post.

  ![Coordinate system diagram]

  The rotating angle (horizontal, vertical) for isometric display of 5) and 6) is fixed at 45° in both cases.

  **Fig. 12.1 (d) Coordinate system**

  **RANGE (Max., Min.)**  
  Set the graphic range displayed on the screen by specifying maximum and minimum values along each axis.  
  \[
  \begin{align*}
  &X=\text{Maximum value} \\
  &Y=\text{Maximum value} \\
  &Z=\text{Maximum value} \\
  &X=\text{Minimum value} \\
  &Y=\text{Minimum value} \\
  &Z=\text{Minimum value}
  \end{align*}
  \]
  Valid range: 0 to ± 9999999

  **NOTE**
  1. The units are 0.001 mm or 0.0001 inch. Note that the maximum value must be greater than the minimum value for each axis.
  2. When setting the graphics range with the graphics parameters for the maximum and minimum values, do not set the parameters for the magnification and screen center coordinates afterwards. Only the parameters set last are effective.

  **SCALE**  
  Set the graphic magnification  
  The setting range is 0 to 10000 (unit:0.01 time).
**GRAPHIC CENTER**

\[ X = \_ \]
\[ Y = \_ \]
\[ Z = \_ \]

Set the coordinate value on the workpiece coordinate system at graphic center.

**NOTE**

1. When MAX. and MIN. of RANGE are set, the values will be set automatically once drawing is executed.
2. When setting the graphics range with the graphics parameters for the magnification and screen center coordinates, do not set the parameters for the maximum and minimum values afterward. Only the parameters set last are effective.

**PROGRAM STOP**

\[ N = \_ \]

Set the sequence No. of the end block when necessary to partially display.

This value is automatically cancelled and set to –1 once drawing is executed.

**AUTO ERASE**

1. Erase the previous drawing automatically when the automatic operation is started under reset condition.
2. Not erase automatically.

- **Executing drawing only**
  
  Since the graphic drawing is done when coordinate value is renewed during automatic operation, etc., it is necessary to start the program by automatic operation. To execute drawing without moving the machine, therefore, enter the machine lock state.

- **Deleting the previous drawing**
  
  When the AUTO operation is started under reset condition, the program is executed after deleting the previous drawing automatically (Automatic deleting=1). It is possible not to delete the previous drawing by graphic parameter (Automatic deleting=0).

- **Drawing a part of a program**
  
  When necessary to display a part of a program, search the starting block to be drawn by the sequence No. search, and set the sequence No. of the end block to the PROGRAM STOP N= of the graphic parameter before starting the program under cycle operation mode.

- **Drawing using dashed lines and solid lines**
  
  The tool path is shown with a dashed line (• - • - • ) for rapid traverse and with a solid line (——) for cutting feed.

**Limitations**

- **Feedrate**
  
  In case the feed rate is considerably high, drawing may not be executed correctly, decrease the speed by dry-run, etc. to execute drawing.

- **Two-path lathe control**
  
  For the two-path lathe control, two paths can not be displayed at the same time.
There are the following two functions in Dynamic Graphics.

<table>
<thead>
<tr>
<th>Path graphic</th>
<th>This is used to draw the path of tool center commanded by the part program.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid graphic</td>
<td>This is used to draw the workpiece figure machined by tool movement commanded by the part program.</td>
</tr>
</tbody>
</table>

The path graphic function is used to precisely check the part program for drawing the tool path with a line. The solid graphic function is used to draw the workpiece figure to be machined with a program. Thus, it is easy to recognize roughly the part program. These two functions can be used freely by switching them.

12.2 DYNAMIC GRAPHIC DISPLAY

12.2.1 Path Drawing

1. Drawing plane
   The user can choose the drawing plane from four types of plane views, two types of isometric projection views, and biplane view.

2. Drawing rotation
   When an isometric projection view is used, the drawing can be rotated horizontally and vertically.

3. Drawing enlargement and reduction
   A drawing can be enlarged or reduced by specifying a magnification from 0.01 to 100 with respect to the actual size. In addition, a drawing can be automatically enlarged or reduced by setting maximum and minimum values.

4. Partial drawing
   A range of the program can be drawn by specifying a starting sequence number and ending sequence number.

5. Programmed path and tool path drawing
   The user can specify whether to apply tool length offset and cutter compensation to drawing. This way, either the actual programmed path or the tool path can be drawn.

6. Color
   When a tool path is drawn on a screen, the colors used can be chosen from seven colors including white. The color of the tool path can be changed according to the T code.

7. Automatic scaling
   The CNC automatically determines the maximum and minimum drawing coordinates for each program. This means that drawing can be performed with a magnification automatically determined according to these maximum and minimum values.

8. Partial enlargement drawing
   Except for biplane views the user can enlarge all types of drawings by a factor of up to 100 while looking at the drawing that has been made.

9. Indicating the current tool position with a mark
   The current tool position can be displayed on the screen.

10. Indicating the coordinates of the current position
    The current position can also be indicated using coordinates.
11. Displaying coordinate axes and actual size dimensions lines

Coordinate axes and actual size dimension lines are displayed together with the drawing so that actual size can be referenced.

The first six functions above (1. to 6.) are available by setting the graphic parameters. The seventh to ninth functions (7. to 9.) are mainly executed using soft keys after drawing has been setup. The tenth function (10.) is enabled by setting a parameter. The eleventh function (11.) can be used at any time.

Path drawing procedure

Procedure

1. To draw a tool path, necessary data must be set beforehand.

So press the function button GRAPH some times (CUSTOM GRAPH for the small MDI). The “PATH GRAPHIC (PARAMETER)” is displayed.

**PATH GRAPHIC (PARAMETER–1) O0000 N00002**

<table>
<thead>
<tr>
<th>AXES</th>
<th>P= 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>(XY=0, YZ=1, ZY=2, XZ=3, XYZ=4, ZXY=5, 2P=6)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ANGLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROTATION A= 0</td>
</tr>
<tr>
<td>TILTING A= 0</td>
</tr>
<tr>
<td>SCALE K= 0.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CENTER OR MAX./MIN.</th>
</tr>
</thead>
<tbody>
<tr>
<td>X=130.000 Y=110.000 Z=50.000</td>
</tr>
<tr>
<td>I= 0.000 J= -10.000 K= 0.000</td>
</tr>
</tbody>
</table>

| START SEQ. NO. N= 0 |
| END SEQ. NO. N= 0 |
| NO. A= |

**PATH GRAPHIC (PARAMETER–2) O0000 N00001**

| TOOL COMP | P= 0 |
| COLOR (0123456) |
| PATH | P= 0 |
| TOOL | Q= 0 |
| AUTO CHANGE | R= 0 |

**MDI  14:25:07**

**MDI  14:25:51**
2 There are two screens for setting drawing parameters. Press the page key according to the setting items for selecting screens.

3 Set the cursor to an item to be set by cursor keys.

4 Input numerics by numeric keys.

5 Press the INPUT key.

The input numerics are set by these operations and the cursor automatically moves to the next setting items. The set data is held even after the power is turned off.

6 Set the operation mode to the memory mode, press function key PROG, and call the part program which should be drawn.

7 Press function key GRAPH (CUSTOM GRAPH for a small MDI) several times to redisplay the PATH GRAPHIC (PARAMETER) screen, then press soft key [EXEC] to display the PATH GRAPHIC (EXECUTION) screen.

8 Press soft key [OPRT], then press soft key [AUTO] or [START]. Pressing [AUTO] enables automatic scaling. See item 7 in introduction of path drawing and the description of soft key [AUTO] in Explanations for details. Drawing is now started. During drawing, the message “DRAWING” blinks at the lower–right corner of the CRT screen.

9 Press soft key [STOP] to pause drawing. The indication of “STOP” blinks at the lower right corner on the CRT screen. Press soft key [START] to start drawing. In addition, press soft key [REWIND] to redraw from the top of program before pressing soft key [START].

10 Execute the last of part program (M02/M30) to end drawing. This will cause, blinking of the “DRAWING” light to turn off. The tool path view drawn can be retained until the power is turned off unless a new tool path view is drawn.
Partial enlargement

11 For partial drawing enlargement, display the PATH GRAPHIC (SCALE) screen by pressing the soft key \texttt{[ZOOM]} on the PATH GRAPHIC (PARAMETER) screen of step 1 above. The tool path is displayed. Next, press soft key \texttt{[(OPRT)]}.

12 Perform positioning of marks displayed at the center of the screen to the center of the part enlarged using soft keys \texttt{[←]}, \texttt{[→]}, \texttt{[↓]}, and \texttt{[↑]}.

13 Set the relative magnification rate for the tool path view which is being drawn using the address keys “P” and “M”. When you press address key P or M, the following results:

<table>
<thead>
<tr>
<th>Address key</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>The relative magnification rate increases by 0.1.</td>
</tr>
<tr>
<td>M</td>
<td>The relative magnification rate decreases by 0.1.</td>
</tr>
</tbody>
</table>

The relative magnification rate is continuously changed by keeping the address keys depressed. It is possible to magnify up to 100 times in reference to the actual dimensions.

14 Press the soft key \texttt{[EXEC]} after setting the relative magnification rate. Then, the screen automatically changes to “TOOL PATH (EXECUTION)” and the drawing of set partial enlargement view starts. The set partial enlargement status is valid until soft key \texttt{[AUTO]} or \texttt{[ERASE]} is pressed.
Mark display

15 To display a mark at the current tool position, display the PATH GRAPHIC (POSITION) screen by pressing soft key [POS] on the PATH GRAPHIC (PARAMETER) screen of step 1 above. This mark blinks at the current tool center position on the tool path.

Explanations

• AXES

The relationship between the setting value and drawing screen is as shown below:

<table>
<thead>
<tr>
<th>Setting value</th>
<th>Drawing screen</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Plane view (XY)</td>
</tr>
<tr>
<td>1</td>
<td>Plane view (YZ)</td>
</tr>
<tr>
<td>2</td>
<td>Plane view (ZY)</td>
</tr>
<tr>
<td>3</td>
<td>Plane view (XZ)</td>
</tr>
<tr>
<td>4</td>
<td>Isometric projection (XYZ)</td>
</tr>
<tr>
<td>5</td>
<td>Isometric projection (ZXY)</td>
</tr>
<tr>
<td>6</td>
<td>Biplane view (XY,XZ)</td>
</tr>
</tbody>
</table>

• Plane view (XY,YZ,ZY,XZ)

The following coordinate systems are selected.

![Fig. 12.1(e) Coordinate systems for the plane view](image-url)
• Isometric projection (XYZ, ZXY)

Projector view by isometric can be drawn.

![Fig. 12.2.1 (a) Coordinate systems for the isometric projection](image)

• Biplane view

Biplanes (XY and XZ) can be drawn simultaneously. The maximum and minimum coordinate values must be set to draw the biplane view. The maximum and minimum coordinate values can also be set by performing automatic scaling.

![Fig. 12.2.1 (b) Coordinate systems for the biplane view](image)

• ANGLE

The direction of the coordinate axis is set when the isometric projection is the setting of the drawing screen. The direction is set by horizontal and vertical rotation angles. The unit is expressed in degrees.

• ROTATION

The horizontal rotation angle is set in the range of -180° to +180° in reference to the vertical axis. Set a positive value for clockwise rotation of the coordinate axis. Thus, the direction of projection (visual arrow) becomes counterclockwise.

![Fig. 12.2.1 (c) Rotating](image)
• TILTING

The tilting angle of the vertical axis is set in the range of $-90^\circ$ to $+90^\circ$ in reference to the horizontal axis crossing the vertical axis at a right angle. When a positive value is set, the vertical axis slants to the other side of the graphic screen. Thus, the projection direction (arrow direction) becomes the horizontal direction.

Fig. 12.2.1 (d) Tilting

• SCALE

Set the magnification rate of drawing from 0.01 to 100.00. When 1.0 is set, drawing is carried out in actual dimensions. When 0 is set, the drawing magnification rate is automatically set based on the setting of maximum and minimum coordinate values of drawing.

• CENTER OR MAX./MIN.

When a graphics (drawing) magnification of 0 is set, maximum coordinates on the X-axis, Y-axis, and Z-axis in the workpiece coordinate system must be set in addresses X, Y, and Z, and minimum coordinates must be set in addresses I, J, and K, to specify the graphics (drawing) range. For biplane view drawing, maximum and minimum coordinates for drawing must be specified.

When a drawing magnification other than 0 is set, the X, Y, and Z coordinates of the drawing center in the workpiece coordinate system must be set in addresses X, Y, and Z. Addresses I, J, and K are not used.

The table below summarizes the setting requirements described above.

<table>
<thead>
<tr>
<th>Setting the drawing magnification rate</th>
<th>Address X/Y/Z</th>
<th>Address I/J/K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other than 0</td>
<td>Drawing center coordinate value of X, Y, and Z axes</td>
<td>Ignored</td>
</tr>
<tr>
<td>0 or biplane view drawing</td>
<td>Drawing maximum coordinate value of X, Y, and Z axes</td>
<td>Drawing minimum coordinate value of X, Y, and Z axes</td>
</tr>
</tbody>
</table>

• START SEQ. NO. and END SEQ. NO.

Set the start and end sequence numbers of drawing in five digits each. The part program for drawing is executed from the head and only the part enclosed by the start sequence and end sequence numbers is drawn. When 0 is commanded as the start sequence number, drawing is performed from the head of the program. In addition, when 0 is commanded as the end sequence number, drawing is performed up to the end of program. The sequence number is referred to regardless of either main program or subprogram.
It is possible to set whether the tool path is drawn by making the tool length offset or cutter compensation valid or invalid.

<table>
<thead>
<tr>
<th>Setting value</th>
<th>Tool length offset or cutter compensation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Perform drawing by making tool compensation valid (An actual tool path is drawn.)</td>
</tr>
<tr>
<td>1</td>
<td>Perform drawing by making tool compensation invalid (A programmed path is drawn.)</td>
</tr>
</tbody>
</table>

Always set 0 before drawing when indicating the mark of the current tool position.

Specify the color of the tool path. In the case of monochrome it is not required to set it. The relationship between the setting value and color is as shown below:

<table>
<thead>
<tr>
<th>Setting value</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>White</td>
</tr>
<tr>
<td>1</td>
<td>Red</td>
</tr>
<tr>
<td>2</td>
<td>Green</td>
</tr>
<tr>
<td>3</td>
<td>Yellow</td>
</tr>
<tr>
<td>4</td>
<td>Blue</td>
</tr>
<tr>
<td>5</td>
<td>Purple</td>
</tr>
<tr>
<td>6</td>
<td>Light blue</td>
</tr>
</tbody>
</table>

- **PATH**: Specify the color of the tool path.
- **TOOL**: Specify the color of the current position mark of the tool.
- **AUTO CHANGE**: Set if for changing the color of the tool path automatically according to the T-code command.

<table>
<thead>
<tr>
<th>Setting value</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>The color of the tool path is not changed.</td>
</tr>
<tr>
<td>1</td>
<td>The color of the tool path is changed automatically.</td>
</tr>
</tbody>
</table>

When 1 is set, the setting value of the color designation of PATH is incremented by 1 every time the T code is commanded. At the same time, the color of the tool path changes. If the setting value exceeds 6, it returns to 0.

**Soft key functions on the “PATH GRAPHIC [EXECUTION]” screen**

<table>
<thead>
<tr>
<th>Software key</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>[AUTO]</td>
<td>Automatic scaling is performed. Obtain the maximum and minimum coordinates of the part program before performing drawing, specify them for the maximum and minimum values of drawing parameters, and set the drawing magnification rate to 0 before starting drawing. Thus, the tool path view is properly laid out on the screen.</td>
</tr>
<tr>
<td>[START]</td>
<td>Drawing starts. When the [START] is pressed while the drawing is not in STOP, the part program starts from the top of the part program. Press the [START] while the drawing is in stop to allow drawing to be carried out continuously.</td>
</tr>
<tr>
<td>[STOP]</td>
<td>Stop drawing. (Single block stop)</td>
</tr>
<tr>
<td>[REWIND]</td>
<td>Press this key to start drawing from the top of part program. Searches for the beginning of a part program.</td>
</tr>
<tr>
<td>[ERASE]</td>
<td>Erase the tool path view which has been drawn.</td>
</tr>
</tbody>
</table>
• Graphic program
No part program which has not been registered in memory can be drawn. Also, it is necessary that the M02 or M30 should be commanded at the end of the part program.

• Mark for the tool current position
The period of mark blinking is short when the tool is moving and becomes longer when the tool stops.
The mark indicating the current position of tool is displayed on the XY plane view when the biplane drawing is performed.

• Position mark
Parameter 6501 (CSR, bit 5) is used to specify whether to use □ or x as the mark for indicating the current tool position and the center of a partially enlarged drawing.

• Display of the coordinate value
Parameter 6500 (DPO, bit 5) is used to specify whether to display the coordinates of the current position on the tool path drawing screen.

• Changing the coordinate system
If a program specifies a coordinate system change, parameter 6501 (ORG, bit 0) is used to specify whether to draw without changing the coordinate system or to draw by regarding the current drawing position as the current position in the new coordinate system.

Restrictions
• Graphic condition
If machine operation is not allowed, no drawing can be carried out. No drawing can be made during machine operation. The setting data and switches required for drawing are as shown below:

<table>
<thead>
<tr>
<th>Setting data and switch</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tool offset amount</td>
<td>Set it properly when performing drawing while the tool offset amount becomes valid.</td>
</tr>
<tr>
<td>Single block</td>
<td>Off</td>
</tr>
<tr>
<td>Optional block skip</td>
<td>Set it properly.</td>
</tr>
<tr>
<td>Feed hold</td>
<td>Off</td>
</tr>
</tbody>
</table>

• Partial enlargement
The partial enlargement can be carried out on the plane view and isometric projection view. No partial enlargement can be made in the drawing of the biplane view.

• Tool current position
In dynamic graphics display, drawing cannot be executed while the machine is operating even though this is possible in ordinary graphics display (see III–12.1). However, after drawing is executed, the operator can see how the tool moves along the tool path by operating the machine while displaying the mark for the current position of the tool.
It is necessary that the setting data and switches related to the machine operation should be the same status between drawing operation and machining operation for properly displaying the current position of tool on the drawn tool path.

• Two–path lathe control
For the two–path lathe control, two paths can not be displayed at the same time.
### 12.2.2 Solid Graphics

The solid graphics draws the figure of a workpieces machined by the movement of a tool.

The following graphic functions are provided:

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Solid model graphic</td>
<td>Solid model graphic is drawn by surfaces so that the machined figure can be recognized concretely.</td>
</tr>
<tr>
<td>2. Blank figure graphics</td>
<td>It is possible to draw a blank figure before machining. A rectangular parallelepiped and a circular column or cylinder can be drawn. A circular column or cylinder parallel to the X-axis, Y-axis, or Z-axis can be selected.</td>
</tr>
<tr>
<td>3. Drawing of machining progress</td>
<td>It is possible to draw the progress of machining by simulation.</td>
</tr>
<tr>
<td>4. Drawing of final machined figure</td>
<td>It is possible to draw the final finish machined figure.</td>
</tr>
<tr>
<td>5. Changing of drawing direction</td>
<td>The user can choose from four drawing directions and eight tilting angles.</td>
</tr>
<tr>
<td>6. Plane view graphics</td>
<td>It is possible to draw XY plane views as well as solid model views. Height of the workpiece is discriminated by color for color or brightness for monochrome.</td>
</tr>
<tr>
<td>7. Triplane view graphic</td>
<td>In addition to a solid drawing, a triplane view can be drawn. The user can choose from four types of plane view and side view positions. The user can freely change the cross-section position of a side view.</td>
</tr>
<tr>
<td>8. Horizontal hole machining</td>
<td>It is possible to install tools in the direction which is parallel to the X or Y axis as well as the Z axis.</td>
</tr>
<tr>
<td>9. Tool change during machining</td>
<td>It is possible to change tools during machining by the part program command.</td>
</tr>
</tbody>
</table>
Solid graphics drawing procedure

**Procedure**

1. To draw a machining profile, necessary data must be set beforehand. So press the function key `GRAPH` for the small MDI). The screen of "SOLID GRAPHIC (PARAMETER)" is displayed.

<table>
<thead>
<tr>
<th>SOLID GRAPHIC (PARAMETER)</th>
<th>O0000 N00003</th>
</tr>
</thead>
<tbody>
<tr>
<td>BLANK FORM</td>
<td>P=</td>
</tr>
<tr>
<td>X= 0.000</td>
<td>Y= 0.000</td>
</tr>
<tr>
<td>I= 120.000</td>
<td>J= 100.000</td>
</tr>
<tr>
<td>TOOL FORM</td>
<td>K= 40.000</td>
</tr>
<tr>
<td>P= 2</td>
<td></td>
</tr>
<tr>
<td>R= 7.500</td>
<td></td>
</tr>
<tr>
<td>INTENSITY</td>
<td></td>
</tr>
<tr>
<td>0123456</td>
<td></td>
</tr>
<tr>
<td>Q= 1</td>
<td>R= 1</td>
</tr>
<tr>
<td>START SEQ.NO.</td>
<td>N= 0</td>
</tr>
<tr>
<td>END SEQ.NO.</td>
<td>N= 0</td>
</tr>
<tr>
<td>ANIM. SPEED</td>
<td>N= 0</td>
</tr>
</tbody>
</table>

   MDI: **14:42:17**

   See Explanations for details on settings.

2. Use a cursor key to move the cursor to an item to be set.

3. Input numerics for the item at the cursor using the numeric key.

4. Press the `INPUT`.

   Input numerics can be set by these operations and the cursor moves to the next setting item automatically. The set data is retained even if the power is turned off.

   See Explanations for details on settings.

   **SOLID GRAPHIC (BLANK)**

5. To draw a blank figure, display the SOLID GRAPHIC (BLANK) screen by pressing soft key [BLANK] on the SOLID GRAPHIC (PARAMETER) screen of step 1 above.
6 Press soft key [ANEW]. This allows the blank figure drawing to be performed based on the blank figure data set.

7 Press soft keys [+ROT] [-ROT] [+TILT], and [-TILT], when performing drawing by changing the drawing directions. Parameters P and Q for the drawing direction are changed and the figure is redrawn with the new parameters.

8 Set the operation mode to the memory mode, press function key [PROG], and call the subject part program of drawing.

9 To draw a machining profile, display the SOLID GRAPHIC (EXECUTION) screen by pressing soft key [EXEC] on the SOLID GRAPHIC (PARAMETER) screen of step 1 above.

---

**SOLID GRAPHICS (EXECUTION)**

---
10 Press soft key [(OPRT)] and press either soft key [A.ST] or [F.ST]. When [A.ST] is pressed, the status of machining in progress is drawn by simulation. When [F.ST] is pressed, the profile during machining is not drawn. Only the finished profile produced by the program is drawn. This allows drawing to be started. When “STOP” is not displayed at the lower right corner of the screen, the program is executed from its head. “DRAWING” blinks at the lower right corner of CRT screen during drawing.

11 Press soft key [STOP] to stop drawing temporarily. Drawing is stopped after drawing the current block and “STOP” blinks at the lower right corner of CRT screen. Press soft key [A.ST] or [F.ST] when restarting drawing. Press soft key [REWIND] and then the [A.ST] or [F.ST] if redrawing from the head. It is possible to continue drawing after changing the solid graphic parameters in temporary stop.

12 When the end of program (M02 or M03) is executed, the drawing ends and the blinking of “DRAWING” stops. Then, the final finish figure is drawn on the CRT screen. The drawn figure view is retained until the power is turned off as long as a new machine figure view is drawn.

• REVIEW

13 The color, intensity, or drawing direction of a machining figure which has been drawn can be changed and the figure redrawn. To redraw the figure, first change the parameters for the color, intensity, or drawing direction on the SOLID GRAPHIC (PARAMETER) screen shown in step 1, then press soft key [REVIEW] to display the SOLID GRAPHIC (REVIEW) screen.

14 Press soft key [(OPRT)], then press soft key [ANEW]. The machining figure is redrawn with the color, intensity, or drawing direction set in step 13.
15 To redraw the figure in a different mode, press soft key [+]ROT, [-ROT], [+]TILT, or [-TILT]. Parameters P and Q for the drawing direction are changed and the figure is redrawn with the new parameters.

- Triplane view drawing

16 The machined figure can be drawn on the tri–plane view. To draw a triplane view, press the rightmost soft key (next–menu key) on the SOLID GRAPHIC (PARAMETER) screen of step 1 above, then press soft key [3–PLN] and [(OPRT)]. The SOLID GRAPHIC (3–PLANE) screen appears.

17 Each time soft key [ ] is pressed, the side–view drawings displayed change as follows.

- Right view and rear view
- Rear view and left view
- Left view and front view
- Front view and right view

18 The sectional position of side view can be changed by the soft keys [←], [→], [↑], and [↓]. With the sectional position of the left/right side view, the marks ▲ and ▼ indicating the sectional position can be moved using the soft keys [←] and [→]. With the sectional position of rear/front side view, the marks ▶ and ◀ indicating the sectional position can be moved using the soft keys [↑], and [↓]. Keep the keys depressed to change sectional/views continuously.
Explanations

GRAPHICS PARAMETER

- **BLANK FORM**
  - **BLANK FORM (P)**
    Set the type of blank figure under P. The relationship between the setting value and figure is as follows:

    | P | Blank figure                        |
    |---|-------------------------------------|
    | 0 | Rectangular parallelepiped (Cubed) |
    | 1 | Column or cylinder (parallel to Z-axis) |

  - **Material positions (X,Y,Z)**
    Set the X-axis, Y-axis, and Z-axis coordinate values of standard point of materials in workpiece coordinate system to the addresses X, Y, and Z. The standard point of materials is the corner point in the negative direction in the case of rectangular parallelepiped blank figure and the center point of bottom in the case of column and cylinder materials.

  - **Material dimensions (I,J,K)**
    Set the dimensions of materials. The relationship between the addresses I, J, and K and setting value is as shown below:

    | Material      | I                     | J                     | K                     |
    |---------------|-----------------------|-----------------------|-----------------------|
    | Rectangular   | Length in X-axis     | Length in Y-axis     | Length in Z-axis     |
    |               | direction             | direction             | direction             |
    | Column        | Radius of circle      | 0                     | Length of column      |
    | Cylinder      | Radius of external circle | Radius of internal circle | Length of cylinder |

---

---
• TOOL FORM
  ♦ Machining tool orientation (P)
  ♦ Dimensions of tools (R,K)

Set the machining direction of tools.

<table>
<thead>
<tr>
<th>P</th>
<th>Machining direction of tools</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,1</td>
<td>Parallel to the Z-axis (perform machining from the + direction)</td>
</tr>
</tbody>
</table>

Set the dimensions of tool. The relationship between the displayed address and setting value is as shown below:

<table>
<thead>
<tr>
<th>Address</th>
<th>Setting numerics</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>Radius of tool</td>
</tr>
<tr>
<td>K</td>
<td>Distance from the program point to tool tip (normally 0)</td>
</tr>
</tbody>
</table>

The relationship between graphic method and direction and setting value is as shown below:

<table>
<thead>
<tr>
<th>P</th>
<th>Graphic method and direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>0, 4</td>
<td>Oblique projection view (+ X-axis)</td>
</tr>
<tr>
<td>1, 5</td>
<td>Oblique projection view (+ Y-axis)</td>
</tr>
<tr>
<td>2, 6</td>
<td>Oblique projection view (– X-axis)</td>
</tr>
<tr>
<td>3, 7</td>
<td>Oblique projection view (– Y-axis)</td>
</tr>
</tbody>
</table>

This setting value can also be incremented or decremented by the soft keys [+ROT] or [– ROT]. In this case, if the setting value exceeds 7, it returns to 0. If it is smaller than 0, it becomes 7.

• PROJECTION
  ♦ Graphics method and direction (P)

Direction of the vertical axis is fixed in Z-axis.
Specify the intensity of the drawing screen when performing drawing on the monochrome, and the color of the drawing screen when performing drawing on the color screen. The relationship between the setting, intensity, and color is as shown below:

However, when the plane view is displayed on the monochrome. The brighter surface, whichever is specified by P or Q becomes the top surface.

<table>
<thead>
<tr>
<th>Setting value</th>
<th>Intensity</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Maximum brightness</td>
<td>White</td>
</tr>
<tr>
<td>1</td>
<td>Dark</td>
<td>Red</td>
</tr>
<tr>
<td>2</td>
<td>↓</td>
<td>Green</td>
</tr>
<tr>
<td>3</td>
<td>Blue</td>
<td>Yellow</td>
</tr>
<tr>
<td>4</td>
<td>Purple</td>
<td>Light</td>
</tr>
<tr>
<td>5</td>
<td>Light blue</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The relationship between the display address, surface, and line on the machined figure view is as shown below:

<table>
<thead>
<tr>
<th>Address</th>
<th>Oblique projection view</th>
<th>Plane view</th>
<th>Triplane view</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>Upper surface</td>
<td>Upper surface</td>
<td>Upper/lower surface</td>
</tr>
<tr>
<td>Q</td>
<td>Side surface</td>
<td>Middle surface</td>
<td>Left/right surface</td>
</tr>
<tr>
<td>R</td>
<td>Ridge</td>
<td>Ridge</td>
<td>Ridge</td>
</tr>
</tbody>
</table>

Remarks: The intensity/color of front surface is between P and Q. Lower surface is blank. The intensity/color of plane view is between P and Q.
• **START SEQ. NO. and END SEQ. NO.**

Specify the start sequence number and end sequence number of each drawing in a five-digit numeric. The subject part program is executed from the head. But only the part enclosed by the start sequence number and end sequence numeric is drawn. When 0 is commanded as the start sequence number, the program is drawn from its head. When 0 is commanded as the end sequence number, the program is drawn to its end. The comparison of sequence number is performed regardless of main program and subprogram.

• **ANIM. SPEED**

Set interval of animated simulation drawing ranging from 0 to 255. Every time the machining proceeds by the number set, the drawing is repeated. If 0 is set, drawing is repeated at every 1 block execution.

<table>
<thead>
<tr>
<th>Soft key</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>[A.ST]</td>
<td>Simulate and draw the progress of machining.</td>
</tr>
<tr>
<td>[F.ST]</td>
<td>No figure during machining is drawn and only the final finish figure by that program is drawn.</td>
</tr>
<tr>
<td>[STOP]</td>
<td>When pressed, stops drawing at the end of block (single block stop).</td>
</tr>
<tr>
<td>[REWIND]</td>
<td>Press this key to perform drawing from the head of part program. Heading is performed automatically after execution of program end (M02/M30).</td>
</tr>
</tbody>
</table>

• **Graphics program**

No part program which has not been registered in memory can be drawn. It is also necessary that the M02 or M30 be commanded at the end of the part program.

• **Specifying the blank form and tool form in the part program**

It is possible to specify BLANK FORM and TOOL FORM in the part program. The command format is as shown below. If it is commanded during execution of drawing, the item corresponding to the screen of “SOLID GRAPHIC (PARAMETER)” is set and drawing continues with the set data.

- Command of BLANK FORM

  \[ G10 \, L90 \, P \_X\_Y\_Z\_I\_J\_K\_ ; \]

  The command value succeeding the address is the same as the numeric set to the address being displayed at the item of BLANK FORM of “SOLID GRAPHIC (PARAMETER)”.

- Command of TOOL FORM

  \[ G10 \, L91 \, P \_R\_K\_ ; \]

  The command value succeeding the address is the same as the numeric set to the address being displayed at the item of TOOL FORM of screen “SOLID GRAPHIC (PARAMETER)”.

• **Display of the coordinate value**

Parameter 6500 (DPO, bit 5) is used to specify whether to display the coordinates of the current position on SOLID GRAPHIC screen.
In solid graphics, parameter 6501 (TLC, bit 1) is used to specify whether to apply tool length offset.

Parameter 6501 (3PL, bit 2) is used to select whether to draw a triplane view with the third-angle or first-angle projection.

Parameter 6501 (RID, bit 3) is used to specify whether to draw ridges in plane view drawing.

Parameter 6501 (FIM, bit 4) is used to specify whether to display a solid graphics in the rough mode or in the fine mode. When a solid graphics is drawn in the fine mode, the drawing speed is slower than when drawn in the rough mode.

In triplane drawing, a value can be specified for changing the position of the cross section while the soft key is held down. A value from 0 to 10 can be set. When 0 is specified, a value of 1 is used. (Parameter No. 6515)
Examples

- Side view selection in triplane drawing

Example) The side views of the figure below are illustrated.

In the above figure, the side views displayed are switched as follows.

Example: Side view selection in triplane drawing
• Cross section position selection in triplane drawing

Some examples of cross-sectional views are given below for the left view and front view shown on the previous page.

Limitations

• Graphic condition

If the machine operation is not enabled, no drawing can be made. No drawing can be made during operation of machine. The main setting data and switches needed on drawing are as shown below:

<table>
<thead>
<tr>
<th>Setting data/switch</th>
<th>Status needed for drawing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tool offset value</td>
<td>It is necessary to set the cutter compensation value properly. The tool length offset is ignored.</td>
</tr>
<tr>
<td>Single block</td>
<td>Off</td>
</tr>
<tr>
<td>Optional block skip</td>
<td>Properly set it.</td>
</tr>
<tr>
<td>Feed hold</td>
<td>Off</td>
</tr>
</tbody>
</table>

• Tool form

Tools which set the tool figure are limited to the cylinder figure (equivalent to flat end mill).

• Helical interpolation

In solid graphics, paths based on helical interpolation cannot be drawn.

• Two–path control

For the two–path control, two paths can not be displayed at the same time.
12.3 BACKGROUND DRAWING

The background drawing function enables the drawing of a figure for one program while machining a workpiece under the control of another program.

Procedure for Background Drawing

Procedure

1. Press the \(\text{GRAPH}\) function key (\(\text{CUSTOM GRAPH}\) for a small MDI).

2. Press the [PARAM] soft key. The following screen appears:

   ![Screen Capture]

3. Press the [(OPRT)] soft key.

4. To select the program to be used for drawing, enter the number of that program, then press the [O SRH] soft key. (The \(O\) number at the top right of the screen indicates the selected program.) Repeatedly pressing only the [O SRH] soft key selects the registered programs in turn.

   To input a graphic parameter, the [INPUT] soft key can be used instead of the [INPUT] MDI key.

5. Press the left-most soft key (return menu key), to return the soft keys to the state existing upon the completion of step 2.

6. Perform dynamic graphic display, as described in Section III–12.2.

Explanations

• Program selection

Immediately after entering background drawing mode, the program which was selected previously remains selected. Any program can be selected for background drawing, by using the background drawing screen.

If no program is selected prior to entering background drawing mode, the program number is set to 0. In such a case, drawing cannot be started until the program to be used for drawing is specified.
• **Tool offsets**

Separate tool offsets are internally provided for machining and background drawing. Upon starting drawing or when selecting a program for drawing, the tool offset data for machining is copied to the tool offset data for background drawing. Changing a tool offset by using a G10 command during machining does not affect that for background drawing. Similarly, changing a tool offset by using a G10 command during drawing does not affect that for machining.

• **Parameters**

The same parameters are used for both background drawing and actual machining.

• **Workpiece coordinate offsets**

Workpiece coordinate system offsets, part of the parameters, are provided separately for machining and background drawing. Upon selecting a program for drawing, the workpiece coordinate system offset data for machining is copied to the workpiece coordinate system offset data for background drawing. Changing a workpiece coordinate system offset by using a G10 command during machining does not affect that for background drawing. Similarly, changing a workpiece coordinate system offset by using a G10 command during drawing does not affect that for machining.

• **Macro variables**

Macro variables are provided separately for machining and background drawing. Upon selecting a program for drawing, the macro variables for machining are copied to the macro variables for background drawing. Changing a macro variable by using a G10 command during machining does not affect that for background drawing. Similarly, changing a macro variable using a G10 command during drawing does not affect that for machining.

• **function key**

When bit 6 (BGOF) of parameter No. 3109 is set to 1, pressing the function key on the background drawing screen displays the tool offsets, workpiece coordinate system offsets, and macro variables for background drawing. In such a case, \[BGGRP\] is displayed at the bottom right of the screen, to indicate that data for background drawing is being displayed.
Bit 5 (DPO) of parameter No. 6500 can be used to specify whether the coordinates of the current position are to be displayed on the tool path drawing.

In background drawing mode, modal information F, S, and T is displayed, together with the current position. If the [POS] soft key has been selected for dynamic graphic display, however, F, S, and T are not displayed.

CAUTION
Once an alarm is issued during background drawing, drawing is stopped and the alarm description is displayed at the bottom right of the screen. To release the alarm state, press the CAN MDI key. Note that pressing the key will also stop foreground machining if currently in progress. Note, however, that bit 0 (RST) of parameter No. 8100 can be used to specify that machining will not be stopped if the key is pressed during background drawing.
13 HELP FUNCTION

The help function displays on the screen detailed information about alarms issued in the CNC and about CNC operations. The following information is displayed.

- Detailed information of alarms
  When the CNC is operated incorrectly or an erroneous machining program is executed, the CNC enters the alarm state. The help screen displays detailed information about the alarm that has been issued and how to reset it. The detailed information is displayed only for a limited number of P/S alarms. These alarms are often misunderstood and are rather difficult to understand.

- Operation method
  If you are not sure about a CNC operation, refer to the help screen for information about each operation.

- Parameter table
  When setting or referring to a system parameter, if you are not sure of the number of the parameter, the help screen displays a list of parameter Nos. for each function.

Help Function Procedure

Procedure

1. Press the HELP key on the MDI. HELP (INITIAL MENU) screen is displayed.

![HELP (INITIAL MENU) Screen]

The user cannot switch the screen display from the PMC screen or CUSTOM screen to the help screen. The user can return to the normal CNC screen by pressing the HELP key or another function key.
2. Press soft key [ALM] on the HELP (INITIAL MENU) screen to display detailed information about an alarm currently being raised.

**Fig. 13 (b) ALARM DETAIL Screen when P/S Alarm No. 27 is issued**

Note that only details of the alarm identified at the top of the screen are displayed on the screen.

If the alarms are all reset while the help screen is displayed, the alarm displayed on the ALARM DETAIL screen is deleted, indicating that no alarm is issued.

**Fig. 13 (c) ALARM DETAIL Screen when No Alarm is issued**
3 To get details on another alarm number, first enter the alarm number, then press soft key [SELECT]. This operation is useful for investigating alarms not currently being raised.

![Figure 13 (d) How to select each ALARM DETAILS](image)

4 To determine an operating procedure for the CNC, press the soft key [OPR] key on the HELP (INITIAL MENU) screen. The OPERATION METHOD menu screen is then displayed. (See Fig. 13 (f).)

![Figure 13 (e) ALARM DETAIL Screen when P/S alarm No. 100 is selected](image)

![Figure 13 (f) OPERATION METHOD Menu Screen](image)

To select an operating procedure, enter an item No. from the keyboard then press the [SELECT] key.
Fig. 13 (g) How to select each OPERATION METHOD screen

When “1. PROGRAM EDIT” is selected, for example, the screen in Figure 13 (g) is displayed.

On each OPERATION METHOD screen, it is possible to change the displayed page by pressing the PAGE key. The current page No. is shown at the upper right corner on the screen.

Fig. 13 (h) Selected OPERATION METHOD screen

To return to the OPERATION METHOD menu screen, press the RETURN MENU key to display “[OPR]” again, and then press the [OPR] key again.

To directly select another OPERATION METHOD screen on the screen shown in Figure 13 (h), enter an item No. from the keyboard and press the [SELECT] key.

Fig. 13 (i) How to select another OPERATION METHOD screen

If you are not sure of the No. of a system parameter to be set, or to refer to a system parameter, press the [PARA] key on the HELP (INITIAL MENU) screen. A list of parameter Nos. for each function is displayed. (See Figure 13 (j).)

It is possible to change the displayed page on the parameter screen. The current page No. is shown at the upper right corner on the screen.
7 To exit from the help screen, press the HELP key or another function key.

Explanation

- Configuration of the Help Screen
The screen hardcopy function outputs the information displayed on the CNC screen as 640*480–dot bitmap data. This function makes it possible to produce a hard copy of a still image displayed on the CNC. The created bitmap data can be displayed on a PC.

**Screen Hardcopy Procedure**

1. Check the parameter settings. To use the screen hardcopy function, set bit 7 (HDC) of parameter 3301 to 1 and parameter 20 (I/O channel selection) to 4 (memory card I/F). Set other relative parameters (bits 0, 2, and 3 of parameter 3301) as needed. In a multipath system, set the parameters for each path.

2. Insert a memory card.

3. To start the function, set hardcopy start signal HDREQ <G067#7> to 1. Alternatively, hold down the [SHIFT] key for five seconds.

4. To end the function, press the [CAN] key. Alternatively, set hardcopy stop signal HDABT <G067#6> to 1.

5. While the screen hardcopy operation is in progress, the hardcopy in progress signal <F061#3> is tied to 1. For several tens of seconds (or several seconds, for a monochrome LCD) before the hardcopy operation ends, the screen image stands still.

6. When the screen hardcopy operation is completed, the hardcopy in progress signal <F061#3> goes 0.

**Supplementary explanation**

While the screen hardcopy operation is in progress, the screen image keeps still. This means that the clock displayed on the screen indicates the beginning and end of the operation. When the clock stops counting seconds, the hard copy operation starts. The clock resumes counting seconds when the screen hard copy operation ends.
NOTE

1. During the screen hardcopy operation, key input is disabled for several tens of seconds. Until the screen hardcopy operation ends, the screen image lies still. During this period, the hardcopy in progress signal <F061#3> is tied to 1. No other signal is output. Avoid turning off the power indiscriminately during that period.
2. If the [SHIFT] or [CAN] key is customized by C executor, for instance, the screen hardcopy operation may disable the [SHIFT] or [CAN] key.
3. A normal hard copy may not be produced while the screen image is moving.

Limitations

A hard copy of the following screens cannot be produced.

1. Screen of the FS–160i/180i/210i (CNC with personal computer function)
2. System alarm screen
3. Screen while RS–232–C is being used
4. Screen during automatic or manual operation (A hard copy can be produced in a rest of the operation.)

Screen hardcopy function can not be used with the 160i/180i/160is/180is.

File name

The bitmap files created by the screen hardcopy function are named as follows, in order in which they are created after power–up:

'HDCPY000.BMP' (Name of the first hardcopy file created after power–up)
'HDCPY001.BMP' (Name of the second hardcopy file created after power–up)


NOTE

1. A screen hardcopy file produced after the file HDCPY099.BMP is output will be named as HDCPY000.BMP.
2. If a BMP file output by the screen hardcopy function has the same name as a file present on a memory card, the file on the memory card is overwritten unconditionally.
3. When the hardcopy function is carried out after power is turned off and on again, the first output file is named as HDCPY000.BMP again. If the inserted memory card has a file having the same name, the file is unconditionally overwritten. Note this when continuously producing hard copies of various screens.
The number of colors used in created bitmap data depend on the display control card, the LCD hardware, and the display mode of the CNC screen. Table 14 (a) indicates the relationships.

Table 14 (a) Colors of BMP data created by the screen hardcopy function

<table>
<thead>
<tr>
<th>LCD hardware</th>
<th>CNC screen display mode</th>
<th>Colors displayed on CNC</th>
<th>Colors used in created BMP data</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monochrome LCD</td>
<td>—</td>
<td>2 colors</td>
<td>2 colors</td>
<td>Shades of gray are not supported.</td>
</tr>
<tr>
<td>Color LCD</td>
<td>VGA–compatible mode</td>
<td>Character: 16 colors Graphic: 16 colors</td>
<td>When bit 0 of parameter 3301 is set to 0: 256 colors When bit 0 of parameter 3301 is set to 1: 16 colors</td>
<td>Most CNC screens use this mode. Note that colors may not be normally displayed in the 16-color mode.</td>
</tr>
<tr>
<td></td>
<td>VGA mode</td>
<td>256 colors</td>
<td>256 colors</td>
<td>A special screen can be prepared by C executor, for instance.</td>
</tr>
</tbody>
</table>

Table 14 (b) indicates the sizes of bitmap data created by the screen hardcopy function.

Table 14 (b) Sizes of bitmap data created by the screen hardcopy function

<table>
<thead>
<tr>
<th>Bitmap colors</th>
<th>File size (bytes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monochrome (2 colors)</td>
<td>38,462</td>
</tr>
<tr>
<td>Color (16 colors)</td>
<td>153,718</td>
</tr>
<tr>
<td>Color (256 colors)</td>
<td>308,278</td>
</tr>
</tbody>
</table>

If bit 2 (HCA) of parameter 3301 is set to 1, an alarm message can be output when the hardcopy operation ends in failure. (P/S alarm Nos. 5212 to 5214)
For descriptions of these alarms, see APPENDIX G, “ALARM LIST.”
IV. MAINTENANCE
This chapter describes how to replace the CNC backup battery and absolute pulse coder battery. This chapter consists of the following sections:

1.1 REPLACING BATTERY FOR LCD–MOUNTED TYPE i SERIES

1.2 REPLACING THE BATTERY FOR STAND–ALONE TYPE i SERIES

1.3 BATTERY IN THE CNC DISPLAY UNIT WITH PC FUNCTIONS (3 VDC)

1.4 BATTERY FOR SEPARATE ABSOLUTE PULSE CODERS (6 VDC)

1.5 BATTERY FOR BUILT–IN ABSOLUTE PULSE CODER (6 VDC)

Battery for memory backup

Part programs, offset data, and system parameters are stored in CMOS memory in the control unit. The power to the CMOS memory is backed up by a lithium battery mounted on the front panel of the control unit. Therefore, the above data is not lost even if the main battery fails. The backup battery is installed in the control unit prior to being shipped from the factory. This battery can provide backup for the memory contents for about a year.

When the battery voltage falls, alarm message “BAT” blinks on the LCD display and the battery alarm signal is output to the PMC. When this alarm is displayed, replace the battery as soon as possible. In general, the battery can be replaced within one or two weeks of the alarm first being issued. This, however, depends on the system configuration.

If the battery voltage subsequently drops further, backup of memory can no longer be provided. Turning on the power to the control unit in this state causes system alarm 910 (SRAM parity alarm) to be issued because the contents of memory are lost. Replace the battery, clear the entire memory, then reenter the data.

Replace the memory backup battery within a few minutes while the control unit is brought off.

The following two kinds of batteries can be used.

- Lithium battery, incorporated into the CNC control unit.
- Two alkaline dry cells (size D) in an external battery case.

NOTE
A lithium battery is installed as standard at the factory.
When a lithium battery is used
Prepare a new lithium battery (ordering code: A02B–0200–K102
(FANUC specification: A98L–0031–0012)).
1) Turn on the power to the CNC. After about 30 seconds, turn off the power.
2) Remove the old battery from the top of the CNC control unit.
   First, unplug the battery connector, then take the battery out of its case.
   The battery case of a control unit without option slots is located at the top end of the unit as shown in the figure of the previous page. The battery case of a control unit with 2 slots or 4 slots is located in the central area of the top of the unit (between fans).
3) Insert a new battery and reconnect the connector.

**WARNING**
Using other than the recommended battery may result in the battery exploding. Replace the battery only with the specified battery (A02B–0200–K102).
CAUTION

Steps 1) to 3) should be completed within 30 minutes. Do not leave the control unit without a battery for any longer than the specified period. Otherwise, the contents of memory may be lost.

If steps 1) to 3) may not be completed within 30 minutes, save all contents of the CMOS memory to the memory card beforehand. Thus, if the contents of the CMOS memory are lost, the contents can be restored easily.

For the method of operation, refer to Maintenance manual (B–63525EN).

When discarding a battery, observe the applicable ordinances or other rules of your local government. Also, cover the terminals of the battery with vinyl tape or the like to prevent a short-circuit.
Replacing commercial alkaline dry cells (size D)

1) Prepare two alkaline dry cells (size D) commercially available.
2) Turn on the power to the Series 16i/18i/160i/180i.
3) Remove the battery case cover.
4) Replace the cells, paying careful attention to their orientation.
5) Reinstall the cover onto the battery case.

CAUTION
When replacing the alkaline dry cells while the power is off, use the same procedure as that for lithium battery replacement described above.
1.2 REPLACING THE BATTERY FOR STAND–ALONE TYPE i SERIES

- Replacing the battery
  
  If a lithium battery is used, have A02B–0200–K102 (FANUC internal code: A98L–0031–0012) handy.

  (1) Turn the CNC on. About 30 seconds later, turn the CNC off.
  (2) Remove the battery from the top area of the CNC unit.
      Disconnect the connector first. Then, remove the battery from the battery case.
      The battery case is provided in the top area of the face plate of the main CPU board.
  (3) Replace the battery, then connect the connector.

  **WARNING**
  The incorrect mounting of the battery may cause an explosion. Avoid using any battery other than the one specified here (A02B–0200–K102).
CAUTION

Complete steps (1) to (3) within 30 minutes.
If the battery is left removed for a long time, the memory would lose the contents.
If there is a danger that the replacement cannot be completed within 30 minutes, save the whole contents of the CMOS memory to a memory card. The contents of the memory can be easily restored with the memory card in case the memory loses the contents.

Discard the dead battery, observing appropriate municipal rules and regulations. When discarding the battery, insulate the terminal with a tape so that no short-circuit would occur.
When using commercial D–size alkaline dry cells

- **Replacing the battery**
  1. Have commercial D–size alkaline dry cells handy.
  2. Turn the CNC on.
  3. Remove the lid from the battery case.
  4. Replace the old dry cells with new ones. Mount the dry cells in a correct orientation.
  5. Replace the lid on the battery case.

**CAUTION**
In the power–off state, the battery should be replaced as in the case of the lithium battery, which is described above.
A lithium battery is used to back up BIOS data in the CNC display unit with PC functions. This battery is factory-set in the CNC display unit with PC functions. This battery has sufficient capacity to retain BIOS data for one year.

When the battery voltage becomes low, the LCD screen blinks. (The LCD screen also blinks if a fan alarm is issued.) If the screen blinks, replace the battery as soon as possible (within one week). FANUC recommends that the battery be replaced once per year regardless of whether a battery alarm is issued.

1. To guard against the possible loss or destruction of BIOS parameters, write down the BIOS parameter values.
2. Obtain a new lithium battery (A02B-0200-K102).
3. After power has been supplied for at least five seconds, turn off the power to CNC display unit with PC functions. Remove the intelligent terminal from the panel so that replacement work can be done from the rear of the intelligent terminal.
4. Detach the connector of the lithium battery, and remove the battery from the battery holder.
5. Run the cable for the new lithium battery as shown in the Fig. 1.3.
6. Attach the connector, and place the battery in the battery holder.
7. Install CNC display unit with PC functions again.
8. Turn on the power, and check that the BIOS parameters are maintained (BIOS setup is not activated forcibly).

Between removing an old battery and inserting new battery, no more than five minutes must be allowed to elapse.
Fig. 1.3 Lithium battery connection for CNC display unit with PC functions
1.4 BATTERY FOR SEPARATE ABSOLUTE PULSE CODERS (6 VDC)

One battery unit can maintain current position data for six absolute pulse coders for a year. When the voltage of the battery becomes low, APC alarms 306 to 308 (+ axis name) are displayed on the CRT display. When APC alarm 3n7 is displayed, replace the battery as soon as possible. In general, the battery should be replaced within two or three weeks, however, this depends on the number of pulse coders used. If the voltage of the battery becomes any lower, the current positions for the pulse coders can no longer be maintained. Turning on the power to the control unit in this state causes APC alarm 300 (reference position return request alarm) to occur. Return the tool to the reference position after replacing the battery. See Section 7.1.3 for details of connecting the battery to separate absolute pulse coders. The battery for the built-in absolute pulse coder is installed in the servo amplifier. For an explanation of the replacement procedure, refer to the FANUC SERVO MOTOR α Series Maintenance Manual.

Replacing batteries

Obtain four commercially available alkaline batteries (size D).

(1) Turn on the power to the machine (i Series CNC).

(2) Loosen the screws on the battery case connected to the interface unit of the detector separately installed, and remove the cover.

(3) Replace the dry batteries in the case.

Note the polarity of the batteries as shown in the figure below (orient two batteries one way and the other two in the opposite direction).

(4) After installing the new batteries, replace the cover.

(5) Turn off the power to the machine (i Series CNC).

WARNING

If the batteries are installed incorrectly, an explosion may occur. Never use batteries other than the specified type (Size D alkaline batteries).

CAUTION

Replace batteries while the power to the i Series CNC is on. Note that, if batteries are replaced while no power is supplied to the CNC, the recorded absolute position is lost.
When the battery voltage falls, APC alarms 306 to 308 are displayed on the screen. When APC alarm 307 is displayed, replace the battery as soon as possible. In general, the battery should be replaced within one or two weeks of the alarm first appearing. This, however, depends on the number of pulse coders being used.

If the battery voltage drops any further, the current positions for the pulse coders will be lost. Turning on the power to the control unit in this state:

1. APC alarm 306 (battery zero alarm) and APC alarm 300 (reference position return request alarm) occur. Return the tool to the reference position after replacing the battery.

2. The battery for the built-in absolute pulse coder is connected with the servo amplifier.

3. Note that the attachment methods of the battery and ordering specifications of battery are different from SERVO AMPLIFIER αi series (SVM) to SERVO AMPLIFIER β series.

The battery unit for the absolute pulse coder can be connected using [Connection scheme 1] and [Connection scheme 2] explained below. Refer to Subsection 9.3.2.6, “Battery” in “FANUC SERVO AMPLIFIER αi series Descriptions (B–63282EN)” for details.

- If a low battery voltage or a battery voltage of 0 V is indicated by an APC (absolute pulse coder) alarm, replace the battery.
- If a battery voltage of 0 V is indicated, you need to make a zero point return.
- The absolute pulse coder of the ai series servo motor is incorporated with a backup capacitor as standard. This backup capacitor enables an absolute position detection to be continued for about 10 minutes. Therefore, no zero point return need be performed if the time during which servo amplifier power is kept off for battery replacement is within 10 minutes.
- When the replacing of the battery takes more than 10 minutes, replace the battery after see Item [Caution No.1 for battery replacement].
The service life of the batteries is about two years if they are used in a six-axis configuration with α series servo motors and one year if they are used in a six-axis configuration with α series servo motors. FANUC recommends that you replace the batteries periodically according to the battery service life.

The battery unit consists of four R20 alkaline batteries. Commercial batteries can be used in the battery unit. The optional battery offered by FANUC is A06B–6050–K061.

**WARNING**

1. Do not connect more than one battery to the same BATL (B3) line. If the output voltage is different between the batteries, they may be short-circuited, resulting in the batteries becoming very hot.
2. Install the battery with correct polarity. If the battery is installed with incorrect polarity, it may overheat, blow out, or catch fire.

---

**Connection scheme 2**

Incorporating each SVM with batteries

If a low battery voltage or a battery voltage of 0 V is indicated by an APC (absolute pulse coder) alarm, replace the battery (A06B–6073–K001). If a battery voltage of 0 V is indicated, you need to make a zero point return.
The absolute pulse coder of the αi series servo motor is incorporated with a backup capacitor as standard. This backup capacitor enables an absolute position detection to be continued for about 10 minutes. Therefore, no zero point return need be performed if the time during which servo amplifier power is kept off for battery replacement is within 10 minutes.

On the contrary, the absolute pulse coder of the standard α series servo motor is not incorporated with a backup capacitor. Be careful when replacing the battery for this pulse coder. See [Caution No. 1 for battery replacement] at the end of this section for details.

The service life of the batteries is about two years with αi series servo motors and one year with α series servo motors. FANUC recommends that you replace the batteries periodically according to the battery service life.

The built-in batteries are not commercially available. They must be purchased from FANUC. So, FANUC recommends that you keep spares.

**WARNING**

1. When using the built-in batteries (A06B-6073-K001), do not connect them to the BATL (B3) of connector CXA2A/CXA2B. The output voltages from different SVM batteries may be short-circuited, resulting in the batteries becoming very hot.

2. Do not connect more than one battery to the same BATL (B3) line. If the output voltage is different between the batteries, they may be short-circuited, resulting in the batteries becoming very hot.

3. Install the battery with correct polarity. If the battery is installed with incorrect polarity, it may overheat, blow out, or catch fire.
[Installation procedure for the battery]
(1) Remove the battery cover from the SVM.
(2) Install the battery in the SVM as shown in the figure below.
(3) Install the battery cover.
(4) Attach the battery connector to CX5X of the SVM.

CAUTION
1 When the battery is installed in the SVM from the side from which the cable is drawn, the cable may be stretched tight, which can lead to a poor contact condition. Therefore, install the battery so that the cable is not extended tightly.
2 Be careful when handling the connector. See [Caution No.2 for battery replacement] at the end of this section for details.

The pulse coder for the α series servo motor is not incorporated with a backup capacitor as standard. To keep the absolute position information in the absolute pulse coder, you need to keep the control power turned on during battery replacement. Follow the procedure explained below.

[Replacing procedure for the battery]
1. Make sure that the power to the SVM is on (the 7-segment LED on the front of the SVM is on).
2. Make sure that the emergency stop button of the system has been pressed.
3. Make sure that the motor is not activated.
4. Make sure that the DC link charge LED of the SVM is off.
5. Remove the old battery, and install a new battery.
6. This completes the replacement. You can turn off the power to the system.
1. METHOD OF REPLACING BATTERY

WARNING

1 When replacing the battery, be careful not to touch bare metal parts in the panel. In particular, be careful not to touch any high-voltage circuits due to the electric shock hazard.

2 Before replacing the battery, check that the DC link charge confirmation LED on the front of the servo amplifier is off. Neglecting this check creates an electric shock hazard.

3 Install the battery with correct polarity. If the battery is installed with incorrect polarity, it may overheat, blow out, or catch fire.

4 Avoid a short-circuit between the +6V and 0V lines of a battery or cable. A short-circuit may lead to a hot battery, an explosion, or fire.

[Caution No.2 for battery replacement]

If an excessive strain is applied to a connector when it is inserted or removed, a poor contact may result. When inserting and removing the battery connector, therefore, be careful not to apply an excessive wrenching force to it; just follow the instructions given in the following table.

(1) Attaching connectors

| <1> | ![Attachment Position](image1) | Check the attachment position. |
| <2> | ![10 degrees or less](image2) | 10 degrees or less |
| <5> | ![5 degrees or less](image3) | 5 degrees or less |
| <3> | ![After passing the lock pin](image4) | After passing the lock pin, insert the connector straight. |
| <4> | ![The attachment of the connector is completed](image5) | The attachment of the connector is completed. |
(2) Detaching the connector

<p>| | | |</p>
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<td>&lt;1&gt;</td>
<td><img src="image1" alt="Diagram of cable and connector" /></td>
<td>Hold both the sides of the cable insulator and the cable, and pull them horizontally.</td>
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<td><img src="image2" alt="Diagram of cable and connector" /></td>
<td>10 degrees or less</td>
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<td>Pull out the cable side while raising it slightly.</td>
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<td>&lt;3&gt;</td>
<td><img src="image3" alt="Diagram of cable and connector" /></td>
<td>5 degrees or less</td>
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<td>Here, the angle of the cable to the horizontal must be 5 degrees or less.</td>
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</tbody>
</table>
1.5.2  Method of Replacing Battery for Servo Amplifier β series

The battery is connected in either of 2 ways as follows.

Method 1: Use the battery case (A06B–6050–K060).
Use the battery: A06B–6050–K061 or D–size alkaline battery.

Method 2: Attach the lithium battery to the SVM.
Use the battery: A06B–6093–K001.

<table>
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<tr>
<th>Method</th>
<th>Item</th>
<th>Ordering specification</th>
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<td>Battery (4 pieces of D–size alkaline battery)</td>
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<tr>
<td>Method 2</td>
<td>Battery (Lithium battery)</td>
<td>A06B–6093–K001</td>
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</table>

• Replacement of batteries in the battery case. (Method 1)
Replace four D–size alkaline batteries in the battery case installed in the machine.

[Attachment procedure]
(1) Turn the servo unit (machine) on.
(2) Place the machine in the emergency stop state.
(3) Confirm that the servo motors are not active.
(4) Have four D–size alkaline batteries on hand.
(5) Loosen the screws on the battery case. Remove the cover.
(6) Replace the alkaline batteries in the case. Pay careful attention to the polarity of the alkaline batteries.
(7) Attach the cover.

• Attach the lithium battery to the amplifier. (Method 2)
Attach the lithium (A06B–6093–K001) battery to the amplifier.

[Attachment procedure]
(1) Turn the servo unit (machine) on.
(2) Place the machine in the emergency stop state.
(3) Confirm that the servo motors are not active.
(4) In case of SVU–12 or SVU–20, remove the battery cover under the servo unit grasping its left and right sides. In case of SVU–40 or SVU–80, remove the cover attached on right side of the servo unit grasping its upper and lower sides.
(5) Remove the battery from the servo unit.
(6) Replace the battery and connect the battery cable with the connector CX5X or CX5Y of the servo unit.
(7) Mount the battery cover.

**CAUTIONS**
- The connector of the battery can be connected with either of CX5X and CX5Y.
**Used batteries**

Old batteries should be disposed as “INDUSTRIAL WASTES” according to the regulations of the country or autonomy where your machine has been installed.
APPENDIX
# TAPE CODE LIST

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NOTE
1 The symbols used in the remark column have the following meanings.
   (Space) : The character will be registered in memory and has a specific meaning.
       It it is used incorrectly in a statement other than a comment, an alarm occurs.
   × : The character will not be registered in memory and will be ignored.
   Δ : The character will be registered in memory, but will be ignored during program
        execution.
   ○ : The character will be registered in memory. If it is used in a statement other than
       a comment, an alarm occurs.
   □ : If it is used in a statement other than a comment, the character will not be
       registered in memory. If it is used in a comment, it will be registered in memory.
2 Codes not in this table are ignored if their parity is correct.
3 Codes with incorrect parity cause the TH alarm. But they are ignored without generating the
   TH alarm when they are in the comment section.
4 A character with all eight holes punched is ignored and does not generate TH alarm in EIA code.
Some functions cannot be added as options depending on the model.

In the tables below, \( \text{PI} \) presents a combination of arbitrary axis addresses using X,Y,Z,A,B and C (such as \( X_{-}Y_{-}Z_{-}A_{-} \)).

- \( x \) = 1st basic axis (X usually)
- \( y \) = 2nd basic axis (Y usually)
- \( z \) = 3rd basic axis (Z usually)

<table>
<thead>
<tr>
<th>Functions</th>
<th>Illustration</th>
<th>Tape format</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positioning (G00)</td>
<td><img src="image" alt="Positioning" /></td>
<td>G00 ( \text{IP}_{-} );</td>
</tr>
<tr>
<td>Linear interpolation (G01)</td>
<td><img src="image" alt="Linear interpolation" /></td>
<td>G01 ( \text{IP}<em>{-} \ F</em>{-} ; )</td>
</tr>
</tbody>
</table>
| Circular interpolation (G02, G03) | ![Circular interpolation](image) | G17 \( \begin{cases} G02 \\ G03 \end{cases} X_{-}Y_{-} \{R_{-} \\ I_{-}J_{-} \} \ F_{-} ; \)  
G18 \( \begin{cases} G02 \\ G03 \end{cases} X_{-}Z_{-} \{R_{-} \\ I_{-}K_{-} \} \ F_{-} ; \)  
G19 \( \begin{cases} G02 \\ G03 \end{cases} Y_{-}Z_{-} \{R_{-} \\ J_{-}K_{-} \} \ F_{-} ; \) |
| Helical interpolation (G02, G03) | ![Helical interpolation](image) | G17 \( \begin{cases} G02 \\ G03 \end{cases} X_{-}Y_{-} \{R_{-} \\ I_{-}J_{-} \} \alpha \ F_{-} ; \)  
G18 \( \begin{cases} G02 \\ G03 \end{cases} X_{-}Z_{-} \{R_{-} \\ I_{-}K_{-} \} \alpha \ F_{-} ; \)  
G19 \( \begin{cases} G02 \\ G03 \end{cases} Y_{-}Z_{-} \{R_{-} \\ J_{-}K_{-} \} \alpha \ F_{-} ; \)  
\( \alpha \) : Any axis other than circular interpolation axes. |
<table>
<thead>
<tr>
<th>Functions</th>
<th>Illustration</th>
<th>Tape format</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dwell (G04)</td>
<td></td>
<td>G04 ( \left{ \begin{array}{l} X_- \ P_- \end{array} \right} ; )</td>
</tr>
<tr>
<td>High-speed cycle machining (G05)</td>
<td>See II 19.1</td>
<td>G05 P10; L_; P10_; Number of the machining cycle to be called first: (P10001 to P10999) L_; Repetition count of the machining cycle (L1 to L999/L1 applies when this parameter is omitted.)</td>
</tr>
<tr>
<td>High-speed remote bufferA (G05)</td>
<td>See II 19.3.1</td>
<td>G05: Turns binary input operation on. Subsequently, enter data for binary input operation. If, in data for binary input operation, the amounts of travel along all axes are specified as 0, binary input operation is turned off.</td>
</tr>
<tr>
<td>High-speed remote bufferB (G05)</td>
<td>See II 19.3.2</td>
<td>G05 P01; Turns binary input operation on. Subsequently, enter data for binary input operation. If, in data for binary input operation, the amounts of travel along all axes are specified as 0, binary input operation is turned off.</td>
</tr>
<tr>
<td>High-precision contour control (G05)</td>
<td>See II 19.8</td>
<td>G05 P10000; Starts high-precision contour control mode G05 P0; Ends high-precision contour control mode</td>
</tr>
<tr>
<td>AI high-precision contour control (G05)</td>
<td>See II 22.1</td>
<td>G05 P10000; Starts AI high-precision contour control mode G05 P0; Ends AI high-precision contour control mode</td>
</tr>
<tr>
<td>AI nano high-precision contour control (G05)</td>
<td>See II 22.1</td>
<td>G05 P10000; Starts AI nano high-precision contour control mode G05 P0; Ends AI nano high-precision contour control mode (Note) For all of the high precision contour control, AI high precision contour control, and AI nano high precision contour control functions, the same command format is used. (G05P10000) Which function to apply depends on the option specification.</td>
</tr>
<tr>
<td>AI contour control (G05.1)</td>
<td>See II 19.7</td>
<td>G05.1 Q1; AI contour control mode on G05.1 Q0; AI contour control mode off</td>
</tr>
<tr>
<td>Functions</td>
<td>Illustration</td>
<td>Tape format</td>
</tr>
<tr>
<td>------------------------------------------------</td>
<td>--------------</td>
<td>------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>AI nano contour control (G05.1)</td>
<td></td>
<td>G05.1 Q1; AI nano contour control mode on&lt;br&gt;G05.1 Q0; AI nano contour control mode off&lt;br&gt;(Note)&lt;br&gt;For both of the AI contour control and AI nano contour control functions, the same command format is used. (G05.1 Q1)&lt;br&gt;Which function to apply depends on the option specification. If, however, the AI nano contour control option is specified, AI contour control can be issued by appropriately setting NAM (bit 0 of parameter No. 7503).</td>
</tr>
<tr>
<td>Cylindrical interpolation (G07.1)</td>
<td></td>
<td>G07 IP r ; Cylindrical interpolation mode on&lt;br&gt;r : Radius of cylinder&lt;br&gt;G07 IP 0 ; Cylindrical interpolation mode off</td>
</tr>
<tr>
<td>Advanced preview control (G08)</td>
<td></td>
<td>G08 P1: Look-ahead control mode on&lt;br&gt;G08 P0: Look-ahead control mode off</td>
</tr>
<tr>
<td>Exact stop (G09)</td>
<td>Velocity</td>
<td>G09 { G01&lt;br&gt;G02&lt;br&gt;G03 } IP_-; Time&lt;br&gt;In-position check</td>
</tr>
<tr>
<td>Change of offset value by program (G10)</td>
<td></td>
<td>Tool offset memory A&lt;br&gt;G10 L11 P_R_-&lt;br&gt;Tool offset memory B&lt;br&gt;G10 L10 P_R_-;(Geometry offset value)&lt;br&gt;G10 L11 P_R_-;(Wear offset value)&lt;br&gt;Tool offset memory C&lt;br&gt;G10 L10 P_R_-;(Geometry offset value/H)&lt;br&gt;G10 L11 P_R_-;(Wear offset value/H)&lt;br&gt;G10 L12 P_R_-;(Geometry offset value/D)&lt;br&gt;G10 L13 P_R_-;(Wear offset value/D)</td>
</tr>
<tr>
<td>Polar coordinate (G15, G16)</td>
<td></td>
<td>G17 G16 Xp_ Yp_ . . . ;&lt;br&gt;G18 G16 Zp_ Xp_ . . . ;&lt;br&gt;G19 G16 Yp_ Zp_ . . . ;&lt;br&gt;G15 ; Cancel</td>
</tr>
</tbody>
</table>

---

**APPENDIX**

B. LIST OF FUNCTIONS AND TAPE FORMAT

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—— 1158 ——
<table>
<thead>
<tr>
<th>Functions</th>
<th>Illustration</th>
<th>Tape format</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plane section (G17, G18, G19)</td>
<td></td>
<td>G17 ; G18 ; G19 ;</td>
</tr>
<tr>
<td>Inch/millimeter conversion (G20, G21)</td>
<td></td>
<td>G20 ; Inch input</td>
</tr>
<tr>
<td></td>
<td></td>
<td>G21 ; Millimeter input</td>
</tr>
<tr>
<td>Stored stroke check (G22, G23)</td>
<td>(XYZ)</td>
<td>G22 X_Y_Z_I_J_K_ ;</td>
</tr>
<tr>
<td></td>
<td>(UK)</td>
<td>G23 Cancel ;</td>
</tr>
<tr>
<td>Spindle speed fluctuation detection (G25, G26)</td>
<td></td>
<td>G25 ; Spindle speed fluctuation detection off</td>
</tr>
<tr>
<td></td>
<td></td>
<td>G26 ; P_Q_R ; Spindle speed fluctuation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>detection on</td>
</tr>
<tr>
<td>Reference position return check (G27)</td>
<td></td>
<td>G27 IP_ ;</td>
</tr>
<tr>
<td>Reference position return (G28) 2nd, reference</td>
<td></td>
<td>G28 IP_ ;</td>
</tr>
<tr>
<td>Reference position return (G30)</td>
<td></td>
<td>G30 IP_ ;</td>
</tr>
<tr>
<td>Return from reference position to start point</td>
<td></td>
<td>G29 IP_ ;</td>
</tr>
<tr>
<td>(G29)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### B. LIST OF FUNCTIONS AND TAPE FORMAT

<table>
<thead>
<tr>
<th>Functions</th>
<th>Illustration</th>
<th>Tape format</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skip function (G31)</td>
<td><img src="image1" alt="Skip function illustration" /></td>
<td>G31 _F_;</td>
</tr>
<tr>
<td>Thread cutting (G33)</td>
<td><img src="image2" alt="Thread cutting illustration" /></td>
<td>G33 _F_;</td>
</tr>
<tr>
<td>Cutter compensation C (G40 – G42)</td>
<td><img src="image3" alt="Cutter compensation illustration" /></td>
<td>{G17 G18 G19} {G41 G42} _D_;</td>
</tr>
<tr>
<td>Normal direction control (G40.1, G41.1, G42.1) (G150, G151, G152)</td>
<td><img src="image4" alt="Normal direction control illustration" /></td>
<td>G41.1 (G151) Normal direction control Left G42.1 (G152) Normal direction control Right G40.1 (G150) Normal direction control Cancel</td>
</tr>
<tr>
<td>Tool length offset A (G43, G44, G49)</td>
<td><img src="image5" alt="Tool length offset A illustration" /></td>
<td>{G43 G44} _Z H_;</td>
</tr>
<tr>
<td>Tool length offset B (G43, G44, G49)</td>
<td><img src="image6" alt="Tool length offset B illustration" /></td>
<td>{G17 G18 G19} {G43 G44} _Z X_; _H_;</td>
</tr>
<tr>
<td>Tool length offset C (G43, G44, G49)</td>
<td><img src="image7" alt="Tool length offset C illustration" /></td>
<td>{G43 G44} _\alpha H_;</td>
</tr>
<tr>
<td>Tool offset (G45 – G48)</td>
<td><img src="image8" alt="Tool offset illustration" /></td>
<td>{G45 G46 G47 G48} _D_;</td>
</tr>
</tbody>
</table>

---

### Tool offset

- **G45**: Increase
- **G46**: Decrease
- **G47**: Double increase
- **G48**: Double decrease

**\_D\_;**: Tool offset
# B. List of Functions and Tape Format

<table>
<thead>
<tr>
<th>Functions</th>
<th>Illustration</th>
<th>Tape format</th>
</tr>
</thead>
</table>
| Scaling (G50, G51) | ![Scaling Illustration](image) | G51 X.Y.Z. \{P-I-J-K\}  
P, I, J, K : Scaling magnification  
X, Y, Z : Control position of scaling  
G50 ; Cancel |
| Programmable mirror image (G50.1, G51.1) | ![Mirror Illustration](image) | G51.1 IP_ ;  
G50.1 ; ......Cancel |
| Setting of local coordinate system (G52) | ![Coordinate System Illustration](image) | G52 IP_ ; |
| Command in machine coordinate system (G53) | ![Command Illustration](image) | G53 IP_ ; |
| Selection of work coordinate system (G54 – G59) | ![Work Coordinate System Illustration](image) | G54 \{ IP_ \} ;  
G59 IP_ ; |
| Single direction positioning (G60) | ![Positioning Illustration](image) | G60 IP_ ; |
| Cutting mode/Exact stop mode, Tapping mode, Automatic corner override | ![Cutting Mode Illustration](image) | G64_ ; Cutting mode  
G61_ ; Exact stop mode  
G63_ ; Tapping mode  
G62_ ; Automatic corner override |
| Custom macro (G65, G66, G67) | ![Custom Macro Illustration](image) | One–shot call  
G65 P_ L_  
<Argument assignment> ;  
P : Program No.  
L : Number of repetition  
Modal call  
G66 P_ L_ <Argument  
G67 ; Cancel assignment> ; |
<table>
<thead>
<tr>
<th>Functions</th>
<th>Illustration</th>
<th>Tape format</th>
</tr>
</thead>
</table>
| Coordinate system rotation (G68, G69)         | ![Coordinate System Rotation](image) | G68 G17 X_ Y_  
|                                                |              | G18 Z_ X_  
|                                                |              | G19 Y_ Z_  
|                                                |              | R_ g_  
|                                                |              | G69_ ; Cancel |
| Canned cycles (G73, G74, G80 – G89)           | ![Canned Cycles](image) | G80_ ; Cancel  
|                                                |              | G73_  
|                                                |              | G74_  
|                                                |              | G76_  
|                                                |              | G81_  
|                                                |              | G89_  
| Absolute/incremental programming (G90/G91)    | ![Absolute/Incremental Programming](image) | G90_ ; Absolute command  
|                                                |              | G91_ ; Incremental command  
|                                                |              | G90_ G91_ ; Combined use |
| Change of workpiece coordinate system (G92)    | ![Change of Workpiece Coordinate System](image) | G92_ ; Change of workpiece coordinate system  
| Maximum spindle speed clamp (G92)             | ![Maximum Spindle Speed Clamp](image) | G92_ S_ ; Constant surface speed control  
|                                                |              | Maximum spindle speed clamp |
| Workpiece coordinate system preset (G92.1)     | ![Workpiece Coordinate System Preset](image) | G92.1_  
|                                                |              | P_ 0_ ; |
| Feed per minute, Feed per revolution (G94, G95)| ![Feed Per Minute/Rev](image) | G94 F_ ; Feed per minute  
|                                                |              | G95 F_ ; Feed per revolution |
| Constant surface speed control (G96, G97)     | ![Constant Surface Speed Control](image) | G96 S_ ; Constant surface speed control on (surface speed specification)  
|                                                |              | G97 S_ ; Constant surface speed control off (spindle speed specification) |
| Initial point return / R point return (G98, G99)| ![Initial Point Return/R Point Return](image) | G98_ ;  
|                                                |              | G99_ ;  
|                                                |              | Z point |
## RANGE OF COMMAND VALUE

### Linear axis
- In case of millimeter input, feed screw is millimeter

<table>
<thead>
<tr>
<th>Increment system</th>
<th>IS–B</th>
<th>IS–C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Least input increment</td>
<td>0.001 mm</td>
<td>0.0001 mm</td>
</tr>
<tr>
<td>Least command increment</td>
<td>0.001 mm</td>
<td>0.0001 mm</td>
</tr>
<tr>
<td>Max. programmable dimension</td>
<td>±99999.999 mm</td>
<td>±9999.9999 mm</td>
</tr>
<tr>
<td>Max. rapid traverse <strong>Note</strong></td>
<td>240000 mm/min</td>
<td>100000 mm/min</td>
</tr>
<tr>
<td>Feedrate range <strong>Note</strong></td>
<td>1 to 240000 mm/min</td>
<td>1 to 100000 mm/min</td>
</tr>
<tr>
<td>Incremental feed</td>
<td>0.001, 0.01, 0.1, 1 mm/step</td>
<td>0.0001, 0.001, 0.01, 0.1 mm/step</td>
</tr>
<tr>
<td>Tool compensation</td>
<td>0 to ±999.999 mm</td>
<td>0 to ±999.9999 mm</td>
</tr>
<tr>
<td>Dwell time</td>
<td>0 to 99999.999 sec</td>
<td>0 to 99999.999 sec</td>
</tr>
</tbody>
</table>

### In case of inch input, feed screw is millimeter

<table>
<thead>
<tr>
<th>Increment system</th>
<th>IS–B</th>
<th>IS–C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Least input increment</td>
<td>0.0001 inch</td>
<td>0.00001 inch</td>
</tr>
<tr>
<td>Least command increment</td>
<td>0.001 mm</td>
<td>0.0001 mm</td>
</tr>
<tr>
<td>Max. programmable dimension</td>
<td>±9999.9999 inch</td>
<td>±393.70078 inch</td>
</tr>
<tr>
<td>Max. rapid traverse <strong>Note</strong></td>
<td>240000 mm/min</td>
<td>100000 mm/min</td>
</tr>
<tr>
<td>Feedrate range <strong>Note</strong></td>
<td>0.01 to 9600 inch/min</td>
<td>0.01 to 4000 inch/min</td>
</tr>
<tr>
<td>Incremental feed</td>
<td>0.0001, 0.001, 0.01, 0.1 inch/step</td>
<td>0.00001, 0.0001, 0.001, 0.01 inch/step</td>
</tr>
<tr>
<td>Tool compensation</td>
<td>0 to ±99.9999 inch</td>
<td>0 to ±99.9999 inch</td>
</tr>
<tr>
<td>Dwell time</td>
<td>0 to 99999.999 sec</td>
<td>0 to 99999.999 sec</td>
</tr>
</tbody>
</table>
### C. RANGE OF COMMAND VALUE

#### • In case of inch input, feed screw is inch

<table>
<thead>
<tr>
<th>Increment system</th>
<th>IS–B</th>
<th>IS–C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Least input increment</td>
<td>0.0001 inch</td>
<td>0.00001 inch</td>
</tr>
<tr>
<td>Least command increment</td>
<td>0.0001 inch</td>
<td>0.00001 inch</td>
</tr>
<tr>
<td>Max. programmable dimension</td>
<td>±9999.9999 inch</td>
<td>±9999.9999 inch</td>
</tr>
<tr>
<td>Max. rapid traverse <strong>Note</strong></td>
<td>9600 inch/min</td>
<td>4000 inch/min</td>
</tr>
<tr>
<td>Feedrate range <strong>Note</strong></td>
<td>0.01 to 9600 inch/min</td>
<td>0.01 to 4000 inch/min</td>
</tr>
<tr>
<td>Incremental feed</td>
<td>0.0001, 0.001, 0.01, 0.1 inch/step</td>
<td>0.00001, 0.0001, 0.001, 0.01 inch/step</td>
</tr>
<tr>
<td>Tool compensation</td>
<td>0 to ±99.9999 inch</td>
<td>0 to ±99.9999 inch</td>
</tr>
<tr>
<td>Dwell time</td>
<td>0 to 99999.999 sec</td>
<td>0 to 99999.999 sec</td>
</tr>
</tbody>
</table>

#### • In case of millimeter input, feed screw is inch

<table>
<thead>
<tr>
<th>Increment system</th>
<th>IS–B</th>
<th>IS–C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Least input increment</td>
<td>0.001 mm</td>
<td>0.0001 mm</td>
</tr>
<tr>
<td>Least command increment</td>
<td>0.0001 inch</td>
<td>0.00001 inch</td>
</tr>
<tr>
<td>Max. programmable dimension</td>
<td>±99999.999 mm</td>
<td>±9999.9999 mm</td>
</tr>
<tr>
<td>Max. rapid traverse <strong>Note</strong></td>
<td>9600 inch/min</td>
<td>4000 inch/min</td>
</tr>
<tr>
<td>Feedrate range <strong>Note</strong></td>
<td>1 to 240000 mm/min</td>
<td>1 to 100000 mm/min</td>
</tr>
<tr>
<td>Incremental feed</td>
<td>0.001, 0.01, 0.1, 1 mm/step</td>
<td>0.0001, 0.001, 0.01, 0.1 mm/step</td>
</tr>
<tr>
<td>Tool compensation</td>
<td>0 to ±999.999 mm</td>
<td>0 to ±999.9999 mm</td>
</tr>
<tr>
<td>Dwell time</td>
<td>0 to 99999.999 sec</td>
<td>0 to 99999.999 sec</td>
</tr>
</tbody>
</table>
Rotation axis

<table>
<thead>
<tr>
<th>Increment system</th>
<th>IS–B</th>
<th>IS–C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Least input increment</td>
<td>0.001 deg</td>
<td>0.0001 deg</td>
</tr>
<tr>
<td>Least command increment</td>
<td>0.001 deg</td>
<td>0.0001 deg</td>
</tr>
<tr>
<td>Max. programmable dimension</td>
<td>±99999.999 deg</td>
<td>±9999.9999 deg</td>
</tr>
<tr>
<td>Max. rapid traverse <strong>Note</strong></td>
<td>240000 deg/min</td>
<td>100000 deg/min</td>
</tr>
<tr>
<td>Feedrate range <strong>Note</strong></td>
<td>1 to 240000 deg/min</td>
<td>1 to 100000 deg/min</td>
</tr>
<tr>
<td>Incremental feed</td>
<td>0.001, 0.01, 0.1, 1 deg/step</td>
<td>0.0001, 0.001, 0.01, 0.1 deg/step</td>
</tr>
</tbody>
</table>

**NOTE**
The feedrate range shown above are limitations depending on CNC interpolation capacity. As a whole system, limitations depending on servo system must also be considered.
The leads of a thread are generally incorrect in $\delta_1$ and $\delta_2$, as shown in Fig. D.1 (a), due to automatic acceleration and deceleration. Thus distance allowances must be made to the extent of $\delta_1$ and $\delta_2$ in the program.

**D.1 INCORRECT THREADED LENGTH**

**Fig. D.1 (a) Incorrect thread position**

### Explanations

- **How to determine $\delta_2$**

  \[ \delta_2 = T_1V \text{ (mm)} \quad \ldots \ldots \quad (1) \]

  \[ V = \frac{1}{60} RL \]

  \[ T_1 : \text{Time constant of servo system (sec)} \]

  \[ V : \text{Cutting speed (mm/ sec)} \]

  \[ R : \text{Spindle speed (rpm)} \]

  \[ L : \text{Thread feed (mm)} \]

- **How to determine $\delta_1$**

  \[ \delta_1 = (t-T_1 + T_1 \exp(-\frac{t}{T_1}))V \quad \ldots \ldots \quad (2) \]

  \[ a = \exp(-\frac{t}{T_1}) \quad \ldots \ldots \quad (3) \]

  \[ T_1 : \text{Time constant of servo system (sec)} \]

  \[ V : \text{Cutting speed (mm/ sec)} \]

  \[ \text{Time constant } T_1 \text{ (sec) of the servo system: Usually 0.033 s.} \]

The lead at the beginning of thread cutting is shorter than the specified lead $L$, and the allowable lead error is $\Delta L$. Then as follows.

\[ a = \frac{\Delta L}{L} \]

When the value of HtI is determined, the time lapse until the thread accuracy is attained. The time HtI is substituted in (2) to determine $\delta_1$: Constants $V$ and $T_1$ are determined in the same way as for $\delta_2$. Since the calculation of $\delta_1$ is rather complex, a nomography is provided on the following pages.
First specify the class and the lead of a thread. The thread accuracy, $\alpha$, will be obtained at (1), and depending on the time constant of cutting feed acceleration/ deceleration, the $\delta_1$ value when $V = 10\text{mm/s}$ will be obtained at (2). Then, depending on the speed of thread cutting, $\delta_1$ for speed other than $10\text{mm/s}$ can be obtained at (3).

![Fig. D.1 (b) Nomograph](image-url)

**NOTE**

The equations for $\delta_1$, and $\delta_2$ are for when the acceleration/ deceleration time constant for cutting feed is 0.
D.2 SIMPLE CALCULATION OF INCORRECT THREAD LENGTH

Explanations

- How to determine $\delta_2$

$$\delta_2 = \frac{LR}{1800^2} \text{ (mm)}$$

R: Spindle speed (min$^{-1}$)
L: Thread lead (mm)

* When time constant T of the servo system is 0.033 s.

- How to determine $\delta_1$

$$\delta_1 = \frac{LR}{1800^2}(-1-\text{ln}a) \text{ (mm)}$$

$$= \delta_2(-1-\text{ln}a) \text{ (mm)}$$

R: Spindle speed (min$^{-1}$)
L: Thread lead (mm)

* When time constant T of the servo system is 0.033 s.

Following a is a permitted value of thread.

<table>
<thead>
<tr>
<th>a</th>
<th>$-1-\text{ln}a$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.005</td>
<td>4.298</td>
</tr>
<tr>
<td>0.01</td>
<td>3.605</td>
</tr>
<tr>
<td>0.015</td>
<td>3.200</td>
</tr>
<tr>
<td>0.02</td>
<td>2.912</td>
</tr>
</tbody>
</table>

Examples

R=350rpm
L=1mm
a=0.01 then

$$\delta_2 = \frac{350 \times 1}{1800} = 0.194 \text{ (mm)}$$

$$\delta_1 = \delta_2 \times 3.605 = 0.701 \text{ (mm)}$$
Fig. D.2 (b) Nomograph for obtaining approach distance $\delta_1$
When servo system delay (by exponential acceleration/deceleration at cutting or caused by the positioning system when a servo motor is used) is accompanied by cornering, a slight deviation is produced between the tool path (tool center path) and the programmed path as shown in Fig. D.3 (a).

Time constant $T_1$ of the exponential acceleration/deceleration is fixed to 0.

![Fig. D.3 (a) Slight deviation between the tool path and the programmed path](image)

This tool path is determined by the following parameters:
- **Feedrate** ($V_1$, $V_2$)
- **Corner angle** ($\theta$)
- **Exponential acceleration / deceleration time constant ($T_1$) at cutting ($T_1 = 0$)**
- **Presence or absence of buffer register.**

The above parameters are used to theoretically analyze the tool path and above tool path is drawn with the parameter which is set as an example. When actually programming, the above items must be considered and programming must be performed carefully so that the shape of the workpiece is within the desired precision.

In other words, when the shape of the workpiece is not within the theoretical precision, the commands of the next block must not be read until the specified feedrate becomes zero. The dwell function is then used to stop the machine for the appropriate period.
Analysis

The tool path shown in Fig. D.3 (b) is analyzed based on the following conditions:
Feedrate is constant at both blocks before and after cornering.
The controller has a buffer register. (The error differs with the reading speed of the tape reader, number of characters of the next block, etc.)

\[ V_{x1} = V \cos \phi_1 \]
\[ V_{y1} = V \sin \phi_1 \]
\[ V_{x2} = V \cos \phi_2 \]
\[ V_{y2} = V \sin \phi_2 \]

- **Description of conditions and symbols**

  - \( V \): Feedrate at both blocks before and after cornering
  - \( V_{x1} \): X-axis component of feedrate of preceding block
  - \( V_{y1} \): Y-axis component of feedrate of preceding block
  - \( V_{x2} \): X-axis component of feedrate of following block
  - \( V_{y2} \): Y-axis component of feedrate of following block
  - \( \theta \): Corner angle
  - \( \phi_1 \): Angle formed by specified path direction of preceding block and X-axis
  - \( \phi_2 \): Angle formed by specified path direction of following block and X-axis
• Initial value calculation

![Fig. D.3 (c) Initial value](image)

The initial value when cornering begins, that is, the X and Y coordinates at the end of command distribution by the controller, is determined by the feedrate and the positioning system time constant of the servo motor.

\[
X_0 = V_x(T_1 + T_2)
\]
\[
Y_0 = V_y(T_1 + T_2)
\]

- \(T_1\): Exponential acceleration / deceleration time constant. (T=0)
- \(T_2\): Time constant of positioning system (Inverse of position loop gain)

• Analysis of corner tool path

The equations below represent the feedrate for the corner section in X-axis direction and Y-axis direction.

\[
V_x(t) = (V_{x2} - V_{x1})[1 - \frac{V_{x1}}{T_1 - T_2} T_1 \exp(-\frac{t}{T_1}) - T_2 \exp(-\frac{t}{T_2})] + V_{x1}
\]
\[
= V_{x2}[1 - \frac{V_{x1}}{T_1 - T_2} (T_1 \exp(-\frac{t}{T_1}) - T_2 \exp(-\frac{t}{T_2}))]
\]
\[
V_y(t) = \frac{V_{y1} - V_{y2}}{T_1 - T_2} (T_1 \exp(-\frac{t}{T_1}) - T_2 \exp(-\frac{t}{T_2})) + V_{y2}
\]

Therefore, the coordinates of the tool path at time \(t\) are calculated from the following equations:

\[
X(t) = \int_0^t V_x(t) dt - X_0
\]
\[
= \frac{V_{x2} - V_{x1}}{T_1 - T_2} T_1 \exp(-\frac{t}{T_1}) - T_2 \exp(-\frac{t}{T_2})] - V_{x2}(T_1 + T_2 - t)
\]
\[
Y(t) = \int_0^t V_y(t) dt - Y_0
\]
\[
= \frac{V_{y2} - V_{y1}}{T_1 - T_2} T_1 \exp(-\frac{t}{T_1}) - T_2 \exp(-\frac{t}{T_2})] - V_{y2}(T_1 + T_2 - t)
\]
When a servo motor is used, the positioning system causes an error between input commands and output results. Since the tool advances along the specified segment, an error is not produced in linear interpolation. In circular interpolation, however, radial errors may be produced, especially for circular cutting at high speeds. This error can be obtained as follows:

\[
\Delta r = \frac{1}{2} \left( T_1^2 + T_2^2 (1 - \alpha^2) \right) \frac{V^2}{T} \ldots \ldots \ (1)
\]

- \( \Delta r \): Maximum radius error (mm)
- \( v \): Feedrate (mm/s)
- \( r \): Circle radius (mm)
- \( T_1 \): Exponential acceleration/deceleration time constant (sec) at cutting (T=0)
- \( T_2 \): Time constant of positioning system (sec), (Inverse of position loop gain)
- \( \alpha \): Feed forward coefficient (%)

In the case of bell–shaped acceleration/deceleration and linear acceleration/deceleration after cutting feed interpolation, an approximation of this radius error can be obtained with the following expression:

Linear acceleration/deceleration after cutting feed interpolation

\[
\Delta r = \left( \frac{1}{24} T_1^2 + \frac{1}{2} T_2^2 (1 - \alpha^2) \right) \frac{V^2}{T}
\]

Bell–shaped acceleration/deceleration after cutting feed interpolation

\[
\Delta r = \left( \frac{1}{48} T_1^2 + \frac{1}{2} T_2^2 (1 - \alpha^2) \right) \frac{V^2}{T}
\]

Thus, the radius error in the case of bell–shaped acceleration/deceleration and linear acceleration/deceleration after interpolation is smaller than in case of exponential acceleration/deceleration by a factor of 12, excluding any error caused by a servo loop time constant.

Since the machining radius \( r \) (mm) and allowable error \( \Delta r \) (mm) of the workpiece is given in actual machining, the allowable limit feedrate \( v \) (mm/sec) is determined by equation (1). Since the acceleration/deceleration time constant at cutting which is set by this equipment varies with the machine tool, refer to the manual issued by the machine tool builder.
Parameter CLR (No. 3402#6) is used to select whether resetting the CNC places it in the cleared state or in the reset state (0: reset state/1: cleared state).

The symbols in the tables below mean the following:
○: The status is not changed or the movement is continued.
×: The status is cancelled or the movement is interrupted.

<table>
<thead>
<tr>
<th>Item</th>
<th>When turning power on</th>
<th>Cleared</th>
<th>Reset</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Setting data</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Offset value</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Data set by the MDI setting operation</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Parameter</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td><strong>Various data</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Programs in memory</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Contents in the buffer storage</td>
<td>×</td>
<td>×</td>
<td>○ : MI mode&lt;br&gt;× : Other mode</td>
</tr>
<tr>
<td>Display of sequence number</td>
<td>○</td>
<td>(Note 1)</td>
<td>(Note 1)</td>
</tr>
<tr>
<td>One shot G code</td>
<td>×</td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td><strong>Modal G code</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial G codes. (The G20 and G21 codes return to the same state they were in when the power was last turned off.)</td>
<td>Initial G codes. (G20/G21 are not changed.)</td>
<td>○</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>Zero</td>
<td>Zero</td>
<td>○</td>
</tr>
<tr>
<td>S, T, M</td>
<td>×</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>K (Number of repeats)</td>
<td>×</td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>Work coordinate value</td>
<td>Zero</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>
### E. STATUS WHEN TURNING POWER ON, WHEN CLEAR AND WHEN RESET

<table>
<thead>
<tr>
<th>Item</th>
<th>When turning power on</th>
<th>Cleared</th>
<th>Reset</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Action in operation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Movement</td>
<td>×</td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>Dwell</td>
<td>×</td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>Issuance of M, S and T codes</td>
<td>×</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tool length compensation</td>
<td>×</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cutter compensation</td>
<td>×</td>
<td>×</td>
<td></td>
</tr>
<tr>
<td>Storing called subprogram number</td>
<td>×</td>
<td>(Note 2)</td>
<td></td>
</tr>
<tr>
<td><strong>Output signals</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CNC alarm signal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AL</td>
<td>Extinguish if there is no cause for the alarm</td>
<td>Extinguish if there is no cause for the alarm</td>
<td>Extinguish if there is no cause for the alarm</td>
</tr>
<tr>
<td>Reference position return completion LED</td>
<td>×</td>
<td></td>
<td>(Note 2)</td>
</tr>
<tr>
<td>S, T and B codes</td>
<td>×</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>M code</td>
<td>×</td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>M, S and T strobe signals</td>
<td>×</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spindle revolution signal (S analog signal)</td>
<td>×</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>CNC ready signal</td>
<td>ON</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Servo ready signal</td>
<td>ON (When other than servo alarm)</td>
<td>ON (When other than servo alarm)</td>
<td>ON (When other than servo alarm)</td>
</tr>
<tr>
<td>Cycle start LED (STL)</td>
<td>×</td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>Feed hold LED (SPL)</td>
<td>×</td>
<td>×</td>
<td>×</td>
</tr>
</tbody>
</table>

**NOTE**

1. When heading is performed, the main program number is displayed.
2. When a reset is performed during execution of a subprogram, control returns the head of main program. Execution cannot be started from the middle of the subprogram.
## CHARACTER–TO–CODES CORRESPONDENCE TABLE

<table>
<thead>
<tr>
<th>Character</th>
<th>Code</th>
<th>Comment</th>
<th>Character</th>
<th>Code</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>065</td>
<td></td>
<td>6</td>
<td>054</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>066</td>
<td></td>
<td>7</td>
<td>055</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>067</td>
<td></td>
<td>8</td>
<td>056</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>068</td>
<td></td>
<td>9</td>
<td>057</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>069</td>
<td></td>
<td></td>
<td>032</td>
<td>Space</td>
</tr>
<tr>
<td>F</td>
<td>070</td>
<td>!</td>
<td></td>
<td>033</td>
<td>Exclamation mark</td>
</tr>
<tr>
<td>G</td>
<td>071</td>
<td>&quot;</td>
<td></td>
<td>034</td>
<td>Quotation mark</td>
</tr>
<tr>
<td>H</td>
<td>072</td>
<td>#</td>
<td></td>
<td>035</td>
<td>Hash sign</td>
</tr>
<tr>
<td>I</td>
<td>073</td>
<td>$</td>
<td></td>
<td>036</td>
<td>Dollar sign</td>
</tr>
<tr>
<td>J</td>
<td>074</td>
<td>%</td>
<td></td>
<td>037</td>
<td>Percent</td>
</tr>
<tr>
<td>K</td>
<td>075</td>
<td>&amp;</td>
<td></td>
<td>038</td>
<td>Ampersand</td>
</tr>
<tr>
<td>L</td>
<td>076</td>
<td>'</td>
<td></td>
<td>039</td>
<td>Apostrophe</td>
</tr>
<tr>
<td>M</td>
<td>077</td>
<td>(</td>
<td></td>
<td>040</td>
<td>Left parenthesis</td>
</tr>
<tr>
<td>N</td>
<td>078</td>
<td>)</td>
<td></td>
<td>041</td>
<td>Right parenthesis</td>
</tr>
<tr>
<td>O</td>
<td>079</td>
<td>*</td>
<td></td>
<td>042</td>
<td>Asterisk</td>
</tr>
<tr>
<td>P</td>
<td>080</td>
<td>+</td>
<td></td>
<td>043</td>
<td>Plus sign</td>
</tr>
<tr>
<td>Q</td>
<td>081</td>
<td>.</td>
<td></td>
<td>044</td>
<td>Comma</td>
</tr>
<tr>
<td>R</td>
<td>082</td>
<td>–</td>
<td></td>
<td>045</td>
<td>Minus sign</td>
</tr>
<tr>
<td>S</td>
<td>083</td>
<td>:</td>
<td></td>
<td>046</td>
<td>Period</td>
</tr>
<tr>
<td>T</td>
<td>084</td>
<td>/</td>
<td></td>
<td>047</td>
<td>Slash</td>
</tr>
<tr>
<td>U</td>
<td>085</td>
<td>;</td>
<td></td>
<td>058</td>
<td>Colon</td>
</tr>
<tr>
<td>V</td>
<td>086</td>
<td>;</td>
<td></td>
<td>059</td>
<td>Semicolon</td>
</tr>
<tr>
<td>W</td>
<td>087</td>
<td>&lt;</td>
<td></td>
<td>060</td>
<td>Left angle bracket</td>
</tr>
<tr>
<td>X</td>
<td>088</td>
<td>=</td>
<td></td>
<td>061</td>
<td>Equal sign</td>
</tr>
<tr>
<td>Y</td>
<td>089</td>
<td>&gt;</td>
<td></td>
<td>062</td>
<td>Right angle bracket</td>
</tr>
<tr>
<td>Z</td>
<td>090</td>
<td>?</td>
<td></td>
<td>063</td>
<td>Question mark</td>
</tr>
<tr>
<td>0</td>
<td>048</td>
<td>@</td>
<td></td>
<td>064</td>
<td>HAtl mark</td>
</tr>
<tr>
<td>1</td>
<td>049</td>
<td>[</td>
<td></td>
<td>091</td>
<td>Left square bracket</td>
</tr>
<tr>
<td>2</td>
<td>050</td>
<td>^</td>
<td></td>
<td>092</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>051</td>
<td>]</td>
<td></td>
<td>094</td>
<td>Right square bracket</td>
</tr>
<tr>
<td>4</td>
<td>052</td>
<td>_</td>
<td></td>
<td>095</td>
<td>Underscore</td>
</tr>
<tr>
<td>5</td>
<td>053</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**1) Program errors (P/S alarm)**

<table>
<thead>
<tr>
<th>Number</th>
<th>Message</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>000</td>
<td>PLEASE TURN OFF POWER</td>
<td>A parameter which requires the power off was input, turn off power.</td>
</tr>
<tr>
<td>001</td>
<td>TH PARITY ALARM</td>
<td>TH alarm (A character with incorrect parity was input). Correct the tape.</td>
</tr>
<tr>
<td>002</td>
<td>TV PARITY ALARM</td>
<td>TV alarm (The number of characters in a block is odd). This alarm will be generated only when the TV check is effective.</td>
</tr>
<tr>
<td>003</td>
<td>TOO MANY DIGITS</td>
<td>Data exceeding the maximum allowable number of digits was input. (Refer to the item of max. programmable dimensions.)</td>
</tr>
<tr>
<td>004</td>
<td>ADDRESS NOT FOUND</td>
<td>A numeral or the sign “–” was input without an address at the beginning of a block. Modify the program.</td>
</tr>
<tr>
<td>005</td>
<td>NO DATA AFTER ADDRESS</td>
<td>The address was not followed by the appropriate data but was followed by another address or EOB code. Modify the program.</td>
</tr>
<tr>
<td>006</td>
<td>ILLEGAL USE OF NEGATIVE SIGN</td>
<td>Sign “.” input error (Sign “–” was input after an address with which it cannot be used. Or two or more “–” signs were input.) Modify the program.</td>
</tr>
<tr>
<td>007</td>
<td>ILLEGAL USE OF DECIMAL POINT</td>
<td>Decimal point “–” input error (A decimal point was input after an address with which it cannot be used. Or two decimal points were input.) Modify the program.</td>
</tr>
<tr>
<td>009</td>
<td>ILLEGAL ADDRESS INPUT</td>
<td>Unusable character was input in significant area. Modify the program.</td>
</tr>
<tr>
<td>010</td>
<td>IMPROPER G–CODE</td>
<td>An unusable G code or G code corresponding to the function not provided is specified. Modify the program.</td>
</tr>
<tr>
<td>011</td>
<td>NO FEEDRATE COMMANDED</td>
<td>Feedrate was not commanded to a cutting feed or the feedrate was inadequate. Modify the program.</td>
</tr>
<tr>
<td>014</td>
<td>CAN NOT COMMAND G95</td>
<td>A synchronous feed is specified without the option for threading / synchronous feed.</td>
</tr>
<tr>
<td>015</td>
<td>TOO MANY AXES COMMANDED</td>
<td>The number of the commanded axes exceeded that of simultaneously controlled axes.</td>
</tr>
<tr>
<td>020</td>
<td>OVER TOLERANCE OF RADIUS</td>
<td>In circular interpolation (G02 or G03), difference of the distance between the start point and the center of an arc and that between the end point and the center of the arc exceeded the value specified in parameter No. 3410.</td>
</tr>
<tr>
<td>021</td>
<td>ILLEGAL PLANE AXIS COMMANDED</td>
<td>An axis not included in the selected plane (by using G17, G18, G19) was commanded in circular interpolation. Modify the program.</td>
</tr>
<tr>
<td>022</td>
<td>NO CIRCULAR RADIUS</td>
<td>When circular interpolation is specified, neither R (specifying an arc radius), nor I, J, and K (specifying the distance from a start point to the center) is specified.</td>
</tr>
<tr>
<td>025</td>
<td>CANNOT COMMAND F0 IN G02/G03</td>
<td>F0 (fast feed) was instructed by F1 –digit column feed in circular interpolation. Modify the program.</td>
</tr>
<tr>
<td>027</td>
<td>NO AXES COMMANDED IN G43/G44</td>
<td>No axis is specified in G43 and G44 blocks for the tool length offset type C. Offset is not canceled but another axis is offset for the tool length offset type C. Modify the program.</td>
</tr>
<tr>
<td>028</td>
<td>ILLEGAL PLANE SELECT</td>
<td>In the plane selection command, two or more axes in the same direction are commanded. Modify the program.</td>
</tr>
<tr>
<td>Number</td>
<td>Message</td>
<td>Contents</td>
</tr>
<tr>
<td>--------</td>
<td>---------------------------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>029</td>
<td><strong>ILLEGAL OFFSET VALUE</strong></td>
<td>The offset values specified by H code is too large. Modify the program.</td>
</tr>
<tr>
<td>030</td>
<td><strong>ILLEGAL OFFSET NUMBER</strong></td>
<td>The offset values specified by D/H code for tool length offset, cutter compensation or 3–dimensional cutter compensation is too large. Otherwise, the number specified by P code for the additional workpiece coordinate system is too large. Modify the program.</td>
</tr>
<tr>
<td>031</td>
<td><strong>ILLEGAL P COMMAND IN G10</strong></td>
<td>In setting an offset amount by G10, the offset number following address P was excessive or it was not specified. Modify the program.</td>
</tr>
<tr>
<td>032</td>
<td><strong>ILLEGAL OFFSET VALUE IN G10</strong></td>
<td>In setting an offset amount by G10 or in writing an offset amount by system variables, the offset amount was excessive.</td>
</tr>
<tr>
<td>033</td>
<td><strong>NO SOLUTION AT CRC</strong></td>
<td>A point of intersection cannot be determined for cutter compensation C. Modify the program.</td>
</tr>
<tr>
<td>034</td>
<td><strong>NO CIRC ALLOWED IN ST–UP / EXT BLK</strong></td>
<td>The start up or cancel was going to be performed in the G02 or G03 mode in cutter compensation C. Modify the program.</td>
</tr>
<tr>
<td>035</td>
<td><strong>CAN NOT COMMANDED G39</strong></td>
<td>G39 is commanded in cutter compensation B cancel mode or on the plane other than offset plane. Modify the program.</td>
</tr>
<tr>
<td>036</td>
<td><strong>CAN NOT COMMANDED G31</strong></td>
<td>Skip cutting (G31) was specified in cutter compensation mode. Modify the program.</td>
</tr>
<tr>
<td>037</td>
<td><strong>CAN NOT CHANGE PLANE IN CRC</strong></td>
<td>G40 is commanded on the plane other than offset plane in cutter compensation. The plane selected by using G17, G18 or G19 is changed in cutter compensation C mode. Modify the program.</td>
</tr>
<tr>
<td>038</td>
<td><strong>INTERFERENCE IN CIRCULAR BLOCK</strong></td>
<td>Overcutting will occur in cutter compensation C because the arc start point or end point coincides with the arc center. Modify the program.</td>
</tr>
<tr>
<td>041</td>
<td><strong>INTERFERENCE IN CRC</strong></td>
<td>Overcutting will occur in cutter compensation C. Two or more blocks are consecutively specified in which functions such as the auxiliary function and dwell functions are performed without movement in the cutter compensation mode. Modify the program.</td>
</tr>
<tr>
<td>042</td>
<td><strong>G45/G48 NOT ALLOWED IN CRC</strong></td>
<td>Tool offset (G45 to G48) is commanded in cutter compensation. Modify the program.</td>
</tr>
<tr>
<td>044</td>
<td><strong>G27–G30 NOT ALLOWED IN FIXED CYC</strong></td>
<td>One of G27 to G30 is commanded in canned cycle mode. Modify the program.</td>
</tr>
<tr>
<td>045</td>
<td><strong>ADDRESS Q NOT FOUND (G73/G83)</strong></td>
<td>In canned cycle G73/G83, the depth of each cut (Q) is not specified. Alternatively, Q0 is specified. Correct the program.</td>
</tr>
<tr>
<td>046</td>
<td><strong>ILLEGAL REFERENCE RETURN COMMAND</strong></td>
<td>Other than P2, P3 and P4 are commanded for 2nd, 3rd and 4th reference position return command.</td>
</tr>
<tr>
<td>047</td>
<td><strong>ILLEGAL AXIS SELECT</strong></td>
<td>For startup of three–dimensional tool compensation or three–dimensional coordinate conversion, two or more axes were specified in the same direction (basic and parallel axes.)</td>
</tr>
<tr>
<td>048</td>
<td><strong>BASIC 3 AXIS NOT FOUND</strong></td>
<td>For startup of three–dimensional tool compensation or three–dimensional coordinate conversion, the three basic axes used when $X_p, Y_p, \text{ and } Z_p$ are omitted were not specified in parameter No. 1022.</td>
</tr>
<tr>
<td>049</td>
<td><strong>ILLEGAL OPERATION (G68/G69)</strong></td>
<td>The commands for three–dimensional coordinate conversion (G68, G69) and tool length compensation (G43, G44, G45) are not nested. Modify the program.</td>
</tr>
<tr>
<td>050</td>
<td><strong>CHF/CNR NOT ALLOWED IN THRD BLK</strong></td>
<td>Chamfering or corner R is commanded in the thread cutting block. Modify the program.</td>
</tr>
<tr>
<td>051</td>
<td><strong>MISSING MOVE AFTER CHF/CNR</strong></td>
<td>Improper movement or the move distance was specified in the block next to the chamfering or corner R block. Modify the program.</td>
</tr>
<tr>
<td>052</td>
<td><strong>CODE IS NOT G01 AFTER CHF/CNR</strong></td>
<td>The block next to the chamfering or corner R block is not G01,G02,or G03. Modify the program.</td>
</tr>
<tr>
<td>Number</td>
<td>Message</td>
<td>Contents</td>
</tr>
<tr>
<td>--------</td>
<td>---------</td>
<td>----------</td>
</tr>
<tr>
<td>053</td>
<td>TOO MANY ADDRESS COMMANDS</td>
<td>For systems without the arbitrary angle chamfering or corner R cutting, a comma was specified. For systems with this feature, a comma was followed by something other than R or C. Correct the program.</td>
</tr>
<tr>
<td>055</td>
<td>MISSING MOVE VALUE IN CHF/CNR</td>
<td>In the arbitrary angle chamfering or corner R block, the move distance is less than chamfer or corner R amount.</td>
</tr>
<tr>
<td>058</td>
<td>END POINT NOT FOUND</td>
<td>In an arbitrary angle chamfering or corner R cutting block, a specified axis is not in the selected plane. Correct the program.</td>
</tr>
<tr>
<td>059</td>
<td>PROGRAM NUMBER NOT FOUND</td>
<td>In an external program number search, a specified program number was not found. Otherwise, a program specified for searching is being edited in background processing. Alternatively, the program with the program number specified in a one-touch macro call is not found in memory. Check the program number and external signal. Or discontinue the background editing.</td>
</tr>
<tr>
<td>060</td>
<td>SEQUENCE NUMBER NOT FOUND</td>
<td>Commanded sequence number was not found in the sequence number search. Check the sequence number.</td>
</tr>
<tr>
<td>070</td>
<td>NO PROGRAM SPACE IN MEMORY</td>
<td>The memory area is insufficient. Delete any unnecessary programs, then retry.</td>
</tr>
<tr>
<td>071</td>
<td>DATA NOT FOUND</td>
<td>The number of programs to be stored exceeded 63 (basic), 125 (option), 200 (option), or 400 (option). Delete unnecessary programs and execute program registration again.</td>
</tr>
<tr>
<td>072</td>
<td>TOO MANY PROGRAMS</td>
<td>The program number is other than 1 to 9999. Modify the program number.</td>
</tr>
<tr>
<td>073</td>
<td>PROGRAM NUMBER ALREADY IN USE</td>
<td>The program number has already been used. Change the program number or delete unnecessary programs and execute program registration again.</td>
</tr>
<tr>
<td>074</td>
<td>ILLEGAL PROGRAM NUMBER</td>
<td>The program number is other than 1 to 9999. Modify the program number.</td>
</tr>
<tr>
<td>075</td>
<td>PROTECT</td>
<td>An attempt was made to register a program whose number was protected.</td>
</tr>
<tr>
<td>076</td>
<td>ADDRESS P NOT DEFINED</td>
<td>Address P (program number) was not commanded in the block which includes an M98, G65, or G66 command. Modify the program.</td>
</tr>
<tr>
<td>077</td>
<td>SUB PROGRAM NESTING ERROR</td>
<td>The subprogram was called in five folds. Modify the program.</td>
</tr>
<tr>
<td>078</td>
<td>NUMBER NOT FOUND</td>
<td>A program number or a sequence number which was specified by address P in the block which includes an M98, M99, M65 or G66 was not found. The sequence number specified by a GOTO statement was not found. Otherwise, a called program is being edited in background processing. Correct the program, or discontinue the background editing.</td>
</tr>
<tr>
<td>079</td>
<td>PROGRAM VERIFY ERROR</td>
<td>In memory or program collation, a program in memory does not agree with that read from an external I/O device. Check both the programs in memory and those from the external device.</td>
</tr>
<tr>
<td>080</td>
<td>G37 ARRIVAL SIGNAL NOT ASSERTED</td>
<td>In the automatic tool length measurement function (G37), the measurement position reach signal (XAE, YAE, or ZAE) is not turned on within an area specified in parameter 6254 (value ε). This is due to a setting or operator error.</td>
</tr>
<tr>
<td>081</td>
<td>OFFSET NUMBER NOT FOUND IN G37</td>
<td>Tool length automatic measurement (G37) was specified without a H code. (Automatic tool length measurement function) Modify the program.</td>
</tr>
<tr>
<td>082</td>
<td>H–CODE NOT ALLOWED IN G37</td>
<td>H code and automatic tool compensation (G37) were specified in the same block. (Automatic tool length measurement function) Modify the program.</td>
</tr>
<tr>
<td>083</td>
<td>ILLEGAL AXIS COMMAND IN G37</td>
<td>In automatic tool length measurement, an invalid axis was specified or the command is incremental. Modify the program.</td>
</tr>
<tr>
<td>Number</td>
<td>Message</td>
<td>Contents</td>
</tr>
<tr>
<td>--------</td>
<td>----------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>085</td>
<td>COMMUNICATION ERROR</td>
<td>When entering data in the memory by using Reader / Puncher interface, an overrun, parity or framing error was generated. The number of bits of input data or setting of baud rate or specification No. of I/O unit is incorrect.</td>
</tr>
<tr>
<td>086</td>
<td>DR SIGNAL OFF</td>
<td>When entering data in the memory by using Reader / Puncher interface, the ready signal (DR) of reader / puncher was off. Power supply of I/O unit or cable is not connected or a P.C.B. is defective.</td>
</tr>
<tr>
<td>087</td>
<td>BUFFER OVERFLOW</td>
<td>When entering data in the memory by using Reader / Puncher interface, an overrun, parity or framing error was generated. The number of bits of input data or setting of baud rate or specification No. of I/O unit is incorrect.</td>
</tr>
<tr>
<td>088</td>
<td>LAN FILE TRANS ERROR (CHANNEL–1)</td>
<td>File data transfer over the OSI–Ethernet was terminated as a result of a transfer error.</td>
</tr>
<tr>
<td>089</td>
<td>LAN FILE TRANS ERROR (CHANNEL–2)</td>
<td>File data transfer over the OSI–Ethernet was terminated as a result of a transfer error.</td>
</tr>
</tbody>
</table>
| 090    | REFERENCE RETURN INCOMPLETE                  | 1. The reference position return cannot be performed normally because the reference position return start point is too close to the reference position or the speed is too slow. Separate the start point far enough from the reference position, or specify a sufficiently fast speed for reference position return.  
  2. During reference position return with the absolute–position detector, if this alarm occurs even though condition 1 is satisfied, do the following: After turning the servo motor for the axis at least one turn, turn the power off and then on again. Then perform reference position return. |
<p>| 091    | REFERENCE RETURN INCOMPLETE                  | In the automatic operation halt state, manual reference position return cannot be performed.                                                                                                                                                     |
| 092    | AXES NOT ON THE REFERENCE POINT              | The commanded axis by G27 (Reference position return check) did not return to the reference position.                                                                                                                                          |
| 094    | P TYPE NOT ALLOWED (COORD CHG)               | P type cannot be specified when the program is restarted. (After the automatic operation was interrupted, the coordinate system setting operation was performed.) Perform the correct operation according to the operator’s manual.                                          |
| 095    | P TYPE NOT ALLOWED (EXT OFS CHG)             | P type cannot be specified when the program is restarted. (After the automatic operation was interrupted, the external workpiece offset amount changed.)                                                                                   |
| 096    | P TYPE NOT ALLOWED (WRK OFS CHG)             | P type cannot be specified when the program is restarted. (After the automatic operation was interrupted, the workpiece offset amount changed.)                                                                                     |
| 097    | P TYPE NOT ALLOWED (AUTO EXEC)               | P type cannot be directed when the program is restarted. (After power ON, after emergency stop or P/S alarm 94 to 97 were reset, no automatic operation is performed.) Perform automatic operation.                                                      |
| 098    | G28 FOUND IN SEQUENCE RETURN                | A command of the program restart was specified without the reference position return operation after power ON or emergency stop, and G28 was found during search. Perform the reference position return.                                 |
| 099    | MDI EXEC NOT ALLOWED AFT. SEARCH             | After completion of search in program restart, a move command is given with MDI.                                                                                                                                                                  |
| 100    | PARAMETER WRITE ENABLE                       | On the PARAMETER(SETTING) screen, PWE(parameter writing enabled) is set to 1. Set it to 0, then reset the system.                                                                                                                                  |
| 101    | PLEASE CLEAR MEMORY                          | The power turned off while rewriting the memory by program edit operation. If this alarm has occurred, press &lt;RESET&gt; while pressing &lt;PROG&gt;, and only the program being edited will be deleted. Register the deleted program.                                     |</p>
<table>
<thead>
<tr>
<th>Number</th>
<th>Message</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>109</td>
<td>FORMAT ERROR IN G08</td>
<td>A value other than 0 or 1 was specified after P in the G08 code, or no value was specified.</td>
</tr>
<tr>
<td>110</td>
<td>DATA OVERFLOW</td>
<td>The absolute value of fixed decimal point display data exceeds the allowable range. Modify the program.</td>
</tr>
<tr>
<td>111</td>
<td>CALCULATED DATA OVERFLOW</td>
<td>The result of calculation is out of the allowable range ((-10^{47}) to (-10^{-29}), 0, and (10^{-29}) to (10^{47})).</td>
</tr>
<tr>
<td>112</td>
<td>DIVIDED BY ZERO</td>
<td>Division by zero was specified. (including tan 90°)</td>
</tr>
<tr>
<td>113</td>
<td>IMPROPER COMMAND</td>
<td>A function which cannot be used in custom macro is commanded. Modify the program.</td>
</tr>
<tr>
<td>114</td>
<td>FORMAT ERROR IN MACRO</td>
<td>There is an error in other formats than (&lt;\text{Formula}&gt;). Modify the program.</td>
</tr>
<tr>
<td>115</td>
<td>ILLEGAL VARIABLE NUMBER</td>
<td>A value not defined as a variable number is designated in the custom macro or in high-speed cycle cutting. This alarm is given in the following cases:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1. The header corresponding to the specified machining cycle number called is not found.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. The cycle connection data value is out of the allowable range (0 – 999).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. The number of data in the header is out of the allowable range (0 – 32767).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4. The start data variable number of executable format data is out of the allowable range ((#20000) – (#85535)).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5. The storing data variable number of executable format data is out of the allowable range ((#85535)).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6. The storing start data variable number of executable format data is overlapped with the variable number used in the header.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Modify the program.</td>
</tr>
<tr>
<td>116</td>
<td>WRITE PROTECTED VARIABLE</td>
<td>The left side of substitution statement is a variable whose substitution is inhibited. Modify the program.</td>
</tr>
<tr>
<td>118</td>
<td>PARENTHESIS NESTING ERROR</td>
<td>The nesting of bracket exceeds the upper limit (quintuple). Modify the program.</td>
</tr>
<tr>
<td>119</td>
<td>ILLEGAL ARGUMENT</td>
<td>The SORT argument is negative, BCD argument is negative, or other values than 0 to 9 are present on each line of BIN argument.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Modify the program.</td>
</tr>
<tr>
<td>122</td>
<td>QUADRUPLElicate MACRO MODAL–CALL</td>
<td>A total of four macro calls and macro modal calls are nested. Correct the program.</td>
</tr>
<tr>
<td>123</td>
<td>CAN NOT USE MACRO COMMAND IN DNC</td>
<td>Macro control command is used during DNC operation. Modify the program.</td>
</tr>
<tr>
<td>124</td>
<td>MISSING END STATEMENT</td>
<td>DO – END does not correspond to 1 : 1. Modify the program.</td>
</tr>
<tr>
<td>125</td>
<td>FORMAT ERROR IN MACRO</td>
<td>(&lt;\text{Formula}&gt;) format is erroneous. Modify the program.</td>
</tr>
<tr>
<td>126</td>
<td>ILLEGAL LOOP NUMBER</td>
<td>In DOn, (1 \leq n \leq 3) is not established. Modify the program.</td>
</tr>
<tr>
<td>127</td>
<td>NC, MACRO STATEMENT IN SAME BLOCK</td>
<td>NC and custom macro commands coexist. Modify the program.</td>
</tr>
<tr>
<td>128</td>
<td>ILLEGAL MACRO SEQUENCE NUMBER</td>
<td>The sequence number specified in the branch command was not 0 to 9999. Or, it cannot be searched. Modify the program.</td>
</tr>
<tr>
<td>129</td>
<td>ILLEGAL ARGUMENT ADDRESS</td>
<td>An address which is not allowed in (&lt;\text{Argument Designation}&gt;) is used. Modify the program.</td>
</tr>
<tr>
<td>130</td>
<td>ILLEGAL AXIS OPERATION</td>
<td>An axis control command was given by PMC to an axis controlled by CNC. Or an axis control command was given by CNC to an axis controlled by PMC. Modify the program.</td>
</tr>
<tr>
<td>Number</td>
<td>Message</td>
<td>Contents</td>
</tr>
<tr>
<td>--------</td>
<td>----------------------------------------------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>131</td>
<td>TOO MANY EXTERNAL ALARM MESSAGES</td>
<td>Five or more alarms have generated in external alarm message. Consult the PMC ladder diagram to find the cause.</td>
</tr>
<tr>
<td>132</td>
<td>ALARM NUMBER NOT FOUND</td>
<td>No alarm No. concerned exists in external alarm message clear. Check the PMC ladder diagram.</td>
</tr>
<tr>
<td>133</td>
<td>ILLEGAL DATA IN EXT. ALARM MSG</td>
<td>Small section data is erroneous in external alarm message or external operator message. Check the PMC ladder diagram.</td>
</tr>
<tr>
<td>135</td>
<td>ILLEGAL ANGLE COMMAND</td>
<td>The index table indexing positioning angle was instructed in other than an integral multiple of the value of the minimum angle. Modify the program.</td>
</tr>
<tr>
<td>136</td>
<td>ILLEGAL AXIS COMMAND</td>
<td>In index table indexing, another control axis was instructed together with the B axis. Modify the program.</td>
</tr>
<tr>
<td>138</td>
<td>SUPERIMPOSED DATA OVERFLOW</td>
<td>In PMC–based axis control, the increment for pulse distribution on the CNC and PMC side are too large when the superimposed control extended function is used.</td>
</tr>
<tr>
<td>139</td>
<td>CAN NOT CHANGE PMC CONTROL AXIS</td>
<td>An axis is selected in commanding by PMC axis control. Modify the program.</td>
</tr>
<tr>
<td>141</td>
<td>CAN NOT COMMAND G51 IN CRC</td>
<td>G51 (Scaling ON) is commanded in the tool offset mode. Modify the program.</td>
</tr>
<tr>
<td>142</td>
<td>ILLEGAL SCALE RATE</td>
<td>Scaling magnification is commanded in other than 1 – 999999. Correct the scaling magnification setting (G51 Pp .. or parameter 5411 or 5421).</td>
</tr>
<tr>
<td>143</td>
<td>SCALED MOTION DATA OVERFLOW</td>
<td>The scaling results, move distance, coordinate value and circular radius exceed the maximum command value. Correct the program or scaling magnification.</td>
</tr>
<tr>
<td>144</td>
<td>ILLEGAL PLANE SELECTED</td>
<td>The coordinate rotation plane and arc or cutter compensation C plane must be the same. Modify the program.</td>
</tr>
<tr>
<td>145</td>
<td>ILLEGAL CONDITIONS IN POLAR COORDINATE INTERPOLATION</td>
<td>The conditions are incorrect when the polar coordinate interpolation starts or it is canceled.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1) In modes other than G40, G12.1/G13.1 was specified.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2) An error is found in the plane selection. Parameters No. 5460 and No. 5461 are incorrectly specified. Modify the value of program or parameter.</td>
</tr>
<tr>
<td>146</td>
<td>IMPROPER G CODE</td>
<td>G codes which cannot be specified in the polar coordinate interpolation mode was specified. See section polar coordinate interpolation and modify the program.</td>
</tr>
<tr>
<td>148</td>
<td>ILLEGAL SETTING DATA</td>
<td>Automatic corner override deceleration rate is out of the settable range of judgement angle. Modify the parameters (No.1710 to No.1714)</td>
</tr>
<tr>
<td>149</td>
<td>FORMAT ERROR IN G10L3</td>
<td>A code other than Q1,Q2,P1 or P2 was specified as the life count type in the extended tool life management.</td>
</tr>
<tr>
<td>150</td>
<td>ILLEGAL TOOL GROUP NUMBER</td>
<td>Tool Group No. exceeds the maximum allowable value. Modify the program.</td>
</tr>
<tr>
<td>151</td>
<td>TOOL GROUP NUMBER NOT FOUND</td>
<td>The tool group commanded in the machining program is not set. Modify the value of program or parameter.</td>
</tr>
<tr>
<td>152</td>
<td>NO SPACE FOR TOOL ENTRY</td>
<td>The number of tools within one group exceeds the maximum value registerable. Modify the number of tools.</td>
</tr>
<tr>
<td>153</td>
<td>T–CODE NOT FOUND</td>
<td>In the registration of tool life data, a T code was not specified in a block where it is required. Alternatively, only M06 was specified in a block for tool change type D. Correct the program.</td>
</tr>
<tr>
<td>154</td>
<td>NOT USING TOOL IN LIFE GROUP</td>
<td>When the group is not commanded, H99 or D99 was commanded. Correct the program.</td>
</tr>
<tr>
<td>155</td>
<td>ILLEGAL T–CODE IN M06</td>
<td>In the machining program, M06 and T code in the same block do not correspond to the group in use. Correct the program.</td>
</tr>
<tr>
<td>Number</td>
<td>Message</td>
<td>Contents</td>
</tr>
<tr>
<td>--------</td>
<td>---------</td>
<td>----------</td>
</tr>
<tr>
<td>156</td>
<td>P/L COMMAND NOT FOUND</td>
<td>P and L commands are missing at the head of program in which the tool group is set. Correct the program.</td>
</tr>
<tr>
<td>157</td>
<td>TOO MANY TOOL GROUPS</td>
<td>The number of tool groups to be set exceeds the maximum allowable value. See parameter GS1, GS2 (No. 6800 bit 0 and 1). Modify the program.</td>
</tr>
<tr>
<td>158</td>
<td>ILLEGAL TOOL LIFE DATA</td>
<td>The tool life to be set is too excessive. Modify the setting value.</td>
</tr>
<tr>
<td>159</td>
<td>TOOL DATA SETTING INCOMPLETE</td>
<td>During executing a life data setting program, power was turned off. Set again.</td>
</tr>
<tr>
<td>160</td>
<td>G72.1 NESTING ERROR</td>
<td>Code G72.1 was specified in a sub–program after the same code had already been specified for copying with rotation.</td>
</tr>
<tr>
<td>161</td>
<td>ILLEGAL P OF WAITING M–CODE (T series) (three–path control)</td>
<td>Code G72.2 was specified in a sub–program after the same code had already been specified for parallel copying.</td>
</tr>
<tr>
<td>169</td>
<td>ILLEGAL TOOL GEOMETRY DATA (At two–path)</td>
<td>Incorrect tool figure data in interference check. Set correct data, or select correct tool figure data.</td>
</tr>
<tr>
<td>175</td>
<td>ILLEGAL G107 COMMAND</td>
<td>Conditions when performing cylindrical interpolation start or cancel not correct. To change the mode to the cylindrical interpolation mode, specify the command in a format of “G07.1 rotation–axis name radius of cylinder.”</td>
</tr>
<tr>
<td>176</td>
<td>IMPROPER G–CODE IN G107</td>
<td>Any of the following G codes which cannot be specified in the cylindrical interpolation mode was specified. 1) G codes for positioning, such as G28, G73, G74, G76, G81 – G89, including the codes specifying the rapid traverse cycle 2) G codes for setting a coordinate system: G52, G92, 3) G code for selecting coordinate system: G53, G54, G59 Modify the program.</td>
</tr>
<tr>
<td>177</td>
<td>CHECK SUM ERROR (G05 MODE)</td>
<td>Check sum error Modify the program.</td>
</tr>
<tr>
<td>178</td>
<td>G05 COMMANDED IN G41/G42 MODE</td>
<td>G05 was commanded in the G41/G42 mode. Correct the program.</td>
</tr>
<tr>
<td>179</td>
<td>PARAM. (PRM NO. 7510) SETTING ERROR</td>
<td>The number of controlled axes set by the parameter 7510 exceeds the maximum number. Modify the parameter setting value.</td>
</tr>
<tr>
<td>180</td>
<td>COMMUNICATION ERROR (REMOTE BUF)</td>
<td>Remote buffer connection alarm has generated. Confirm the number of cables, parameters and I/O device.</td>
</tr>
<tr>
<td>181</td>
<td>FORMAT ERROR IN G81 BLOCK (gear hobbing machine, EGB)</td>
<td>G81 block format error (hobbing machine) 1) T (number of teeth) has not been instructed. 2) Data outside the command range was instructed by either T, L, Q or P. 3) Calculation of the synchronization coefficient has overflowed. Modify the program.</td>
</tr>
<tr>
<td>182</td>
<td>G81 NOT COMMANDED (gear hobbing machine)</td>
<td>G83 (C axis servo lag quantity offset) was instructed though synchronization by G81 has not been instructed. Correct the program. (hobbing machine)</td>
</tr>
<tr>
<td>183</td>
<td>DUPLICATE G83 (COMMANDS) (gear hobbing machine)</td>
<td>G83 was instructed before canceled by G82 after compensating for the C axis servo lag quantity by G83. (hobbing machine)</td>
</tr>
<tr>
<td>184</td>
<td>ILLEGAL COMMAND IN G81 (gear hobbing machine, EGB)</td>
<td>A command not to be instructed during synchronization by G81 was instructed. (hobbing machine) 1) A C axis command by G00, G27, G28, G29, G30, etc. was instructed. 2) Inch/Metric switching by G20, G21 was instructed.</td>
</tr>
<tr>
<td>Number</td>
<td>Message</td>
<td>Contents</td>
</tr>
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</tr>
<tr>
<td>185</td>
<td>RETURN TO REFERENCE POINT</td>
<td>G81 was instructed without performing reference position return after power on or emergency stop. (hobbing machine) Perform reference position return.</td>
</tr>
<tr>
<td>186</td>
<td>PARAMETER SETTING ERROR</td>
<td>Parameter error regarding G81 (hobbing machine) 1) The C axis has not been set to be a rotary axis.  2) A hob axis and position coder gear ratio setting error</td>
</tr>
<tr>
<td>190</td>
<td>ILLEGAL AXIS SELECT</td>
<td>In the constant surface speed control, the axis specification is wrong. (See parameter No. 3770.) The specified axis command (P) contains an illegal value. Correct the program.</td>
</tr>
<tr>
<td>194</td>
<td>SPINDLE COMMAND IN SYNCHRO–MODE</td>
<td>A contour control mode, spindle positioning (Cs–axis control) mode, or rigid tapping mode was specified during the serial spindle synchronous control mode. Correct the program so that the serial spindle synchronous control mode is released in advance.</td>
</tr>
<tr>
<td>197</td>
<td>C–AXIS COMMANDED IN SPINDLE MODE</td>
<td>The program specified a movement along the Cs–axis when the signal CON(DGN=G027#7) was off. Correct the program, or consult the PMC ladder diagram to find the reason the signal is not turned on.</td>
</tr>
<tr>
<td>199</td>
<td>MACRO WORD UNDEFINED</td>
<td>Undefined macro word was used. Modify the custom macro.</td>
</tr>
<tr>
<td>200</td>
<td>ILLEGAL S CODE COMMAND</td>
<td>In the rigid tap, an S value is out of the range or is not specified. The maximum value for S which can be specified in rigid tapping is set in parameter (No.5241 to 5243). Change the setting in the parameter or modify the program.</td>
</tr>
<tr>
<td>201</td>
<td>FEEDRATE NOT FOUND IN RIGID TAP</td>
<td>In the rigid tapping, no F value is specified. Correct the program.</td>
</tr>
<tr>
<td>202</td>
<td>POSITION LSI OVERFLOW</td>
<td>In the rigid tapping, spindle distribution value is too large.</td>
</tr>
<tr>
<td>203</td>
<td>PROGRAM MISS AT RIGID TAPPING</td>
<td>In the rigid tapping, position for a rigid M code (M29) or an S command is incorrect. Modify the program.</td>
</tr>
<tr>
<td>204</td>
<td>ILLEGAL AXIS OPERATION</td>
<td>In the rigid tapping, an axis movement is specified between the rigid M code (M29) block and G84 (G74) block. Modify the program.</td>
</tr>
<tr>
<td>205</td>
<td>RIGID MODE DI SIGNAL OFF</td>
<td>Rigid tapping signal (DGNG 061#1) is not 1 when G84 (G74) is executed though the rigid M code (M29) is specified. Consult the PMC ladder diagram to find the reason the DI signal is not turned on. Modify the program.</td>
</tr>
<tr>
<td>206</td>
<td>CAN NOT CHANGE PLANE (RIGID TAP)</td>
<td>Plane changeover was instructed in the rigid mode. Correct the program.</td>
</tr>
<tr>
<td>207</td>
<td>RIGID DATA MISMATCH</td>
<td>The specified distance was too short or too long in rigid tapping.</td>
</tr>
<tr>
<td>210</td>
<td>CAN NOT COMAND M198/M99</td>
<td>1) M198 and M99 are executed in the schedule operation. Or M198 is executed in the DNC operation.  2) In a multiple repetitive pocketing canned cycle, an interrupt macro was specified, and M99 was executed.</td>
</tr>
<tr>
<td>212</td>
<td>ILLEGAL PLANE SELECT</td>
<td>The arbitrary angle chamfering or a corner R is commanded or the plane including an additional axis. Correct the program.</td>
</tr>
<tr>
<td>213</td>
<td>ILLEGAL COMMAND IN SYNCHRO–MODE</td>
<td>Any of the following alarms occurred in the operation with the simple synchronization control.  1) The program issued the move command to the slave axis.  2) The program issued the manual continuous feed/manual handle feed/incremental feed command to the slave axis.  3) The program issued the automatic reference position return command without executing the manual reference position return after the power was turned on.  4) The difference between the position error amount of the master and slave axes exceeded the value specified in parameter No. 8313.</td>
</tr>
<tr>
<td>Number</td>
<td>Message</td>
<td>Contents</td>
</tr>
<tr>
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<td>------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>214</td>
<td>ILLEGAL COMMAND IN SYNCHRON--MODE</td>
<td>Coordinate system is set or tool compensation of the shift type is executed in the synchronous control. Correct the program.</td>
</tr>
<tr>
<td>222</td>
<td>DNC OP. NOT ALLOWED IN BG.--EDIT</td>
<td>Input and output are executed at a time in the background edition. Execute a correct operation.</td>
</tr>
<tr>
<td>224</td>
<td>RETURN TO REFERENCE POINT</td>
<td>Reference position return has not been performed before the automatic operation starts. Perform reference position return only when parameter ZRN(_\text{N} ) (No.1005#0) is 0.</td>
</tr>
<tr>
<td>230</td>
<td>R CODE NOT FOUND</td>
<td>The infeed quantity R has not been instructed for the G161 block. Or the R command value is negative. Correct the program.</td>
</tr>
<tr>
<td>231</td>
<td>ILLEGAL FORMAT IN G10 OR L50</td>
<td>Any of the following errors occurred in the specified format at the programmable-parameter input.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1) Address N or R was not entered.</td>
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<tr>
<td></td>
<td></td>
<td>2) A number not specified for a parameter was entered.</td>
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<tr>
<td></td>
<td></td>
<td>3) The axis number was too large.</td>
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<td></td>
<td>4) An axis number was not specified in the axis-type parameter.</td>
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<td></td>
<td>5) An axis number was specified in the parameter which is not an axis type.</td>
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<td></td>
<td></td>
<td>6) An attempt was made to reset bit 4 of parameter 3202 (NE9) or change parameter 3210 (PSSWD) when they are protected by a password. Correct the program.</td>
</tr>
<tr>
<td>232</td>
<td>TOO MANY HELICAL AXIS COMMANDS</td>
<td>Three or more axes (in the normal direction control mode two or more axes) were specified as helical axes in the helical interpolation mode.</td>
</tr>
<tr>
<td>233</td>
<td>DEVICE BUSY</td>
<td>When an attempt was made to use a unit such as that connected via the RS--232--C interface, other users were using it.</td>
</tr>
<tr>
<td>239</td>
<td>BP/S ALARM</td>
<td>While punching was being performed with the function for controlling external I/O units, background editing was performed.</td>
</tr>
<tr>
<td>240</td>
<td>BP/S ALARM</td>
<td>Background editing was performed during MDI operation.</td>
</tr>
<tr>
<td>241</td>
<td>ILLEGAL FORMAT IN G02.2/G03.2</td>
<td>The end point, I, J, K, or R was not specified for involute interpolation.</td>
</tr>
<tr>
<td>242</td>
<td>ILLEGAL COMMAND IN G02.2/G03.2</td>
<td>An erroneous value was specified for involute interpolation. The start or end point was specified within the base circle. The value 0 was specified for I, J, K, or R. The start or end point exceeds 100 revolutions from the involute curve start point.</td>
</tr>
<tr>
<td>243</td>
<td>OVER TOLERANCE OF END POINT</td>
<td>The end point was not positioned on the involute curve which started at the start point, and the end point was out of the range specified by parameter No.5610.</td>
</tr>
<tr>
<td>246</td>
<td></td>
<td>During read of an encrypted program, an attempt was made to store the program with a number exceeding the protection range. (See parameter Nos. 3222 and 223.)</td>
</tr>
<tr>
<td>247</td>
<td></td>
<td>When an encrypted program is output, EIA is set for the punch code. Specify ISO.</td>
</tr>
<tr>
<td>250</td>
<td>Z AXIS WRONG COMMAND (ATC)</td>
<td>Movement along the Z--axis was specified in a block in which a command for changing tools (M06 T_) was specified. (Only for the ROBO-DRILL)</td>
</tr>
<tr>
<td>Number</td>
<td>Message</td>
<td>Contents</td>
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</tr>
<tr>
<td>251</td>
<td>ATC ERROR</td>
<td>An error occurs in the following cases (Only for the ROBODRILL):</td>
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<tr>
<td></td>
<td></td>
<td>• When unusable T code is specified in M06 T_.</td>
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<tr>
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<td></td>
<td>• When the M06 code is specified when the Z coordinate is positive in the machine coordinate system.</td>
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<td></td>
<td>• When parameter No. 7810, which specifies the current tool number, is 0.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• When the M06 code is specified in the canned–cycle mode.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• When the M06 code is specified in a block in which a reference position return code, G27, G28, G29, or G30 is specified.</td>
</tr>
<tr>
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<td>• When the M06 code is specified in the tool compensation mode (G41 to G44).</td>
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<tr>
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<td></td>
<td>• When the M06 code is specified without any reference position return after the power is turned on or after the emergency stop is released.</td>
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<td></td>
<td></td>
<td>• When the machine lock signal or the signal for ignoring the Z–axis is turned on while the tool is being changed.</td>
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<tr>
<td></td>
<td></td>
<td>• When a “prying” condition is detected while the tool is changed.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Refer to diagnosis parameter No. 530 for identifying the situations above.</td>
</tr>
<tr>
<td>252</td>
<td>ATC SPINDLE ALARM</td>
<td>An error due to excessive deviation occurs in spindle positioning during ATC operation. For details, see diagnosis parameter No. 531.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Only for the ROBODRILL)</td>
</tr>
<tr>
<td>253</td>
<td>G05 IS NOT AVAILABLE</td>
<td>Binary–input operation with a high–speed remote buffer (G05) or high–speed cycle machining (G05) has been specified in look–ahead control mode (G08P1).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Before attempting to specify these commands, first specify G08P0; to cancel look–ahead control mode.</td>
</tr>
<tr>
<td>5000</td>
<td>ILLEGAL COMMAND CODE</td>
<td>The specified code was incorrect in the high–precision contour control (HPCC) mode.</td>
</tr>
<tr>
<td>5003</td>
<td>ILLEGAL PARAMETER (HPCC)</td>
<td>The parameter setting is incorrect.</td>
</tr>
<tr>
<td>5004</td>
<td>HPCC NOT READY</td>
<td>High–precision contour control is not ready.</td>
</tr>
<tr>
<td>5006</td>
<td>TOO MANY WORD IN ONE BLOCK</td>
<td>The number of words specified in a block exceeded 26 in the HPCC mode.</td>
</tr>
<tr>
<td>5007</td>
<td>TOO LARGE DISTANCE</td>
<td>In the HPCC mode, the machine moved beyond the limit.</td>
</tr>
<tr>
<td>5009</td>
<td>PARAMETER ZERO (DRY RUN)</td>
<td>The maximum feedrate (parameter No. 1422) or the feedrate in dry run (parameter No. 1410) is 0 in the HPCC model.</td>
</tr>
<tr>
<td>5010</td>
<td>END OF RECORD</td>
<td>The end of record (%) was specified.</td>
</tr>
<tr>
<td>5011</td>
<td>PARAMETER ZERO (CUT MAX)</td>
<td>The maximum cutting feedrate (parameter No. 1422) is 0 in the HPCC mode.</td>
</tr>
<tr>
<td>5012</td>
<td>G05 P10000 ILLEGAL START UP</td>
<td>G05 P10000 has been specified in a mode from which HPCC mode cannot be entered.</td>
</tr>
<tr>
<td></td>
<td>(HPCC)</td>
<td></td>
</tr>
<tr>
<td>5013</td>
<td>HPCC.CRC OFS REMAIN AT CANCEL</td>
<td>G05P0 has been specified in G41/G42 mode or before cancellation axis is not found.</td>
</tr>
<tr>
<td>5014</td>
<td>TRACE DATA NOT FOUND</td>
<td>Trace data is not available, preventing transfer from being performed.</td>
</tr>
<tr>
<td>5015</td>
<td>NO ROTATION AXIS</td>
<td>During tool axis direction handle feed or tool axis normal direction handle feed, the specified rotation axis cannot be found.</td>
</tr>
<tr>
<td>5016</td>
<td>ILLEGAL COMBINATION OF M CODE</td>
<td>M codes which belonged to the same group were specified in a block. Alternatively, an M code which must be specified without other M codes in the block was specified in a block with other M codes.</td>
</tr>
<tr>
<td>5020</td>
<td>PARAMETER OF RESTART ERROR</td>
<td>The parameter for specifying program restart is not set correctly.</td>
</tr>
<tr>
<td>5043</td>
<td>TOO MANY G68 NESTING</td>
<td>The G68 command for three–dimensional coordinate conversion has been specified three or more times.</td>
</tr>
<tr>
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<tr>
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<td>---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>5044</td>
<td>G68 FORMAT ERROR</td>
<td>The G68 block contains a format error. This alarm occurs in the following cases: 1 One of I, J, and K is not specified in the G68 block (missing option for coordinate conversion). 2 I, J, and K are 0 in the G68 block. 3 R is not specified in the G68 block.</td>
</tr>
<tr>
<td>5046</td>
<td>ILLEGAL PARAMETER (ST.COMP)</td>
<td>An illegal parameter has been specified for straightness compensation. Possible reasons are as follows: 1 There is no axis corresponding to the axis number specified in the move axis or compensation axis parameter. 2 More than 128 pitch error compensation points are not sequentially numbered. 3 The straightness compensation points are not sequentially numbered. 4 A specified straightness compensation point is outside the range between the pitch error compensation points having the maximum positive and negative coordinates. 5 The compensation value specified for each compensation point is too large or too small. 6 The settings of parameters Nos. 13881 to 13886 are illegal.</td>
</tr>
<tr>
<td>5050</td>
<td>ILL–COMMAND IN CHOPPING MODE</td>
<td>When the chopping function is used, a move command was specified for a chopping axis in chopping mode (during reciprocation between a top dead point and bottom dead point).</td>
</tr>
<tr>
<td>5051</td>
<td>M–NET CODE ERROR</td>
<td>When the chopping function is used, a move command was specified for a chopping axis in chopping mode (during reciprocation between a top dead point and bottom dead point).</td>
</tr>
<tr>
<td>5052</td>
<td>M–NET ETX ERROR</td>
<td>“ETX” code is abnormal.</td>
</tr>
<tr>
<td>5053</td>
<td>M–NET CONNECT ERROR</td>
<td>Connection time supervision error (parameter No.175)</td>
</tr>
<tr>
<td>5054</td>
<td>M–NET RECEIVE ERROR</td>
<td>Boring time supervision error (parameter No.176)</td>
</tr>
<tr>
<td>5055</td>
<td>M–NET PRT/FRM ERROR</td>
<td>Vertical parity or framing error detection</td>
</tr>
<tr>
<td>5057</td>
<td>M–NET BOARD SYSTEM DOWN</td>
<td>Transmit time-out error (parameter No. 177) ROM parity error CPU interruption detection of not listed above</td>
</tr>
<tr>
<td>5060</td>
<td>ILLEGAL PARAMETER IN G02.3/G03.3</td>
<td>Parameter setting is illegal. No. 5641 (setting of the linear axis) is not specified. No. 5641 specifies an axis other than a linear axis. No. 5642 (setting of the rotation axis) is not specified. No. 5642 specifies an axis other than a rotation axis. The CNC cannot control the linear or rotation axis (the value of No. 1010 is exceeded).</td>
</tr>
<tr>
<td>5061</td>
<td>ILLEGAL FORMAT IN G02.3/G03.3</td>
<td>The command for exponential interpolation (G02.3/G03.3) contains a format error. Address I, J, or K is not specified. Addresses I, J, and K are 0.</td>
</tr>
<tr>
<td>5062</td>
<td>ILLEGAL COMMAND IN G02.3/G03.3</td>
<td>The command for exponential interpolation (G02.3/G03.3) contains an illegal value. The specified value is not suitable for exponential interpolation (for example, a negative value is subject to ln).</td>
</tr>
<tr>
<td>Number</td>
<td>Message Description</td>
<td>Contents</td>
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</tr>
</tbody>
</table>
| 5063   | IS NOT PRESET AFTER REF. | This message is output when the position counter has not been preset before the start of plate thickness measurement. This alarm is issued in one of the cases below.  
1) When an attempt was made to perform measurement before a reference position had been established.  
2) When, after manual reference position return, an attempt was made to start measurement without first setting the position counter. |
| 5064   | DIFFERRENT AXIS UNIT (IS–B, IS–C) | Circular interpolation was specified for a plane formed by axes using different increment systems. |
| 5065   | DIFFERRENT AXIS UNIT (PMC AXIS) | In PMC–based axis control, axes using different increment systems are specified for the same DI/DO group. Modify parameter No. 8010. |
| 5067   | G05 PO COMMANDED IN G68/G51 MODE (HPCC) | HPCC mode cannot be canceled during G51 (scaling) or G68 (coordinate system rotation). Correct the program. |
| 5068   | G31 P90 FORMAT ERROR | The continuous high–speed skip command (G31 P90) has one of the following errors:  
1. The axis along which the tool is moved is not specified.  
2. More than one axis is specified as the axis along which the tool is moved.  
Alternatively, the EGB skip command (G31.8) or continuous high–speed skip command (G31.9) has one of the following errors:  
1. A move command is specified for the EGB axis (workpiece axis).  
2. More than one axis is specified.  
3. P is not specified.  
4. The specified Q value exceeds the allowable range. Correct the program. |
| 5069   | WHL–C; ILLEGAL P–DATA | The P data, specified for selecting the compensation center for grinding wheel wear compensation, is invalid. |
| 5073   | NO DECIMAL POINT | A decimal point is not specified for a command for which a decimal point must be specified. |
| 5074   | ADDRESS DUPLICATION ERROR | The same address appears more than once in a block. Alternatively, a block contains two or more G codes belonging to the same group. |
| 5082   | DATA SERVER ERROR | Details are displayed on the data server message screen. |
| 5085   | SMOOTH IPL ERROR 1 | A block for specifying smooth interpolation contains a syntax error. |
| 5096   | MISMATCH WAITING M–CODE | Different wait codes (M codes) were specified in HEAD1 and HEAD2. Correct the program. |
| 5110   | IMPROPER G–CODE (G05.1 G1 MODE) | An illegal G code was specified in simple high–precision contour control mode.  
A command was specified for the index table indexing axis in simple high–precision contour control mode. |
<p>| 5111   | IMPROPER MODAL G–CODE (G05.1 G1) | An illegal G code is left modal when simple high–precision contour control mode was specified. |
| 5112   | G08 CAN NOT BE COMMANDED (G05.1 G1) | Look–ahead control (G08) was specified in simple high–precision contour control mode. |
| 5114   | NOT STOP POSITION (G05.1 Q1) | At the time of restart after manual intervention, the coordinates at which the manual intervention occurred have not been restored. |</p>
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<tr>
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</thead>
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<td>5115</td>
<td>SPL : ERROR</td>
<td>There is an error in the specification of the rank.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- No knot is specified.</td>
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<tr>
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<td></td>
<td>- The knot specification has an error.</td>
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<tr>
<td></td>
<td></td>
<td>- The number of axes exceeds the limits.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Other program errors</td>
</tr>
<tr>
<td>5116</td>
<td>SPL : ERROR</td>
<td>There is a program error in a block under look-ahead control.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Monotone increasing of knots is not observed.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- In NURBS interpolation mode, a mode that cannot be used together is</td>
</tr>
<tr>
<td></td>
<td></td>
<td>specified.</td>
</tr>
<tr>
<td>5117</td>
<td>SPL : ERROR</td>
<td>The first control point of NURBS is incorrect.</td>
</tr>
<tr>
<td>5118</td>
<td>SPL : ERROR</td>
<td>After manual intervention with manual absolute mode set to on, NURBS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>interpolation was restarted.</td>
</tr>
<tr>
<td>5122</td>
<td>ILLEGAL COMMAND IN SPIRAL</td>
<td>A spiral interpolation or conical interpolation command has an error.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Specifically, this error is caused by one of the following:</td>
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<tr>
<td></td>
<td></td>
<td>1) L = 0 is specified.</td>
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<td></td>
<td></td>
<td>2) Q = 0 is specified.</td>
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<td></td>
<td></td>
<td>3) R/, R/, C is specified.</td>
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<tr>
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<td></td>
<td>4) Zero is specified as height increment.</td>
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<td></td>
<td>5) Three or more axes are specified as the height axes.</td>
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<td></td>
<td>6) A height increment is specified when there are two height axes.</td>
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<tr>
<td></td>
<td></td>
<td>7) Conical interpolation is specified when the helical interpolation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>function is not selected.</td>
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<tr>
<td></td>
<td></td>
<td>8) Q &lt; 0 is specified when radius difference &gt; 0.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9) Q &gt; 0 is specified when radius difference &lt; 0.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10) A height increment is specified when no height axis is specified.</td>
</tr>
<tr>
<td>5123</td>
<td>OVER TOLERANCE OF END POINT</td>
<td>The difference between a specified end point and the calculated end</td>
</tr>
<tr>
<td></td>
<td></td>
<td>point exceeds the allowable range (parameter 3471).</td>
</tr>
<tr>
<td>5124</td>
<td>CAN NOT COMMAND SPIRAL</td>
<td>A spiral interpolation or conical interpolation was specified in any of</td>
</tr>
<tr>
<td></td>
<td></td>
<td>the following modes:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1) Scaling</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2) Programmable mirror image</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3) Polar coordinate interpolation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>In cutter compensation C mode, the center is set as the start point</td>
</tr>
<tr>
<td></td>
<td></td>
<td>or end point.</td>
</tr>
<tr>
<td>5134</td>
<td>FSSB : OPEN READY TIME OUT</td>
<td>Initialization did not place FSSB in the open ready state.</td>
</tr>
<tr>
<td>5135</td>
<td>FSSB : ERROR MODE</td>
<td>FSSB has entered error mode.</td>
</tr>
<tr>
<td>5136</td>
<td>FSSB : NUMBER OF AMPS IS</td>
<td>In comparison with the number of controlled axes, the number of amplifi-</td>
</tr>
<tr>
<td></td>
<td>SMALL</td>
<td>ers recognized by FSSB is not enough.</td>
</tr>
<tr>
<td>5137</td>
<td>FSSB : CONFIGURATION ERROR</td>
<td>FSSB detected a configuration error.</td>
</tr>
<tr>
<td>5138</td>
<td>FSSB : AXIS SETTING NOT COM-</td>
<td>In automatic setting mode, axis setting has not been made yet.</td>
</tr>
<tr>
<td></td>
<td>PLETE</td>
<td>Perform axis setting on the FSSB setting screen.</td>
</tr>
<tr>
<td>5139</td>
<td>FSSB : ERROR</td>
<td>Servo initialization did not terminate normally.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The optical cable may be defective, or there may be an error in connec-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>tion to the amplifier or another module.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Check the optical cable and the connection status.</td>
</tr>
<tr>
<td>5155</td>
<td>NOT RESTART PROGRAM BY G05</td>
<td>During servo leaning control by G05, an attempt was made to perform</td>
</tr>
<tr>
<td></td>
<td></td>
<td>restart operation after feed hold or interlock. This restart operation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>cannot be performed.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(G05 leaning control terminates at the same time.)</td>
</tr>
<tr>
<td>Number</td>
<td>Message</td>
<td>Contents</td>
</tr>
<tr>
<td>--------</td>
<td>----------------------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>5156</td>
<td>ILLEGAL AXIS OPERATION (SHPCC)</td>
<td>In simple high–precision contour control (SHPCC) mode, the controlled axis selection signal (PMC axis control) changes. In SHPCC mode, the simple synchronous axis selection signal changes.</td>
</tr>
<tr>
<td>5157</td>
<td>PARAMETER ZERO (AICC)</td>
<td>Zero is set in the parameter for the maximum cutting feedrate (parameter No. 1422 or 1432). Zero is set in the parameter for the acceleration/deceleration before interpolation (parameter No. 1770 or 1771). Set the parameter correctly.</td>
</tr>
<tr>
<td>5196</td>
<td>ILLEGAL OPERATION (HPCC)</td>
<td>Detach operation was performed in HPCC mode. (If detach operation is performed in HPCC mode, this alarm is issued after the currently executed block terminates.)</td>
</tr>
<tr>
<td>5197</td>
<td>FSSB : OPEN TIME OUT</td>
<td>The CNC permitted FSSB to open, but FSSB was not opened.</td>
</tr>
<tr>
<td>5198</td>
<td>FSSB : ID DATA NOT READ</td>
<td>Temporary assignment failed, so amplifier initial ID information could not be read.</td>
</tr>
<tr>
<td>5199</td>
<td>FINE TORQUE SENSING PARAMETER</td>
<td>A parameter related to the fine torque sensing function is illegal. The storage interval is invalid. An invalid axis number is set as the target axis. Correct the parameter.</td>
</tr>
<tr>
<td>5212</td>
<td>SCREEN COPY : PARAMETER ERROR</td>
<td>There is a parameter setting error. Check that 4 is set as the I/O channel.</td>
</tr>
<tr>
<td>5213</td>
<td>SCREEN COPY : COMMUNICATION ERROR</td>
<td>The memory card cannot be used. Check the memory card. (Check whether the memory card is write–protected or defective.)</td>
</tr>
<tr>
<td>5214</td>
<td>SCREEN COPY : DATA TRANSFER ERROR</td>
<td>Data transfer to the memory card failed. Check whether the memory card space is insufficient and whether the memory card was removed during data transfer.</td>
</tr>
<tr>
<td>5218</td>
<td>ILLEGAL PARAMETER (INCL. COMP)</td>
<td>There is an inclination compensation parameter setting error. Cause: 1. The number of pitch error compensation points between the negative (-) end and positive (+) end exceeds 128. 2. The relationship in magnitude among the inclination compensation point numbers is incorrect. 3. An inclination compensation point is not located between the negative (-) end and positive (+) end of the pitch error compensation points. 4. The amount of compensation per compensation point is too large or too small. Correct the parameter.</td>
</tr>
<tr>
<td>5219</td>
<td>CAN NOT RETURN</td>
<td>Manual intervention or return is not allowed during three–dimensional coordinate conversion.</td>
</tr>
<tr>
<td>5220</td>
<td>REFERENCE POINT ADJUSTMENT MODE</td>
<td>A parameter for automatically set a reference position is set. (Bit 2 of parameter No. 1819 = 1) Perform automatic setting. (Position the machine at the reference position manually, then perform manual reference position return.) Supplementary: Automatic setting sets bit 2 of parameter No. 1819 to 0.</td>
</tr>
<tr>
<td>5222</td>
<td>SRAM CORRECTABLE ERROR</td>
<td>The SRAM correctable error cannot be corrected. Cause: A memory problem occurred during memory initialization. Action: Replace the master printed circuit board (SRAM module).</td>
</tr>
<tr>
<td>Number</td>
<td>Message</td>
<td>Contents</td>
</tr>
<tr>
<td>--------</td>
<td>--------------------------------------</td>
<td>------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>5227</td>
<td>FILE NOT FOUND</td>
<td>A specified file is not found during communication with the built-in Handy File.</td>
</tr>
<tr>
<td>5228</td>
<td>SAME NAME USED</td>
<td>There are duplicate file names in the built-in Handy File.</td>
</tr>
<tr>
<td>5229</td>
<td>WRITE PROTECTED</td>
<td>A floppy disk in the built-in Handy File is write protected.</td>
</tr>
<tr>
<td>5231</td>
<td>TOO MANY FILES</td>
<td>The number of files exceeds the limit during communication with the built-in Handy File.</td>
</tr>
<tr>
<td>5232</td>
<td>DATA OVER-FLOW</td>
<td>There is not enough floppy disk space in the built-in Handy File.</td>
</tr>
<tr>
<td>5235</td>
<td>COMMUNICATION ERROR</td>
<td>A communication error occurred during communication with the built-in Handy File.</td>
</tr>
<tr>
<td>5237</td>
<td>READ ERROR</td>
<td>A floppy disk in the built-in Handy File cannot be read from. The floppy disk may be defective, or the head may be dirty. Alternatively, the Handy File is defective.</td>
</tr>
<tr>
<td>5238</td>
<td>WRITE ERROR</td>
<td>A floppy disk in the built-in Handy File cannot be written to. The floppy disk may be defective, or the head may be dirty. Alternatively, the Handy File is defective.</td>
</tr>
<tr>
<td>5242</td>
<td>ILLEGAL AXIS NUMBER</td>
<td>The axis number of the synchronous master axis or slave axis is incorrect.</td>
</tr>
<tr>
<td>5243</td>
<td>DATA OUT OF RANGE</td>
<td>The gear ratio is not set correctly.</td>
</tr>
<tr>
<td>5244</td>
<td>TOO MANY DI ON</td>
<td>Even when an M code was encountered in automatic operation mode, the flexible synchronization mode signal was not driven on or off. Check the ladder and M codes.</td>
</tr>
<tr>
<td>5245</td>
<td>OTHER AXIS ARE COMMANDED</td>
<td>One of the following command conditions was present during flexible synchronization or when flexible synchronization was turned on:</td>
</tr>
<tr>
<td></td>
<td>(M series)</td>
<td>1. The synchronous master axis or slave axis is the EGB axis.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. The synchronous master axis or slave axis is the chopping axis.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. In reference position return mode</td>
</tr>
<tr>
<td>5251</td>
<td>ILLEGAL PARAMETER IN G54.2</td>
<td>A fixture offset parameter (No. 7580 to 7588) is illegal. Correct the parameter.</td>
</tr>
<tr>
<td>5252</td>
<td>ILLEGAL P COMMAND IN G54.2</td>
<td>The P value specifying the offset number of a fixture offset is too large. Correct the program.</td>
</tr>
<tr>
<td>5257</td>
<td>G41/G42 NOT ALLOWED IN MDI MODE</td>
<td>G41/G42 (cutter compensation C: M series, tool–nose radius compensation: T series) was specified in MDI mode. (Depending on the setting of bit 4 of parameter No. 5008)</td>
</tr>
<tr>
<td>5300</td>
<td>SET ALL OFFSET DATAS AGAIN</td>
<td>After the inch/metric automatic conversion function (OIM: Bit 0 of parameter No. 5006) for tool offset data is enabled or disabled, all the tool offset data must be reset. This message reminds the operator to reset the data. If this alarm is issued, reset all the tool offset data. Operating the machine without resetting the data will result in a malfunction.</td>
</tr>
<tr>
<td>5302</td>
<td>ILLEGAL COMMAND IN G68 MODE</td>
<td>A command to set the coordinate system is specified in the coordinate system rotation mode.</td>
</tr>
<tr>
<td>5303</td>
<td>TOUCH PANEL ERROR</td>
<td>A touch panel error occurred.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cause:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1. The touch panel is kept pressed.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. The touch panel was pressed when power was turned on.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Remove the above causes, and turn on the power again.</td>
</tr>
<tr>
<td>5306</td>
<td>MODE CHANGE ERROR</td>
<td>In a one-touch macro call, mode switching at the time of activation is not performed correctly.</td>
</tr>
<tr>
<td>Number</td>
<td>Message</td>
<td>Contents</td>
</tr>
<tr>
<td>--------</td>
<td>----------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
</tbody>
</table>
| 5307   | INTERNAL DATA OVER FLOW          | In the following function, internal data exceeds the allowable range.  
1) Improvement of the rotation axis feedrate                                                                                                                                                           |
| 5311   | FSSB:ILLEGAL CONNECTION          | A connection related to FSSB is illegal.  
This alarm is issued when either of the following is found:  
1. Two axes having adjacent servo axis numbers (parameter No. 1023), odd number and even number, are assigned to amplifiers to which different FSSB systems are connected.  
2. The system does not satisfy the requirements for performing HRV control, and use of two pulse modules connected to different FSSB systems having different FSSB current control cycles is specified. |
| 5321   | S–COMP. VALUE OVERFLOW           | The straightness compensation value has exceeded the maximum value of 32767.  
After this alarm is issued, make a manual reference position return.                                                                                                                                       |
| 5400   | SPL:ILLEGAL AXIS COMMAND         | An axis specified for spline interpolation or smooth interpolation is incorrect.  
If an axis that is not the spline axis is specified in spline interpolation mode, this alarm is issued. The spline axis is the axis specified in a block containing G06.1 or the next block. For smooth interpolation, the axis specified in G5.1Q2 is incorrect. |
| 5401   | SPL:ILLEGAL COMMAND              | In a G code mode in which specification of G06.1 is not permitted, G06.1 is specified.                                                                                                                 |
| 5402   | SPL:ILLEGAL AXIS MOVING          | A movement is made along an axis that is not the spline interpolation axis.  
For example, in three–dimensional tool compensation mode using an offset vector of which components are the X–, Y–, and Z–axes, when two–axis spline interpolation is performed with the two spline axes set to the X– and Y–axes, a movement along the Z–axis occurs, resulting in this alarm. |
| 5403   | SPL:CAN NOT MAKE VECTOR          | Three–dimensional tool compensation vectors cannot be generated.  
· When a three–dimensional tool compensation vector is created for the second or subsequent point, that point, previous point, and next point are on the same straight line, and that straight line and the three–dimensional tool compensation vector for the previous point are in parallel.  
· When a three–dimensional tool compensation vector is created at the end point of smooth interpolation or spline interpolation, the end point and the point two points before are the same. |
| 5405   | ILLEGAL PARAMETER IN G41.2/       | The parameter setting that determines the relationship between the rotation axis and rotation plane is incorrect.                                                                                         |
| 5406   | G41.3/G40 FORMAT ERROR           | 1) A G41.3 or G40 block contains a move command.  
2) A G1.3 block contains a G code or M code for which buffering is suppressed.                                                                                                                            |
| 5407   | ILLEGAL COMMAND IN G41.3         | 1) A G code that belongs to group 01 except G00 and G01 is specified in G41.3 mode.  
2) An offset command (a G code belonging to group 07) is specified in G41.3 mode.                                                                                                               
3) The block next to G41.3 (startup) contains no movement.                                                                                                                                                  |
| 5408   | G41.3 ILLEGAL START_UP           | 1) In a mode of group 01 except G00 and G01, G41.3 (startup) is specified.  
2) At startup, the included angle of the tool direction vector and move direction vector is 0 or 180 degrees.                                                                                       |
<p>| 5409   | ILLEGAL PARAMETER IN G41.3       | The parameter setting (No. xxxx to xxxx) that determines the relationship between the rotation axis and rotation plane is incorrect.                                                                            |
| 5411   | NURBS:ILLEGAL ORDER              | The number of steps is specified incorrectly.                                                                                                                                                             |
| 5412   | NURBS:NO KNOT COMMAND            | No knot is specified. Alternatively, in NURBS interpolation mode, a block not relating to NURBS interpolation is specified.                                                                              |</p>
<table>
<thead>
<tr>
<th>Number</th>
<th>Message</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>5413</td>
<td>NURBS:ILLEGAL AXIS COMMAND</td>
<td>An axis not specified with controlled points is specified in the first block.</td>
</tr>
<tr>
<td>5414</td>
<td>NURBS:ILLEGAL KNOT</td>
<td>The number of blocks containing knots only is insufficient.</td>
</tr>
<tr>
<td>5415</td>
<td>NURBS:ILLEGAL CANCEL</td>
<td>Although NURBS interpolation is not completed yet, the NURBS interpolation mode is turned off.</td>
</tr>
<tr>
<td>5416</td>
<td>NURBS:ILLEGAL MODE</td>
<td>A mode that cannot be used with NURBS interpolation mode is specified in NURBS interpolation mode.</td>
</tr>
<tr>
<td>5417</td>
<td>NURBS:ILLEGAL MULTI–KNOT</td>
<td>As many knots as the number of steps are not specified at the start and end points.</td>
</tr>
<tr>
<td>5418</td>
<td>NURBS:ILLEGAL KNOT VALUE</td>
<td>Knots do not increase in monotone.</td>
</tr>
<tr>
<td>5420</td>
<td>ILLEGAL PARAMETER IN G43.4/G43.5</td>
<td>A parameter related to pivot tool length compensation is incorrect.</td>
</tr>
<tr>
<td>5421</td>
<td>ILLEGAL COMMAND IN G43.4/G43.5</td>
<td>In pivot tool length compensation (type 2) mode, a rotation axis is specified.</td>
</tr>
<tr>
<td>5422</td>
<td>EXCESS VELOCITY IN G43.4/G43.5</td>
<td>As a result of pivot tool length compensation, an attempt was made to move the tool along an axis at a feedrate exceeding the maximum cutting feedrate.</td>
</tr>
<tr>
<td>5425</td>
<td>ILLEGAL OFFSET VALUE</td>
<td>The offset number is incorrect.</td>
</tr>
<tr>
<td>5430</td>
<td>ILLEGAL COMMAND IN 3–D CIR</td>
<td>In a modal state in which three–dimensional circular interpolation cannot be specified, a three–dimensional circular interpolation (G02.4/G03.4) is specified. Alternatively, in three–dimensional circular interpolation mode, a code that cannot be specified is specified.</td>
</tr>
<tr>
<td>5432</td>
<td>G02.4/G03.4 FORMAT ERROR</td>
<td>A three–dimensional circular interpolation command (G02.4/G03.4) is incorrect.</td>
</tr>
<tr>
<td>5433</td>
<td>MANUAL INTERVENTION IN 3–D CIR</td>
<td>In three–dimensional circular interpolation mode (G02.4/G03.4), manual intervention was made when the manual absolute switch was on.</td>
</tr>
<tr>
<td>5435</td>
<td>PARAMETER OUT OF RANGE (TLAC)</td>
<td>Incorrect parameter setting (set value range)</td>
</tr>
<tr>
<td>5436</td>
<td>PARAMETER SETTING ERROR 1 (TLAC)</td>
<td>Incorrect parameter setting (setting of the rotation axis)</td>
</tr>
<tr>
<td>5437</td>
<td>PARAMETER SETTING ERROR 2 (TLAC)</td>
<td>Incorrect parameter setting (setting of the tool axis)</td>
</tr>
<tr>
<td>5440</td>
<td>ILLEGAL DRILLING AXIS SELECTED</td>
<td>The drilling axis specified for the drilling canned cycle is incorrect. The G code command block of the canned cycle does not specify the Z point of the drilling axis. When there is a parallel axis with the drilling axis, the parallel axis is also specified at the same time.</td>
</tr>
<tr>
<td>5445</td>
<td>CRC:MOTION IN G39</td>
<td>Corner circular interpolation (G39) of cutter compensation is not specified alone but is specified with a move command.</td>
</tr>
<tr>
<td>5446</td>
<td>CRC:NO AVOIDANCE</td>
<td>Because there is no interference evade vector, the interference check evade function of cutter compensation cannot evade interference.</td>
</tr>
<tr>
<td>5447</td>
<td>CRC:DANGEROUS AVOIDANCE</td>
<td>The interference check evade function of cutter compensation determines that an evade operation will lead to danger.</td>
</tr>
<tr>
<td>5448</td>
<td>CRC:INTERFERENCE TO AVD.</td>
<td>In the interference check evade function of cutter compensation, a further interference occurs for an already created interference evade vector.</td>
</tr>
<tr>
<td>Number</td>
<td>Message</td>
<td>Contents</td>
</tr>
<tr>
<td>--------</td>
<td>---------</td>
<td>----------</td>
</tr>
</tbody>
</table>
| 5452  | IMPROPER G–CODE (5AXIS MODE) | A G code that cannot be specified is found. (5–axis mode) This alarm is issued when:  
1) Three–dimensional cutter compensation (side–face offset and leading–edge offset) is applied during cutter compensation, or cutter compensation is applied during three–dimensional cutter compensation (side–face offset and leading–edge offset).  
2) A leading–edge offset of three–dimensional cutter compensation is applied during side–face offsetting of three–dimensional cutter compensation, or a side–face offset of three–dimensional cutter compensation is applied during leading–edge offsetting of three–dimensional cutter compensation.  
3) Tool axis direction tool length compensation is applied during tool length compensation, or tool length compensation is applied during tool axis direction tool length compensation.  
4) Tool center point control is provided during tool length compensation, or tool length compensation is applied during tool center point control.  
5) Tool center point control is provided during tool axis direction tool length compensation, or tool axis direction tool length compensation is applied during tool center point control.  
If this alarm is issued, cancel the relevant mode, then specify a different mode. |
| 5453  | NOTE: G68 IS CANCELED (HPCC) | When bit 2 of parameter No. 5400 is set to 1, and a reset does not cancel G68, this alarm is issued at the time of program restart. To release this alarm, press <RESET> and <CAN>. Once this operation is performed, the alarm will not be issued at the next restart. |
| 5455  | ILLEGAL ACC. PARAMETER | A permissible acceleration parameter for optimum torque acceleration/deceleration is incorrect. The cause is one of the following:  
1) The ratio of the deceleration rate to the acceleration rate is below the limit.  
2) The time required for deceleration to a speed of 0 exceeds the maximum value. |

**NOTE**  
AICC designates AI contour control.

---

**2) Background edit alarm**

<table>
<thead>
<tr>
<th>Number</th>
<th>Message</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>???</td>
<td>BP/S alarm</td>
<td>BP/S alarm occurs in the same number as the P/S alarm that occurs in ordinary program edit. (P/S alarm No. 070, 071, 072, 073, 074, 085 to 087) Modify the program.</td>
</tr>
<tr>
<td>140</td>
<td>BP/S alarm</td>
<td>It was attempted to select or delete in the background a program being selected in the foreground. (NOTE) Use background editing correctly.</td>
</tr>
</tbody>
</table>

**NOTE**  
Alarm in background edit is displayed in the key input line of the background edit screen instead of the ordinary alarm screen and is resettable by any of the MDI key operation.
3) Absolute pulse coder (APC) alarm

<table>
<thead>
<tr>
<th>Number</th>
<th>Message</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>300</td>
<td>nth-axis origin return</td>
<td>Manual reference position return is required for the nth-axis (n=1 to 8).</td>
</tr>
<tr>
<td>301</td>
<td>APC alarm: nth-axis communication</td>
<td>nth-axis (n=1 to 8) APC communication error. Failure in data transmission. Possible causes include a faulty APC, cable, or servo interface module.</td>
</tr>
<tr>
<td>302</td>
<td>APC alarm: nth-axis over time</td>
<td>nth-axis (n=1 to 8) APC overtime error. Failure in data transmission. Possible causes include a faulty APC, cable, or servo interface module.</td>
</tr>
<tr>
<td>303</td>
<td>APC alarm: nth-axis framing</td>
<td>nth-axis (n=1 to 8) APC framing error. Failure in data transmission. Possible causes include a faulty APC, cable, or servo interface module.</td>
</tr>
<tr>
<td>304</td>
<td>APC alarm: nth-axis parity</td>
<td>nth-axis (n=1 to 8) APC parity error. Failure in data transmission. Possible causes include a faulty APC, cable, or servo interface module.</td>
</tr>
<tr>
<td>305</td>
<td>APC alarm: nth-axis pulse error</td>
<td>nth-axis (n=1 to 8) APC pulse error alarm. APC alarm. APC or cable may be faulty.</td>
</tr>
<tr>
<td>306</td>
<td>APC alarm: nth-axis battery voltage 0</td>
<td>nth-axis (n=1 to 8) APC battery voltage has decreased to a low level so that the data cannot be held. APC alarm. Battery or cable may be faulty.</td>
</tr>
<tr>
<td>307</td>
<td>APC alarm: nth-axis battery low 1</td>
<td>nth-axis (n=1 to 8) axis APC battery voltage reaches a level where the battery must be renewed. APC alarm. Replace the battery.</td>
</tr>
<tr>
<td>308</td>
<td>APC alarm: nth-axis battery low 2</td>
<td>nth-axis (n=1 to 8) APC battery voltage has reached a level where the battery must be renewed (including when power is OFF). APC alarm. Replace battery.</td>
</tr>
<tr>
<td>309</td>
<td>APC ALARM : n AXIS ZRN IMPOSSIBL</td>
<td>An attempt was made to perform reference position return without rotating the motor through one or more turns. Rotate the motor through one or more turns, turn off the power then on again, then perform reference position return.</td>
</tr>
</tbody>
</table>

4) Inductosyn alarms

<table>
<thead>
<tr>
<th>No.</th>
<th>Message</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>330</td>
<td>INDUCTOSYN:DATA ALARM</td>
<td>The absolute−position data (offset data) from Inductosyn cannot be detected.</td>
</tr>
<tr>
<td>331</td>
<td>INDUCTOSYN:ILLEGAL PRM</td>
<td>Parameter No. 1874, 1875, or 1876 is set to 0.</td>
</tr>
</tbody>
</table>

5) Serial pulse coder (SPC) alarms
When either of the following alarms is issued, a possible cause is a faulty serial pulse coder or cable.

<table>
<thead>
<tr>
<th>No.</th>
<th>Message</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>360</td>
<td>n AXIS : ABNORMAL CHECKSUM (INT)</td>
<td>A checksum error occurred in the built−in pulse coder.</td>
</tr>
<tr>
<td>361</td>
<td>n AXIS : ABNORMAL PHASE DATA (INT)</td>
<td>A phase data error occurred in the built−in pulse coder.</td>
</tr>
<tr>
<td>362</td>
<td>n AXIS : ABNORMAL REV.DATA (INT)</td>
<td>A rotation speed count error occurred in the built−in pulse coder.</td>
</tr>
<tr>
<td>363</td>
<td>n AXIS : ABNORMAL CLOCK (INT)</td>
<td>A clock error occurred in the built−in pulse coder.</td>
</tr>
<tr>
<td>364</td>
<td>n AXIS : SOFT PHASE ALARM (INT)</td>
<td>The digital servo software detected invalid data in the built−in pulse coder.</td>
</tr>
<tr>
<td>365</td>
<td>n AXIS : BROKEN LED (INT)</td>
<td>An LED error occurred in the built−in pulse coder.</td>
</tr>
<tr>
<td>366</td>
<td>n AXIS : PULSE MISS (INT)</td>
<td>A pulse error occurred in the built−in pulse coder.</td>
</tr>
<tr>
<td>367</td>
<td>n AXIS : COUNT MISS (INT)</td>
<td>A count error occurred in the built−in pulse coder.</td>
</tr>
<tr>
<td>No.</td>
<td>Message</td>
<td>Description</td>
</tr>
<tr>
<td>-----</td>
<td>---------</td>
<td>-------------</td>
</tr>
<tr>
<td>368</td>
<td>n AXIS : SERIAL DATA ERROR (INT)</td>
<td>Communication data from the built-in pulse coder cannot be received.</td>
</tr>
<tr>
<td>369</td>
<td>n AXIS : DATA TRANS. ERROR (INT)</td>
<td>A CRC or stop bit error occurred in the communication data being received from the built-in pulse coder.</td>
</tr>
<tr>
<td>380</td>
<td>n AXIS : BROKEN LED (EXT)</td>
<td>The separate detector is erroneous.</td>
</tr>
<tr>
<td>381</td>
<td>n AXIS : ABNORMAL PHASE (EXT LIN)</td>
<td>A phase data error occurred in the separate linear scale.</td>
</tr>
<tr>
<td>382</td>
<td>n AXIS : COUNT MISS (EXT)</td>
<td>A pulse error occurred in the separate detector.</td>
</tr>
<tr>
<td>383</td>
<td>n AXIS : PULSE MISS (EXT)</td>
<td>A count error occurred in the separate detector.</td>
</tr>
<tr>
<td>384</td>
<td>n AXIS : SOFT PHASE ALARM (EXT)</td>
<td>The digital servo software detected invalid data in the separate detector.</td>
</tr>
<tr>
<td>385</td>
<td>n AXIS : SERIAL DATA ERROR (EXT)</td>
<td>Communication data from the separate detector cannot be received.</td>
</tr>
<tr>
<td>386</td>
<td>n AXIS : DATA TRANS. ERROR (EXT)</td>
<td>A CRC or stop bit error occurred in the communication data being received from the separate detector.</td>
</tr>
<tr>
<td>387</td>
<td>n AXIS : ABNORMAL ENCODER (EXT)</td>
<td>An error occurs in the separate detector. For details, contact the manufacturer of the scale.</td>
</tr>
</tbody>
</table>

- The details of serial pulse coder alarm

<table>
<thead>
<tr>
<th>#7</th>
<th>#6</th>
<th>#5</th>
<th>#4</th>
<th>#3</th>
<th>#2</th>
<th>#1</th>
<th>#0</th>
</tr>
</thead>
<tbody>
<tr>
<td>202</td>
<td>CSA</td>
<td>BLA</td>
<td>PHA</td>
<td>PCA</td>
<td>BZA</td>
<td>CKA</td>
<td>SPH</td>
</tr>
</tbody>
</table>

- #6 (CSA) : Check sum alarm has occurred.
- #5 (BLA) : Battery low alarm has occurred.
- #4 (PHA) : Phase data trouble alarm has occurred.
- #3 (PCA) : Speed count trouble alarm has occurred.
- #2 (BZA) : Battery zero alarm has occurred.
- #1 (CKA) : Clock alarm has occurred.
- #0 (SPH) : Soft phase data trouble alarm has occurred.

<table>
<thead>
<tr>
<th>#7</th>
<th>#6</th>
<th>#5</th>
<th>#4</th>
<th>#3</th>
<th>#2</th>
<th>#1</th>
<th>#0</th>
</tr>
</thead>
<tbody>
<tr>
<td>203</td>
<td>DTE</td>
<td>CRC</td>
<td>STB</td>
<td>PRM</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- #7 (DTE) : Data error has occurred.
- #6 (CRC) : CRC error has occurred.
- #5 (STB) : Stop bit error has occurred.
- #4 (PRM) : Parameter error alarm has occurred. In this case, a servo parameter error alarm (No. 417) is also output.
## 6) Servo alarms (1/2)

<table>
<thead>
<tr>
<th>Number</th>
<th>Message</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>401</td>
<td>SERVO ALARM: n–TH AXIS VRDY OFF</td>
<td>The n–th axis (axis 1–8) servo amplifier READY signal (DRDY) went off. Refer to procedure of trouble shooting.</td>
</tr>
<tr>
<td>402</td>
<td>SERVO ALARM: SV CARD NOT EXIST</td>
<td>The axis control card is not provided.</td>
</tr>
</tbody>
</table>
| 403    | SERVO ALARM: CARD/SOFT MIS-MATCH | The combination of the axis control card and servo software is illegal. The possible causes are as follows:  
  - A correct axis control card is not provided.  
  - Correct servo software is not installed on flash memory. |
<p>| 404    | SERVO ALARM: n–TH AXIS VRDY ON | Even though the n–th axis (axis 1–8) READY signal (MCON) went off, the servo amplifier READY signal (DRDY) is still on. Or, when the power was turned on, DRDY went on even though MCON was off. Check that the servo interface module and servo amp are connected. |
| 405    | SERVO ALARM: (ZERO POINT RETURN FAULT) | Position control system fault. Due to an NC or servo system fault in the reference position return, there is the possibility that reference position return could not be executed correctly. Try again from the manual reference position return. |
| 407    | SERVO ALARM: EXCESS ERROR | The difference in synchronous axis position deviation exceeded the set value. Position control system fault. Due to an NC or servo system fault in the reference position return, there is the possibility that reference position return could not be executed correctly. Try again from the manual reference position return. |
| 409    | SERVO ALARM: n AXIS TORQUE ALM | Abnormal servo motor load has been detected. Alternatively, abnormal spindle motor load has been detected in Cs mode. |
| 410    | SERVO ALARM: n–TH AXIS – EXCESS ERROR | The position deviation value when the n–th axis (axis 1–8) stops is larger than the set value. Refer to procedure of trouble shooting. |
| 411    | SERVO ALARM: n–TH AXIS – EXCESS ERROR | The position deviation value when the n–th axis (axis 1–8) moves is larger than the set value. Refer to procedure of trouble shooting. |
| 413    | SERVO ALARM: n–th AXIS – LSI OVERFLOW | The contents of the error register for the n–th axis (axis 1–8) exceeded ( \pm 2^{31} ) power. This error usually occurs as the result of an improperly set parameters. |
| 415    | SERVO ALARM: n–TH AXIS – EXCESS SHIFT | A speed higher than 524288000 units/s was attempted to be set in the n–th axis (axis 1–8). This error occurs as the result of improperly set CMR. |</p>
<table>
<thead>
<tr>
<th>Number</th>
<th>Message</th>
<th>Contents</th>
</tr>
</thead>
</table>
| 417    | SERVO ALARM: n–TH AXIS – PARMETER INCORRECT | This alarm occurs when the n–th axis (axis 1–8) is in one of the conditions listed below. (Digital servo system alarm)  
1) The value set in Parameter No. 2020 (motor form) is out of the specified limit.  
2) A proper value (111 or –111) is not set in parameter No.2022 (motor revolution direction).  
3) Illegal data (a value below 0, etc.) was set in parameter No. 2023 (number of speed feedback pulses per motor revolution).  
4) Illegal data (a value below 0, etc.) was set in parameter No. 2024 (number of position feedback pulses per motor revolution).  
5) Parameters No. 2084 and No. 2085 (flexible field gear rate) have not been set.  
6) A value outside the limit of {1 to the number of control axes} or a non–continuous value (Parameter 1023 (servo axis number) contains a value out of the range from 1 to the number of axes, or an isolated value (for example, 4 not preceded by 3).was set in parameter No. 1023 (servo axis number). |
| 420    | SERVO ALARM: n AXIS SYNC TORQUE | During simple synchronous control, the difference between the torque commands for the master and slave axes exceeded the value set in parameter No. 2031. |
| 421    | SERVO ALARM: n AXIS EXCESS ER (D) | The difference between the errors in the semi–closed loop and closed loop has become excessive during dual position feedback. Check the values of the dual position conversion coefficients in parameters No. 2078 and 2079. |
| 422    | SERVO ALARM: n AXIS | In torque control of PMC axis control, a specified allowable speed has been exceeded. |
| 423    | SERVO ALARM: n AXIS | In torque control of PMC axis control, the parameter–set allowable cumulative travel distance has been exceeded. |
| 430    | n AXIS : SV. MOTOR OVERHEAT | A servo motor overheat occurred. |
| 431    | n AXIS : CNV. OVERLOAD | 1) PSM: Overheat occurred.  
2) β series SVU: Overheat occurred. |
| 432    | n AXIS : CNV. LOWVOLT CON. | 1) PSM: The control power supply voltage has dropped.  
2) PSMR: The control power supply voltage has dropped.  
3) β series SVU: The control power supply voltage has dropped. |
| 433    | n AXIS : CNV. LOWVOLT DC LINK | 1) PSM: The DC link voltage has dropped.  
2) PSMR: The DC link voltage has dropped.  
3) α series SVU: The DC link voltage has dropped.  
4) β series SVU: The DC link voltage has dropped. |
| 434    | n AXIS : INV. LOWVOLT CONTROL | SVM: The control power supply voltage has dropped. |
| 435    | n AXIS : INV. LOWVOLT DC LINK | SVM: The DC link voltage has dropped. |
| 436    | n AXIS : SOFTTHERMAL (OVC) | The digital servo software detected the soft thermal state (OVC). |
| 437    | n AXIS : CNV. OVERCURRENT POWER | PSM: Overcurrent flowed into the input circuit. |
| 438    | n AXIS : INV. ABNORMAL CURRENT | 1) SVM: The motor current is too high.  
2) α series SVU: The motor current is too high.  
3) β series SVU: The motor current is too high. |
<table>
<thead>
<tr>
<th>Number</th>
<th>Message</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>439</td>
<td>n AXIS : CNV. OVERVOLT POWER</td>
<td>1) PSM: The DC link voltage is too high.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2) PSMR: The DC link voltage is too high.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3) α series SVU: The C link voltage is too high.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4) β series SVU: The link voltage is too high.</td>
</tr>
<tr>
<td>440</td>
<td>n AXIS : CNV. EX DECELERATION POW.</td>
<td>1) PSMR: The regenerative discharge amount is too large.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2) α series SVU: The regenerative discharge amount is too large.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Alternately, the regenerative discharge circuit is abnormal.</td>
</tr>
<tr>
<td>441</td>
<td>n AXIS : ABNORMAL CURRENT OFFSET</td>
<td>The digital servo software detected an abnormality in the motor current detection circuit.</td>
</tr>
<tr>
<td>442</td>
<td>n AXIS : CNV. CHARGE FAULT</td>
<td>1) PSM: The spare discharge circuit of the DC link is abnormal.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2) PSMR: The spare discharge circuit of the DC link is abnormal.</td>
</tr>
<tr>
<td>443</td>
<td>n AXIS : CNV. COOLING FAN FAILURE</td>
<td>1) PSM: The internal stirring fan failed.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2) PSMR: The internal stirring fan failed.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3) β series SVU: The internal stirring fan failed.</td>
</tr>
<tr>
<td>444</td>
<td>n AXIS : INV. COOLING FAN FAILURE</td>
<td>SVM: The internal stirring fan failed.</td>
</tr>
<tr>
<td>445</td>
<td>n AXIS : SOFT DISCONNECT ALARM</td>
<td>The digital servo software detected a broken wire in the pulse coder.</td>
</tr>
<tr>
<td>446</td>
<td>n AXIS : HARD DISCONNECT ALARM</td>
<td>A broken wire in the built-in pulse coder was detected by hardware.</td>
</tr>
<tr>
<td>447</td>
<td>n AXIS : HARD DISCONNECT (EXT)</td>
<td>A broken wire in the separate detector was detected by hardware.</td>
</tr>
<tr>
<td>448</td>
<td>n AXIS : UNMATCHED FEEDBACK ALARM</td>
<td>The sign of feedback data from the built-in pulse coder differs from that of feedback data from the separate detector.</td>
</tr>
<tr>
<td>449</td>
<td>n AXIS : INV. IPM ALARM</td>
<td>1) SVM: IPM (intelligent power module) detected an alarm.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2) α series SVU: IPM (intelligent power module) detected an alarm.</td>
</tr>
<tr>
<td>453</td>
<td>n AXIS : SPC SOFT DISCONNECT ALARM</td>
<td>Software disconnection alarm of the α pulse coder.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Turn off the power to the CNC, then remove and insert the pulse coder cable. If this alarm is issued again, replace the pulse coder.</td>
</tr>
<tr>
<td>456</td>
<td>ILLEGAL CURRENT LOOP</td>
<td>The current control cycle settings (parameter No. 2004, bit 0 of parameter No. 2003, and bit 0 of parameter No. 2013) are incorrect. Possible problems are as follows.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- For the two axes whose servo axis numbers (settings of parameter No. 1023) are an odd number followed by an even number (a pair of axes 1 and 2 or axes 5 and 6, for example), a different current control cycle is set for each of the axes.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- The requirements for slaves needed for the set current control cycle, including the number, type, and connection method of them, are not satisfied.</td>
</tr>
<tr>
<td>457</td>
<td>ILLEGAL HI HRV (250US)</td>
<td>Use of high-speed HRV is specified although the current control cycle is 200 μs.</td>
</tr>
<tr>
<td>458</td>
<td>CURRENT LOOP ERROR</td>
<td>The current control cycle setting does not match the actual current control cycle.</td>
</tr>
<tr>
<td>459</td>
<td>HI HRV SETTING ERROR</td>
<td>For the two axes whose servo axis numbers (settings of parameter No. 1023) are an odd number followed by an even number (a pair of axes 1 and 2 or axes 5 and 6, for example), the SVM for one of the axes supports high-speed HRV control but the SVM for the other does not. Refer to the SVM specification.</td>
</tr>
<tr>
<td>Number</td>
<td>Message</td>
<td>Contents</td>
</tr>
<tr>
<td>--------</td>
<td>---------------------------------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>460</td>
<td>n AXIS : FSSB DISCONNECT</td>
<td>FSSB communication was disconnected suddenly. The possible causes are as follows:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1) The FSSB communication cable was disconnected or broken.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2) The power to the amplifier was turned off suddenly.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3) A low-voltage alarm was issued by the amplifier.</td>
</tr>
<tr>
<td>461</td>
<td>n AXIS : ILLEGAL AMP INTERFACE</td>
<td>The axes of the 2-axis amplifier were assigned to the fast type interface.</td>
</tr>
<tr>
<td>462</td>
<td>n AXIS : SEND CNC DATA FAILED</td>
<td>Because of an FSSB communication error, a slave could not receive correct data.</td>
</tr>
<tr>
<td>463</td>
<td>n AXIS : SEND SLAVE DATA FAILED</td>
<td>Because of an FSSB communication error, the servo system could not receive correct data.</td>
</tr>
<tr>
<td>464</td>
<td>n AXIS : WRITE ID DATA FAILED</td>
<td>An attempt was made to write maintenance information on the amplifier maintenance screen, but it failed.</td>
</tr>
<tr>
<td>465</td>
<td>n AXIS : READ ID DATA FAILED</td>
<td>At power-up, amplifier initial ID information could not be read.</td>
</tr>
<tr>
<td>466</td>
<td>n AXIS : MOTOR/AMP COMBINATION</td>
<td>The maximum current rating for the amplifier does not match that for the motor.</td>
</tr>
<tr>
<td>467</td>
<td>n AXIS : ILLEGAL SETTING OF AXIS</td>
<td>The servo function for the following has not been enabled when an axis occupying a single DSP (corresponding to two ordinary axes) is specified on the axis setting screen.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1. Learning control (bit 5 of parameter No. 2008 = 1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. High-speed current loop (bit 0 of parameter No. 2004 = 1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. High-speed interface axis (bit 4 of parameter No. 2005 = 1)</td>
</tr>
<tr>
<td>468</td>
<td>HI HRV SETTING ERROR (AMP)</td>
<td>Use of high-speed HRV is specified for a controlled axis of an amplifier which does not support high-speed HRV.</td>
</tr>
</tbody>
</table>

**Details of servo alarm**

The details of servo alarm are displayed in the diagnosis display (No. 200 and No. 204) as shown below.

<table>
<thead>
<tr>
<th>200</th>
<th>#7</th>
<th>#6</th>
<th>#5</th>
<th>#4</th>
<th>#3</th>
<th>#2</th>
<th>#1</th>
<th>#0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OVL</td>
<td>LV</td>
<td>OVC</td>
<td>HCA</td>
<td>HVA</td>
<td>DCA</td>
<td>FBA</td>
<td>OFA</td>
</tr>
</tbody>
</table>

- **#7 (OVL)**: An overload alarm is being generated.
- **#6 (LV)**: A low voltage alarm is being generated in servo amp.
- **#5 (OVC)**: An overcurrent alarm is being generated inside of digital servo.
- **#4 (HCA)**: An abnormal current alarm is being generated in servo amp.
- **#3 (HVA)**: An overvoltage alarm is being generated in servo amp.
- **#2 (DCA)**: A regenerative discharge circuit alarm is being generated in servo amp.
- **#1 (FBA)**: A disconnection alarm is being generated.
- **#0 (OFA)**: An overflow alarm is being generated inside of digital servo.

When OVL equal 1 in diagnostic data No.200 (servo alarm No. 400 is being generated):

- **#7 (ALD)**: Motor overheating
- **1**: Amplifier overheating

When FBAL equal 1 in diagnostic data No.200 (servo alarm No. 416 is being generated):
### ALARM LIST B

<table>
<thead>
<tr>
<th>ALD</th>
<th>EXP</th>
<th>Alarm details</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>Built-in pulse coder disconnection (hardware)</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>Separately installed pulse coder disconnection (hardware)</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>Pulse coder is not connected due to software.</td>
</tr>
</tbody>
</table>

#### 7) Over travel alarms

<table>
<thead>
<tr>
<th>Number</th>
<th>Message</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>OVER TRAVEL : +n</td>
<td>Exceeded the n-th axis (axis 1 to 8) + side stored stroke limit. (Parameter No.1320 or 1326 NOTE)</td>
</tr>
<tr>
<td>501</td>
<td>OVER TRAVEL : –n</td>
<td>Exceeded the n-th axis (axis 1 to 8) – side stored stroke limit. (Parameter No.1321 or 1327 NOTE)</td>
</tr>
<tr>
<td>502</td>
<td>OVER TRAVEL : +n</td>
<td>Exceeded the n-th axis (axis 1 to 8) + side stored stroke limit II. (Parameter No.1322)</td>
</tr>
<tr>
<td>503</td>
<td>OVER TRAVEL : –n</td>
<td>Exceeded the n-th axis (axis 1 to 8) – side stored stroke limit II. (Parameter No.1323)</td>
</tr>
<tr>
<td>504</td>
<td>OVER TRAVEL : +n</td>
<td>Exceeded the n-th axis (axis 1 to 8) – side stored stroke limit III. (Parameter No.1324)</td>
</tr>
<tr>
<td>505</td>
<td>OVER TRAVEL : –n</td>
<td>Exceeded the n-th axis (axis 1 to 8) – side stored stroke limit III. (Parameter No.1325)</td>
</tr>
<tr>
<td>506</td>
<td>OVER TRAVEL : +n</td>
<td>Exceeded the n-th axis (axis 1 to 8) + side hardware OT.</td>
</tr>
<tr>
<td>507</td>
<td>OVER TRAVEL : –n</td>
<td>Exceeded the n-th axis (axis 1 to 8) – side hardware OT.</td>
</tr>
<tr>
<td>510</td>
<td>OVER TRAVEL : +n</td>
<td>A stroke limit check, made before starting movement, found that the end point of a block falls within the plus (+) side inhibited area along the n-axis defined by a stroke limit. Correct the program.</td>
</tr>
<tr>
<td>511</td>
<td>OVER TRAVEL : –n</td>
<td>A stroke limit check, made before starting movement, found that the end point of a block falls within the minus (–) side inhibited area along the N-axis defined by a stroke limit. Correct the program.</td>
</tr>
<tr>
<td>514</td>
<td>INTERFERENCE : +n</td>
<td>The rotation area interference check function found interference on the plus side of the n axis.</td>
</tr>
<tr>
<td>515</td>
<td>INTERFERENCE : –n</td>
<td>The rotation area interference check function found interference on the minus side of the n axis.</td>
</tr>
</tbody>
</table>

**NOTE**

Parameters 1326 and 1327 are effective when EXLM (stroke limit switch signal) is on.
## 8) Servo alarms (2/2)

<table>
<thead>
<tr>
<th>Number</th>
<th>Message</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>600</td>
<td>n AXIS : INV. DC LINK OVERCURRENT</td>
<td>DC link current is too large.</td>
</tr>
<tr>
<td>601</td>
<td>n AXIS : INV. RADIATOR FAN FAILURE</td>
<td>The external dissipator stirring fan failed.</td>
</tr>
<tr>
<td>602</td>
<td>n AXIS : INV. OVERHEAT</td>
<td>The servo amplifier was overheated.</td>
</tr>
<tr>
<td>603</td>
<td>n AXIS : INV. IPM ALARM (OH)</td>
<td>The IPM (intelligent power module) detected an overheat alarm.</td>
</tr>
<tr>
<td>604</td>
<td>n AXIS : AMP. COMMUNICATION ERROR</td>
<td>Communication between the SVM and the PSM failed.</td>
</tr>
<tr>
<td>605</td>
<td>n AXIS : CNV. EX. DISCHARGE POW.</td>
<td>PSMR: Regenerative power is too large.</td>
</tr>
<tr>
<td>606</td>
<td>n AXIS : CNV. RADIATOR FAN FAILURE</td>
<td>PSM: The external dissipator stirring fan failed.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PSMR: The external dissipator stirring fan failed.</td>
</tr>
<tr>
<td>607</td>
<td>n AXIS : CNV. SINGLE PHASE FAILURE</td>
<td>PSM: Input voltage is in the open-phase condition.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PSMR: Input voltage is in the open-phase condition.</td>
</tr>
</tbody>
</table>

## 9) Overheat alarms

<table>
<thead>
<tr>
<th>Number</th>
<th>Message</th>
<th>Contents</th>
</tr>
</thead>
</table>
| 700    | OVERHEAT: CONTROL UNIT | Control unit overheat  
Check that the fan motor operates normally, and clean the air filter. |
| 701    | OVERHEAT: FAN MOTOR    | The fan motor on the top of the cabinet for the control unit is overheated. 
Check the operation of the fan motor and replace the motor if necessary. |
| 704    | OVERHEAT: SPINDLE      | Spindle overheat in the spindle fluctuation detection  
1) If the cutting load is heavy, relieve the cutting condition.  
2) Check whether the cutting tool is share.  
3) Another possible cause is a faulty spindle amp. |

## 10) Rigid tapping alarm

<table>
<thead>
<tr>
<th>Number</th>
<th>Message</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>740</td>
<td>RIGID TAP ALARM : EXCESS ERROR</td>
<td>During rigid tapping, the position deviation of the spindle in the stop state exceeded the setting.</td>
</tr>
<tr>
<td>741</td>
<td>RIGID TAP ALARM : EXCESS ERROR</td>
<td>During rigid tapping, the position deviation of the spindle in the stop state exceeded the setting.</td>
</tr>
<tr>
<td>742</td>
<td>RIGID TAP ALARM : LSI OVERFLOW</td>
<td>During rigid tapping, an LSI overflow occurred on the spindle side.</td>
</tr>
</tbody>
</table>
## 11) Serial spindle alarms

<table>
<thead>
<tr>
<th>Number</th>
<th>Message</th>
<th>Contents</th>
</tr>
</thead>
</table>
| 749 | S–SPINDLE LSI ERROR | It is serial communication error while system is executing after power supply on. Following reasons can be considered.  
1) Optical cable connection is fault or cable is not connected or cable is cut.  
2) MAIN CPU board or option 2 board is fault.  
3) Spindle amp. printed board is fault.  
4) The spindle amplifier is under an abnormal condition. (The SPM indication is A, A1, A2, or the like, depending on the type of the abnormality.)  
If this alarm occurs when CNC power supply is turned on or when this alarm can not be cleared even if CNC is reset, turn off the power supply also turn off the power supply in spindle side.  
If the spindle amplifier is under an abnormal condition, check the SPM indication (A, A1, A2, or the like). Then, refer to the FANUC SERVO MOTOR αi series MAINTENANCE MANUAL (B–65285EN) or FANUC SERVO MOTOR α series MAINTENANCE MANUAL (B–65165E) to solve the problem. |
| 750 | SPINDLE SERIAL LINK START FAULT | This alarm is generated when the spindle control unit is not ready for starting correctly when the power is turned on in the system with the serial spindle.  
The four reasons can be considered as follows:  
1) An improperly connected optic cable, or the spindle control unit’s power is OFF.  
2) When the NC power was turned on under alarm conditions other than SU–01 or AL–24 which are shown on the LED display of the spindle control unit.  
In this case, turn the spindle amplifier power off once and perform startup again.  
3) Other reasons (improper combination of hardware)  
This alarm does not occur after the system including the spindle control unit is activated.  
4) The second spindle (when SP2, bit 4 of parameter No. 3701, is 1) is in one of the above conditions 1) to 3).  
See diagnostic display No. 409 for details. |
<p>| 752 | FIRST SPINDLE MODE CHANGE FAULT | This alarm is generated if the system does not properly terminate a mode change. The modes include the Cs contouring, spindle positioning, rigid tapping, and spindle control modes. The alarm is activated if the spindle control unit does not respond correctly to the mode change command issued by the NC. |
| 754 | SPINDLE–1 ABNORMAL TORQUE ALM | Abnormal first spindle motor load has been detected. |
| 762 | SECOND SPINDLE MODE CHANGE FAULT | Refer to alarm No. 752.(For 2nd axis) |
| 764 | SPINDLE–2 ABNORMAL TORQUE ALM | Same as alarm No. 754 (for the second spindle) |
| 772 | SPINDLE–3 MODE CHANGE ERROR | Same as alarm No. 752 (for the third spindle) |
| 774 | SPINDLE–3 ABNORMAL TORQUE ALM | Same as alarm No. 754 (for the third spindle) |</p>
<table>
<thead>
<tr>
<th>Number</th>
<th>Message</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>782</td>
<td>SPINDLE–4 MODE CHANGE ERROR</td>
<td>Same as alarm number 752 (for the fourth spindle)</td>
</tr>
<tr>
<td>784</td>
<td>SPINDLE–4 ABNORMAL TORQUE ALM</td>
<td>Same as alarm number 754 (for the fourth spindle)</td>
</tr>
</tbody>
</table>

- The details of spindle alarm No. 750

- 1st and 2nd spindles

  #7  #6  #5  #4  #3  #2  #1  #0

  409  SPE  S2E  S1E  SHE

  #3 (SPE) 0: In the spindle serial control, the serial spindle parameters fulfill the spindle unit startup conditions.

  1: In the spindle serial control, the serial spindle parameters do not fulfill the spindle unit startup conditions.

  #2 (S2E) 0: The second spindle is normal during the spindle serial control startup.

  1: The second spindle was detected to have a fault during the spindle serial control startup.

  #1 (S1E) 0: The first spindle is normal during the spindle serial control startup.

  1: The first spindle was detected to have a fault during the spindle axis serial control startup.

  #0 (SHE) 0: The serial communications module in the CNC is normal.

  1: The serial communications module in the CNC was detected to have a fault.

- 3rd and 4th spindles

  The details of spindle alarm No. 750 are displayed in the diagnosis display (No. 409) as shown below.

  #7  #6  #5  #4  #3  #2  #1  #0

  409  SPE  S4E  S3E  SHE

  #3 (SPE) 0: In the spindle serial control, the serial spindle parameters fulfill the spindle unit startup conditions.

  1: In the spindle serial control, the serial spindle parameters do not fulfill the spindle unit startup conditions.

  #2 (S2E) 0: The fourth spindle is normal during the spindle serial control startup.

  1: The fourth spindle was detected to have a fault during the spindle serial control startup.

  #1 (S1E) 0: The third spindle is normal during the spindle serial control startup.

  1: The third spindle was detected to have a fault during the spindle axis serial control startup.

  #0 (SHE) 0: The serial communications module in the CNC is normal.

  1: The serial communications module in the CNC was detected to have a fault.
Alarm List (Serial Spindle)

When a serial spindle alarm occurs, the following number is displayed on the CNC. n is a number corresponding to the spindle on which an alarm occurs. (n = 1: First spindle; n = 2: Second spindle; etc.)

NOTE*1
Note that the meanings of the SPM indications differ depending on which LED, the red or yellow LED, is on. When the red LED is on, the SPM indicates a 2-digit alarm number. When the yellow LED is on, the SPM indicates an error number that designates a sequence problem (for example, when a rotation command is entered with the emergency stop state not released).
→ See Appendix A.4, “Error Codes (Serial Spindle).”

Alarm Numbers and Alarms Displayed on the \( \alpha \) Series Spindle Amplifier

<table>
<thead>
<tr>
<th>No.</th>
<th>Message</th>
<th>SPM indication*1</th>
<th>Faulty location and remedy</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>(750)</td>
<td>SPINDLE SERIAL LINK ERRORS</td>
<td>A0</td>
<td>1 Replace the ROM on the SPM control printed circuit board. 2 Replace the SPM control printed circuit board.</td>
<td>The program does not start normally. ROM series error or hardware abnormality on the SPM control printed circuit board.</td>
</tr>
<tr>
<td>(749)</td>
<td>S–SPINDLE LSI ERROR</td>
<td>A1</td>
<td>Replace the SPM control printed circuit board.</td>
<td>An abnormality was detected in the CPU peripheral circuit of the SPM control circuit.</td>
</tr>
<tr>
<td>7n01</td>
<td>SPN_n_: MOTOR OVERHEAT</td>
<td>01</td>
<td>1 Check and correct the peripheral temperature and load status. 2 If the cooling fan stops, replace it.</td>
<td>The thermostat embedded in the motor winding operated. The internal temperature of the motor exceeds the specified level. The motor is used in excess of the continuous rating, or the cooling component is abnormal.</td>
</tr>
<tr>
<td>7n02</td>
<td>SPN_n_: EX SPEED ERROR</td>
<td>02</td>
<td>1 Check and correct the cutting conditions to decrease the load. 2 Correct parameter No. 4082.</td>
<td>The motor speed cannot follow a specified speed. An excessive motor load torque is detected. The acceleration/deceleration time in parameter No. 4082 is insufficient.</td>
</tr>
<tr>
<td>7n03</td>
<td>SPN_n_: FUSE ON DC LINK BLOWN</td>
<td>03</td>
<td>1 Replace the SPM unit. 2 Check the motor insulation status. 3 Replace the interface cable.</td>
<td>The PSM becomes ready (00 is indicated), but the DC link voltage is too low in the SPM. The fuse in the DC link section in the SPM is blown. (The power device is damaged or the motor is ground-fault.) The JX1A/JX1B connection cable is abnormal.</td>
</tr>
<tr>
<td>7n06</td>
<td>SPN_n_: THERMAL SENSOR DISCONNECT</td>
<td>06</td>
<td>1 Check and correct the parameter. 2 Replace the feedback cable.</td>
<td>The temperature sensor of the motor is disconnected.</td>
</tr>
<tr>
<td>No.</td>
<td>Message</td>
<td>SPM indication(*1)</td>
<td>Faulty location and remedy</td>
<td>Description</td>
</tr>
<tr>
<td>-----</td>
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<td>-------------</td>
</tr>
<tr>
<td>7n07</td>
<td>SPN_n_: OVERSPEED</td>
<td>07</td>
<td>Check for a sequence error. (For example, check whether spindle synchronization was specified when the spindle could not be turned.)</td>
<td>The motor speed has exceeded 115% of its rated speed. When the spindle axis was in position control mode, positional deviations were accumulated excessively (SFR and SRV were turned off during spindle synchronization.)</td>
</tr>
<tr>
<td>7n09</td>
<td>SPN_n_: OVERHEAT MAIN CIRCUIT</td>
<td>09</td>
<td>1 Improve the heat sink cooling status. 2 If the heat sink cooling fan stops, replace the SPM unit.</td>
<td>Abnormal temperature rise of the power transistor radiator</td>
</tr>
<tr>
<td>7n11</td>
<td>SPN_n_: OVERVOLT POW CIRCUIT</td>
<td>11</td>
<td>1 Check the selected PSM. 2 Check the input power voltage and change in power during motor deceleration. If the voltage exceeds 253 VAC (for the 200–V system) or 530 VAC (for the 400–V system), improve the power supply impedance.</td>
<td>Overvoltage of the DC link section of the PSM was detected. (PSM alarm indication: 7) PSM selection error. (The maximum output specification of the PSM is exceeded.)</td>
</tr>
<tr>
<td>7n12</td>
<td>SPN_n_: OVERCURRENT POW CIRCUIT</td>
<td>12</td>
<td>1 Check the motor insulation status. 2 Check the spindle parameters. 3 Replace the SPM unit.</td>
<td>The motor output current is abnormally high. A motor–specific parameter does not match the motor model. Poor motor insulation</td>
</tr>
<tr>
<td>7n15</td>
<td>SPN_n_: SP SWITCH CONTROL ALARM</td>
<td>15</td>
<td>1 Check and correct the ladder sequence. 2 Replace the switching MC.</td>
<td>The switch sequence in spindle switch/output switch operation is abnormal. The switching MC contact status check signal and command do not match.</td>
</tr>
<tr>
<td>7n16</td>
<td>SPN_n_: RAM FAULT</td>
<td>16</td>
<td>Replace the SPM control printed circuit board.</td>
<td>Abnormality in an SPM control circuit component is detected. (RAM for external data is abnormal.)</td>
</tr>
<tr>
<td>7n18</td>
<td>SPN_n_: SUMCHECK ERROR PGM DATA</td>
<td>18</td>
<td>Replace the SPM control printed circuit board.</td>
<td>Abnormality in an SPM control circuit component is detected. (Program ROM data is abnormal.)</td>
</tr>
<tr>
<td>7n19</td>
<td>SPN_n_: EX OFFSET CURRENT U</td>
<td>19</td>
<td>Replace the SPM unit.</td>
<td>Abnormality in an SPM component is detected. (The initial value for the U phase current detection circuit is abnormal.)</td>
</tr>
<tr>
<td>7n20</td>
<td>SPN_n_: EX OFFSET CURRENT V</td>
<td>20</td>
<td>Replace the SPM unit.</td>
<td>Abnormality in an SPM component is detected. (The initial value of the V phase current detection circuit is abnormal.)</td>
</tr>
<tr>
<td>7n21</td>
<td>SPN_n_: POS SENSOR POLARITY ERROR</td>
<td>21</td>
<td>Check and correct the parameters. (No. 4000#0, 4001#4)</td>
<td>The polarity parameter setting of the position sensor is wrong.</td>
</tr>
<tr>
<td>No.</td>
<td>Message</td>
<td>SPM indication(*1)</td>
<td>Faulty location and remedy</td>
<td>Description</td>
</tr>
<tr>
<td>-----</td>
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</tr>
</tbody>
</table>
| 7n24 | SPN_n_ : SERIAL TRANSFER ERROR | 24 | 1 Place the CNC-to-spindle cable away from the power cable.  
2 Replace the cable. | The CNC power is turned off (normal power-off or broken cable).  
An error is detected in communication data transferred to the CNC. |
| 7n26 | SPN_n_ : DISCONNECT C–VELO DETECT | 26 | 1 Replace the cable.  
2 Re–adjust the pre–amplifier. | The signal amplitude of the detection signal (connector JY2) on the Cs contour control motor side is abnormal.  
(Unconnected cable, adjustment error, etc.) |
| 7n27 | SPN_n_ : DISCONNECT POS–CODER | 27 | 1 Replace the cable.  
2 Re–adjust the BZ sensor signal. | 1 The spindle position coder (connector JY4) signal is abnormal.  
2 The signal amplitude (connector JY2) of the MZ or BZ sensor is abnormal.  
(Unconnected cable, adjustment error, etc.) |
| 7n28 | SPN_n_ : DISCONNECT C–POS DETECT | 28 | 1 Replace the cable  
2 Re–adjust the pre–amplifier. | The position detection signal (connector JY5) for Cs contour control is abnormal.  
(Unconnected cable, adjustment error, etc.) |
| 7n29 | SPN_n_ : SHORTTIME OVERLOAD | 29 | Check and correct the load status. | Excessive load has been applied continuously for a certain period of time.  
(This alarm is issued also when the motor shaft has been locked in the excitation state.) |
| 7n30 | SPN_n_ : OVERCURRENT POW CIRCUIT | 30 | Check and correct the power supply voltage. | Overcurrent is detected in PSM main circuit input.  
(PSM alarm indication: 1)  
Unbalanced power supply.  
PSM selection error (The maximum PSM output specification is exceeded.) |
| 7n31 | SPN_n_ : MOTOR LOCK OR V–SIG LOS | 31 | 1 Check and correct the load status.  
2 Replace the motor sensor cable (JY2 or JY5). | The motor cannot rotate at a specified speed.  
(A level not exceeding the SST level for the rotation command has existed continuously.)  
Abnormality in the speed detection signal. |
| 7n32 | SPN_n_ : RAM FAULT SERIAL LSI | 32 | Replace the SPM control printed circuit board. | Abnormality in an SPM control circuit component is detected.  
(The LSI device for serial transfer is abnormal.) |
| 7n33 | SPN_n_ : SHORTAGE POWER CHARGE | 33 | 1 Check and correct the power supply voltage.  
2 Replace the PSM unit. | Charging of direct current power supply voltage in the power circuit section is insufficient when the magnetic contractor in the amplifier is turned on  
(such as open phase and defective charging resistor). |
<table>
<thead>
<tr>
<th>No.</th>
<th>Message</th>
<th>SPM indication(*1)</th>
<th>Faulty location and remedy</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>7n34</td>
<td>SPN_n_: PARAMETER SETTING ERROR</td>
<td>34</td>
<td>Correct a parameter value according to the manual. If the parameter number is unknown, connect the spindle check board, and check the indicated parameter.</td>
<td>Parameter data exceeding the allowable limit is set.</td>
</tr>
<tr>
<td>7n35</td>
<td>SPN_n_: EX SETTING GEAR RATIO</td>
<td>35</td>
<td>Correct the value according to the parameter manual.</td>
<td>Gear ratio data exceeding the allowable limit is set.</td>
</tr>
<tr>
<td>7n36</td>
<td>SPN_n_: OVERFLOW ERROR COUNTER</td>
<td>36</td>
<td>Check whether the position gain value is too large, and correct the value.</td>
<td>An error counter overflow occurred.</td>
</tr>
<tr>
<td>7n37</td>
<td>SPN_n_: SPEED DETECT PAR. ERROR</td>
<td>37</td>
<td>Correct the value according to the parameter manual.</td>
<td>The setting of the parameter for the number of pulses in the speed detector is incorrect.</td>
</tr>
<tr>
<td>7n39</td>
<td>SPN_n_: 1–ROT Cs SIGNAL ERROR</td>
<td>39</td>
<td>1 Adjust the 1–rotation signal in the pre–amplifier. 2 Check the cable shield status. 3 Replace the cable.</td>
<td>An incorrect relationship between the 1–rotation signal and the number of AB phase pulses was detected during Cs contour control.</td>
</tr>
<tr>
<td>7n40</td>
<td>SPN_n_: NO 1–ROT Cs SIGNAL DETECT</td>
<td>40</td>
<td>1 Adjust the 1–rotation signal in the pre–amplifier. 2 Check the cable shield status. 3 Replace the cable.</td>
<td>The 1–rotation signal is not generated during Cs contour control.</td>
</tr>
<tr>
<td>7n41</td>
<td>SPN_n_: 1–ROT POS-CODER ERROR</td>
<td>41</td>
<td>1 Check and correct the parameter. 2 Replace the cable. 3 Re–adjust the BZ sensor signal.</td>
<td>1 The 1–rotation signal of the spindle position coder (connector JY4) is abnormal. 2 The 1–rotation signal (connector JY2) of the MZ or BZ sensor is abnormal. 3 Parameter setting error.</td>
</tr>
<tr>
<td>7n42</td>
<td>SPN_n_: NO 1–ROT. POS–CODER DETECT</td>
<td>42</td>
<td>1 Replace the cable. 2 Re–adjust the BZ sensor signal.</td>
<td>1 The 1–rotation signal of the spindle position coder (connector JY4) is disconnected. 2 The 1–rotation signal (connector JY2) of the MZ or BZ sensor is disconnected.</td>
</tr>
<tr>
<td>7n43</td>
<td>SPN_n_: DISCON. PC FOR DIF. SP. MODE</td>
<td>43</td>
<td>Replace the cable.</td>
<td>The differential speed position coder signal (connector JY8) in SPM type 3 is abnormal.</td>
</tr>
<tr>
<td>7n44</td>
<td>SPN_n_: CONTROL CIRCUIT(AD) ERROR</td>
<td>44</td>
<td>Replace the SPM control printed circuit board.</td>
<td>Abnormality in an SPM control circuit component was detected (A/D converter abnormality).</td>
</tr>
<tr>
<td>7n46</td>
<td>SPN_n_: SCREW 1–ROT POS–COD. ALARM</td>
<td>46</td>
<td>1 Check and correct the parameter. 2 Replace the cable. 3 Re–adjust the BZ sensor signal.</td>
<td>An abnormality equivalent to alarm 41 was detected during thread cutting operation.</td>
</tr>
<tr>
<td>No.</td>
<td>Message</td>
<td>SPM indication*1</td>
<td>Faulty location and remedy</td>
<td>Description</td>
</tr>
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</tbody>
</table>
| 7n47 | SPN_n_ : POS-CODER SIGNAL ABNORMAL | 47 | 1 Replace the cable.  
2 Re-adjust the BZ sensor signal.  
3 Correct the cable layout (vicinity of the power line). | 1 The A/B phase signal of the spindle position coder (connector JY4) is abnormal.  
2 The A/B phase signal (connector JY2) of the MZ or BZ sensor is abnormal.  
The relationship between the A/B phase and 1–rotation signal is incorrect (Pulse interval mismatch). |
| 7n49 | SPN_n_ : HIGH CONV. DIF. SPEED | 49 | Check whether the calculated differential speed value exceeds the maximum motor speed. | In differential speed mode, the speed of the other spindle converted to the speed of the local spindle has exceeded the allowable limit (the differential speed is calculated by multiplying the speed of the other spindle by the gear ratio). |
| 7n50 | SPN_n_ : SPNDL CONTROL OVERSPEED | 50 | Check whether the calculated value exceeds the maximum motor speed. | In spindle synchronization, the speed command calculation value exceeded the allowable limit (the motor speed is calculated by multiplying the specified spindle speed by the gear ratio). |
| 7n51 | SPN_n_ : LOW VOLT DC LINK | 51 | 1 Check and correct the power supply voltage.  
2 Replace the MC. | Input voltage drop was detected. (PSM alarm indication: 4) (Momentary power failure or poor MC contact) |
| 7n52 | SPN_n_ : ITP SIGNAL ABNORMAL I | 52 | 1 Replace the SPM control printed circuit board.  
2 Replace the spindle interface printed circuit board in the CNC. | NC interface abnormality was detected (the ITP signal stopped). |
| 7n53 | SPN_n_ : ITP SIGNAL ABNORMAL II | 53 | 1 Replace the SPM control printed circuit board.  
2 Replace the spindle interface printed circuit board in the CNC. | NC interface abnormality was detected (the ITP signal stopped). |
| 7n54 | SPN_n_ : OVERLOAD CURRENT | 54 | Review the load state. | An overload current was detected. |
| 7n55 | SPN_n_ : POWER LINE SWITCH ERROR | 55 | 1 Replace the magnetic contactor.  
2 Check and correct the sequence. | The power line state signal of the magnetic contactor for selecting a spindle or output is abnormal. |
| 7n56 | SPN_n_ : INNER COOLING FAN STOP | 56 | Replace the SPM unit. | The cooling fan in the SPM control circuit stopped. |
| 7n57 | SPN_n_ : EX DECCELERATION POWER | 57 | 1 Decrease the acceleration/deceleration duty.  
2 Check the cooling condition (peripheral temperature).  
3 If the cooling fan stops, replace the resistor.  
4 If the resistance is abnormal, replace the resistor. | An overload was detected in the regenerative resistance. (PSMR alarm indication: 8) Thermostat operation or short–time overload was detected.  
The regenerative resistor was disconnected, or an abnormal resistance was detected. |
<table>
<thead>
<tr>
<th>No.</th>
<th>Message</th>
<th>SPM indication(*1)</th>
<th>Faulty location and remedy</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>7n58</td>
<td>SPN_n_: OVERLOAD IN PSM</td>
<td>58</td>
<td>1. Check the PSM cooling status. 2. Replace the PSM unit.</td>
<td>The temperature of the radiator of the PSM has increased abnormally. (PSM alarm indication: 3)</td>
</tr>
<tr>
<td>7n59</td>
<td>SPN_n_: COOLING FAN STOP IN PSM</td>
<td>59</td>
<td>Replace the SPM unit.</td>
<td>The cooling fan in the PSM stopped. (PSM alarm indication: 2)</td>
</tr>
<tr>
<td>7n62</td>
<td>SPN_n_: MOTOR VCMD OVERLOWED</td>
<td>62</td>
<td>Check and correct the parameters. (No. 4021, 4056 to 4059)</td>
<td>The specified motor speed is too large.</td>
</tr>
<tr>
<td>7n66</td>
<td>SPN_n_: AMP MODULE COMMUNICATION</td>
<td>66</td>
<td>1. Replace the cable. 2. Check and correct the connection.</td>
<td>An error was found in communication between amplifiers.</td>
</tr>
<tr>
<td>7n73</td>
<td>SPN_n_: MOTOR SENSOR DISCONNECTED</td>
<td>73</td>
<td>1. Replace the feedback cable. 2. Check the shield processing. 3. Check and correct the connection. 4. Adjust the sensor.</td>
<td>The motor sensor feedback signal is not present.</td>
</tr>
<tr>
<td>7n74</td>
<td>SPN_n_: CPU TEST ERROR</td>
<td>74</td>
<td>Replace the SPM control printed–circuit board.</td>
<td>An error was detected in a CPU test.</td>
</tr>
<tr>
<td>7n75</td>
<td>SPN_n_: CRC ERROR</td>
<td>75</td>
<td>Replace the SPM control printed–circuit board.</td>
<td>An error was detected in a CRC test.</td>
</tr>
<tr>
<td>7n79</td>
<td>SPN_n_: INITIAL TEST ERROR</td>
<td>79</td>
<td>Replace the SPM control printed–circuit board.</td>
<td>An error was detected in an initial test operation.</td>
</tr>
<tr>
<td>7n81</td>
<td>SPN_n_: 1–ROT MOTOR SENSOR ERROR</td>
<td>81</td>
<td>1. Check and correct the parameter. 2. Replace the feedback cable. 3. Adjust the sensor.</td>
<td>The one–rotation signal of the motor sensor cannot be correctly detected.</td>
</tr>
<tr>
<td>7n82</td>
<td>SPN_n_: NO 1–ROT MOTOR SENSOR</td>
<td>82</td>
<td>1. Replace the feedback cable. 2. Adjust the sensor.</td>
<td>The one–rotation signal of the motor sensor is not generated.</td>
</tr>
<tr>
<td>7n83</td>
<td>SPN_n_: MOTOR SENSOR SIGNAL ERROR</td>
<td>83</td>
<td>1. Replace the feedback cable. 2. Adjust the sensor.</td>
<td>An irregularity was detected in a motor sensor feedback signal.</td>
</tr>
<tr>
<td>7n84</td>
<td>SPN_n_: SPNDL SENSOR DISCONNECTED</td>
<td>84</td>
<td>1. Replace the feedback cable. 2. Check the shield processing. 3. Check and correct the connection. 4. Check and correct the parameter. 5. Adjust the sensor.</td>
<td>The spindle sensor feedback signal is not present.</td>
</tr>
<tr>
<td>7n85</td>
<td>SPN_n_: 1–ROT SPNDL SENSOR ERROR</td>
<td>85</td>
<td>1. Check and correct the parameter. 2. Replace the feedback cable. 3. Adjust the sensor.</td>
<td>The one–rotation signal of the spindle sensor cannot be correctly detected.</td>
</tr>
<tr>
<td>7n87</td>
<td>SPN_n_: SPNDL SENSOR SIGNAL ERROR</td>
<td>87</td>
<td>The one–rotation signal of the spindle sensor is not generated.</td>
<td>An irregularity was detected in a spindle sensor feedback signal.</td>
</tr>
<tr>
<td>7n88</td>
<td>SPN_n_: COOLING RADIIFAN FAILURE</td>
<td>88</td>
<td>Replace the SPM external cooling fan.</td>
<td>The external cooling fan stopped.</td>
</tr>
<tr>
<td>No.</td>
<td>Message</td>
<td>SPM indication(*1)</td>
<td>Faulty location and remedy</td>
<td>Description</td>
</tr>
<tr>
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</tr>
<tr>
<td>7n97</td>
<td>SPN_n_: OTHER SPINDLE ALARM</td>
<td>97</td>
<td>Replace the SPM.</td>
<td>Another irregularity was detected.</td>
</tr>
<tr>
<td>7n98</td>
<td>SPN_n_: OTHER CONVERTER ALARM</td>
<td>98</td>
<td>Check the PSM alarm display.</td>
<td>A PSM alarm was detected.</td>
</tr>
<tr>
<td>9n01</td>
<td>SPN_n_: MOTOR OVERHEAT</td>
<td>01</td>
<td>1. Check and correct the peripheral temperature and load status.</td>
<td>The thermostat embedded in the motor winding operated.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2. If the cooling fan stops, replace it.</td>
<td>The internal temperature of the motor exceeds the specified level.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>The motor is used in excess of the continuous rating, or the cooling component is abnormal.</td>
</tr>
<tr>
<td>9n02</td>
<td>SPN_n_: EX SPEED ERROR</td>
<td>02</td>
<td>1. Check and correct the cutting conditions to decrease the load.</td>
<td>The motor speed cannot follow a specified speed.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2. Correct parameter No. 4082.</td>
<td>An excessive motor load torque is detected.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>The acceleration/deceleration time in parameter No. 4082 is insufficient.</td>
</tr>
<tr>
<td>9n03</td>
<td>SPN_n_: FUSE ON DC LINK BLOWN</td>
<td>03</td>
<td>1. Replace the SPM unit.</td>
<td>The PSM becomes ready (00 is indicated), but the DC link voltage is too low in the SPM.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2. Check the motor insulation status.</td>
<td>(The power device is damaged or the motor is ground-fault.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3. Replace the interface cable.</td>
<td>The JX1A/JX1B connection cable is abnormal.</td>
</tr>
<tr>
<td>9n06</td>
<td>SPN_n_: TERMAL SENSOR DISCONN</td>
<td>06</td>
<td>1. Check and correct the parameter.</td>
<td>The temperature sensor of the motor is disconnected.</td>
</tr>
<tr>
<td></td>
<td>CONNECT</td>
<td></td>
<td>2. Replace the feedback cable.</td>
<td></td>
</tr>
<tr>
<td>9n07</td>
<td>SPN_n_: OVERSPEED</td>
<td>07</td>
<td>Check for a sequence error. (For example, check whether spindle synchronization was specified when the spindle could not be turned.)</td>
<td>The motor speed has exceeded 115% of its rated speed.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>When the spindle axis was in position control mode, positional deviations were accumulated excessively (SFR and SRV were turned off during spindle synchronization.)</td>
</tr>
<tr>
<td>9n09</td>
<td>SPN_n_: OVERHEAT MAIN CIRCUIT</td>
<td>09</td>
<td>1. Improve the heat sink cooling status.</td>
<td>Abnormal temperature rise of the power transistor radiator</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2. If the heat sink cooling fan stops, replace the SPM unit.</td>
<td></td>
</tr>
<tr>
<td>No.</td>
<td>Message</td>
<td>SPM indication(*1)</td>
<td>Faulty location and remedy</td>
<td>Description</td>
</tr>
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<td>-----------------------------------------------------------------------------</td>
</tr>
</tbody>
</table>
| 9n11 | SPN_n_ : OVERVOLT POW CIRCUIT    | 11                 | 1. Check the selected PSM.  
2. Check the input power voltage and change in power during motor deceleration. If the voltage exceeds 253 VAC (for the 200–V system) or 530 VAC (for the 400–V system), improve the power supply impedance. | Overvoltage of the DC link section of the PSM was detected. (PSM alarm indication: 7) PSM selection error. (The maximum output specification of the PSM is exceeded.) |
| 9n12 | SPN_n_ : OVERCURRENT POW CIRCUIT | 12                 | 1. Check the motor insulation status.  
2. Check the spindle parameters.  
3. Replace the SPM unit. | The motor output current is abnormally high. A motor–specific parameter does not match the motor model. Poor motor insulation |
| 9n15 | SPN_n_ : SP SWITCH CONTROL ALARM | 15                 | 1. Check and correct the ladder sequence.  
2. Replace the switching MC. | The switch sequence in spindle switch/output switch operation is abnormal. The switching MC contact status check signal and command do not match. |
| 9n16 | SPN_n_ : RAM FAULT               | 16                 | Replace the SPM control printed circuit board.                                                | Abnormality in an SPM control circuit component is detected. (RAM for external data is abnormal.) |
| 9n18 | SPN_n_ : SUMCHECK ERROR PGM DATA | 18                 | Replace the SPM control printed circuit board.                                                | Abnormality in an SPM control circuit component is detected. (Program ROM data is abnormal.) |
| 9n19 | SPN_n_ : EX OFFSET CURRENT U     | 19                 | Replace the SPM unit.                                                                          | Abnormality in an SPM component is detected. (The initial value for the U phase current detection circuit is abnormal.) |
| 9n20 | SPN_n_ : EX OFFSET CURRENT V     | 20                 | Replace the SPM unit.                                                                          | Abnormality in an SPM component is detected. (The initial value for the V phase current detection circuit is abnormal.) |
| 9n21 | SPN_n_ : POS SENSOR POLARITY ERROR | 21               | Check and correct the parameters. (No. 4000#0, 4001#4)                                         | The polarity parameter setting of the position sensor is wrong.             |
| 9n24 | SPN_n_ : SERIAL TRANSFER ERROR   | 24                 | 1. Place the CNC–to–spindle cable away from the power cable.  
2. Replace the cable. | The CNC power is turned off (normal power–off or broken cable). An error is detected in communication data transferred to the CNC. |
| 9n27 | SPN_n_ : DISCONNECT POS–CODER    | 27                 | 1. Replace the cable.  
2. Re–adjust the BZ sensor signal. | 1. The spindle position coder (connector JY4) signal is abnormal.  
2. The signal amplitude (connector JY2) of the MZ or BZ sensor is abnormal. (Unconnected cable, adjustment error, etc.) |
<table>
<thead>
<tr>
<th>No.</th>
<th>Message</th>
<th>SPM indication(*1)</th>
<th>Faulty location and remedy</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>9n29</td>
<td>SPN_n_: SHORTTIME OVERLOAD</td>
<td>29</td>
<td>Check and correct the load status.</td>
<td>Excessive load has been applied continuously for a certain period of time. (This alarm is issued also when the motor shaft has been locked in the excitation state.)</td>
</tr>
<tr>
<td>9n30</td>
<td>SPN_n_: OVERCURRENT POWER CIRCUIT</td>
<td>30</td>
<td>Check and correct the power supply voltage.</td>
<td>Overcurrent is detected in PSM main circuit input. (PSM alarm indication: 1) Unbalanced power supply. PSM selection error (The maximum PSM output specification is exceeded.)</td>
</tr>
<tr>
<td>9n31</td>
<td>SPN_n_: MOTOR LOCK OR V–SIG LOS</td>
<td>31</td>
<td>1 Check and correct the load status. 2 Replace the motor sensor cable (JY2 or JY5).</td>
<td>The motor cannot rotate at a specified speed. (A level not exceeding the SST level for the rotation command has existed continuously.) Abnormality in the speed detection signal.</td>
</tr>
<tr>
<td>9n32</td>
<td>SPN_n_: RAM FAULT SERIAL LSI</td>
<td>32</td>
<td>Replace the SPM control printed circuit board.</td>
<td>Abnormality in an SPM control circuit component is detected. (The LSI device for serial transfer is abnormal.)</td>
</tr>
<tr>
<td>9n33</td>
<td>SPN_n_: SHORTAGE POWER CHARGE</td>
<td>33</td>
<td>1 Check and correct the power supply voltage. 2 Replace the PSM unit.</td>
<td>Charging of direct current power supply voltage in the power circuit section is insufficient when the magnetic contractor in the amplifier is turned on (such as open phase and defective charging resistor).</td>
</tr>
<tr>
<td>9n34</td>
<td>SPN_n_: PARAMETER SETTING ERROR</td>
<td>34</td>
<td>Correct a parameter value according to the manual. If the parameter number is unknown, connect the spindle check board, and check the indicated parameter.</td>
<td>Parameter data exceeding the allowable limit is set.</td>
</tr>
<tr>
<td>9n35</td>
<td>SPN_n_: EX SETTING GEAR RATIO</td>
<td>35</td>
<td>Correct the value according to the parameter manual.</td>
<td>Gear ratio data exceeding the allowable limit is set.</td>
</tr>
<tr>
<td>9n36</td>
<td>SPN_n_: OVERFLOW ERROR COUNTER</td>
<td>36</td>
<td>Check whether the position gain value is too large, and correct the value.</td>
<td>An error counter overflow occurred.</td>
</tr>
<tr>
<td>9n37</td>
<td>SPN_n_: SPEED DETECT PAR. ERROR</td>
<td>37</td>
<td>Correct the value according to the parameter manual.</td>
<td>The setting of the parameter for the number of pulses in the speed detector is incorrect.</td>
</tr>
<tr>
<td>9n41</td>
<td>SPN_n_: 1–ROT POS-CODER ERROR</td>
<td>41</td>
<td>1 Check and correct the parameter. 2 Replace the cable. 3 Re–adjust the BZ sensor signal.</td>
<td>1 The 1–rotation signal of the spindle position coder (connector JY4) is abnormal. 2 The 1–rotation signal (connector JY2) of the MZ or BZ sensor is abnormal. 3 Parameter setting error</td>
</tr>
<tr>
<td>No.</td>
<td>Message</td>
<td>SPM indication(*1)</td>
<td>Faulty location and remedy</td>
<td>Description</td>
</tr>
<tr>
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<td>-------------</td>
</tr>
</tbody>
</table>
| 9n42 | SPN_n_: NO 1–ROT. POS–CODER DETECT | 42 | 1 Replace the cable.  
2 Re–adjust the BZ sensor signal. | 1 The 1–rotation signal of the spindle position coder (connector JY4) is disconnected.  
2 The 1–rotation signal (connector JY2) of the MZ or BZ sensor is disconnected. |
| 9n43 | SPN_n_: DISCON. PC FOR DIF. SP. MODE | 43 | Replace the cable. | The differential speed position coder signal (connector JY8) in SPM type 3 is abnormal. |
| 9n46 | SPN_n_: SCREW 1–ROT POS–COD. ALARM | 46 | 1 Check and correct the parameter.  
2 Replace the cable.  
3 Re–adjust the BZ sensor signal. | An abnormality equivalent to alarm 41 was detected during thread cutting operation. |
| 9n47 | SPN_n_: POS–CODER SIGNAL ABNORMAL | 47 | 1 Replace the cable.  
2 Re–adjust the BZ sensor signal.  
3 Correct the cable layout (vicinity of the power line). | 1 The A/B phase signal of the spindle position coder (connector JY4) is abnormal.  
2 The A/B phase signal (connector JY2) of the MZ or BZ sensor is abnormal.  
The relationship between the A/B phase and 1–rotation signal is incorrect (Pulse interval mismatch). |
| 9n49 | SPN_n_: HIGH CONV. DIF. SPEED | 49 | Check whether the calculated differential speed value exceeds the maximum motor speed. | In differential speed mode, the speed of the other spindle converted to the speed of the local spindle has exceeded the allowable limit (the differential speed is calculated by multiplying the speed of the other spindle by the gear ratio). |
| 9n50 | SPN_n_: SPNDL CONTROL OVERSPEED | 50 | Check whether the calculated value exceeds the maximum motor speed. | In spindle synchronization, the speed command calculation value exceeded the allowable limit (the motor speed is calculated by multiplying the specified spindle speed by the gear ratio). |
| 9n51 | SPN_n_: LOW VOLT DC LINK | 51 | 1 Check and correct the power supply voltage.  
2 Replace the MC. | Input voltage drop was detected. (PSM alarm indication: 4) (Momen tary power failure or poor MC contact) |
| 9n52 | SPN_n_: ITP SIGNAL ABNORMAL I | 52 | 1 Replace the SPM control printed circuit board.  
2 Replace the spindle interface printed circuit board in the CNC. | NC interface abnormality was detected (the ITP signal stopped). |
| 9n53 | SPN_n_: ITP SIGNAL ABNORMAL II | 53 | 1 Replace the SPM control printed circuit board.  
2 Replace the spindle interface printed circuit board in the CNC. | NC interface abnormality was detected (the ITP signal stopped). |
| 9n54 | SPN_n_: OVERLOAD CURRENT | 54 | Review the load state. | An overload current was detected. |
| 9n55 | SPN_n_: POWER LINE SWITCH ERROR | 55 | 1 Replace the magnetic contactor.  
2 Check and correct the sequence. | The power line state signal of the magnetic contactor for selecting a spindle or output is abnormal. |
<table>
<thead>
<tr>
<th>No.</th>
<th>Message</th>
<th>SPM indication(*1)</th>
<th>Faulty location and remedy</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>9n56</td>
<td>SPN_n__ : INNER COOL-ING FAN STOP</td>
<td>56</td>
<td>Replace the SPM unit.</td>
<td>The cooling fan in the SPM control circuit stopped.</td>
</tr>
<tr>
<td>9n57</td>
<td>SPN_n__ : EX DECEL-ERATION POWER</td>
<td>57</td>
<td>1 Decrease the acceleration/deceleration duty. 2 Check the cooling condition (peripheral temperature). 3 If the cooling fan stops, replace the resistor. 4 If the resistance is abnormal, replace the resistor.</td>
<td>An overload was detected in the regenerative resistance. (PSMR alarm indication: 8) Thermostat operation or short-time overload was detected. The regenerative resistor was disconnected, or an abnormal resistance was detected.</td>
</tr>
<tr>
<td>9n58</td>
<td>SPN_n__ : OVERLOAD IN PSM</td>
<td>58</td>
<td>1 Check the PSM cooling status. 2 Replace the PSM unit.</td>
<td>The temperature of the radiator of the PSM has increased abnormally. (PSM alarm indication: 3)</td>
</tr>
<tr>
<td>9n59</td>
<td>SPN_n__ : COOLING FAN STOP IN PSM</td>
<td>59</td>
<td>Replace the SPM unit.</td>
<td>The cooling fan in the PSM stopped. (PSM alarm indication: 2)</td>
</tr>
<tr>
<td>9n66</td>
<td>SPN_n__ : AMP MODULE COMMUNICA-TION</td>
<td>66</td>
<td>1 Replace the cable. 2 Check and correct the connection.</td>
<td>An error was found in communication between amplifiers.</td>
</tr>
<tr>
<td>9n73</td>
<td>SPN_n__ : MOTOR SEN-SOR DISCON-NECTED</td>
<td>73</td>
<td>1 Replace the feedback cable. 2 Check the shield processing. 3 Check and correct the connection. 4 Adjust the sensor.</td>
<td>The motor sensor feedback signal is not present.</td>
</tr>
<tr>
<td>9n74</td>
<td>SPN_n__ : CPU TEST ERR-OR</td>
<td>74</td>
<td>Replace the SPM control printed-circuit board.</td>
<td>An error was detected in a CPU test.</td>
</tr>
<tr>
<td>9n75</td>
<td>SPN_n__ : CRC ERROR</td>
<td>75</td>
<td>Replace the SPM control printed-circuit board.</td>
<td>An error was detected in a CRC test.</td>
</tr>
<tr>
<td>9n79</td>
<td>SPN_n__ : INITIAL TEST ERROR</td>
<td>79</td>
<td>Replace the SPM control printed-circuit board.</td>
<td>An error was detected in an initial test operation.</td>
</tr>
<tr>
<td>9n81</td>
<td>SPN_n__ : 1–ROT MO-TOR SENSOR ERROR</td>
<td>81</td>
<td>1 Check and correct the parameter. 2 Replace the feedback cable. 3 Adjust the sensor.</td>
<td>The one–rotation signal of the motor sensor cannot be correctly detected.</td>
</tr>
<tr>
<td>9n82</td>
<td>SPN_n__ : NO 1–ROT MOTOR SEN-SOR</td>
<td>82</td>
<td>1 Replace the feedback cable. 2 Adjust the sensor.</td>
<td>The one–rotation signal of the motor sensor is not generated.</td>
</tr>
<tr>
<td>9n83</td>
<td>SPN_n__ : MOTOR SEN-SOR SINGNAL ERROR</td>
<td>83</td>
<td>1 Replace the feedback cable. 2 Adjust the sensor.</td>
<td>An irregularity was detected in a motor sensor feedback signal.</td>
</tr>
<tr>
<td>9n84</td>
<td>SPN_n__ : SPNDL SEN-SOR DISCON-NECTED</td>
<td>84</td>
<td>1 Replace the feedback cable. 2 Check the shield processing. 3 Check and correct the connection. 4 Check and correct the parameter. 5 Adjust the sensor.</td>
<td>The spindle sensor feedback signal is not present.</td>
</tr>
<tr>
<td>9n85</td>
<td>SPN_n__ : 1–ROT SPNDL SENSOR ERR-OR</td>
<td>85</td>
<td>1 Check and correct the parameter. 2 Replace the feedback cable. 3 Adjust the sensor.</td>
<td>The one–rotation signal of the spindle sensor cannot be correctly detected.</td>
</tr>
<tr>
<td>No.</td>
<td>Message</td>
<td>SPM indication(*1)</td>
<td>Faulty location and remedy</td>
<td>Description</td>
</tr>
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</tr>
<tr>
<td>9n87</td>
<td>SPN_n_ : SPNDL SENSOR SIGNAL ERROR</td>
<td>87</td>
<td>The one-rotation signal of the spindle sensor is not generated.</td>
<td>An irregularity was detected in a spindle sensor feedback signal.</td>
</tr>
<tr>
<td>9n88</td>
<td>SPN_n_ : COOLING RADIFAN FAILURE</td>
<td>88</td>
<td>Replace the SPM external cooling fan.</td>
<td>The external cooling fan stopped.</td>
</tr>
<tr>
<td>9097</td>
<td>SPN_n_ : OTHER SPINDLE ALARM</td>
<td></td>
<td>Check the SPM alarm display.</td>
<td>Other spindle alarm</td>
</tr>
<tr>
<td>9098</td>
<td>SPN_n_ : OTHER CONVERTER ALARM</td>
<td></td>
<td>Check the PSM alarm display.</td>
<td>Other converter alarm</td>
</tr>
<tr>
<td>9110</td>
<td>SPN_n_ : AMP COMMUNICATION ERROR</td>
<td>b0</td>
<td>1 Replace the communication cable between amplifier and module.</td>
<td>Communication error between amplifier and module</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2 Replace the SPM or PSM control printed circuit board.</td>
<td></td>
</tr>
<tr>
<td>9111</td>
<td>SPN_n_ : CONV.LOW VOLT CONTROL</td>
<td>b1</td>
<td>Replace the PSM control printed circuit board.</td>
<td>Low converter control power supply voltage (PSM indication = 6)</td>
</tr>
<tr>
<td>9112</td>
<td>SPN_n_ : CONV.EXDISCHARGE POW.</td>
<td>b2</td>
<td>1 Check the regenerative resistance.</td>
<td>Excessive converter regenerative power (PSM indication = 8)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2 Check the motor selection.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3 Replace the PSM</td>
<td></td>
</tr>
<tr>
<td>9113</td>
<td>SPN_n_ : CONV.COOLING FAN FAILURE</td>
<td>b3</td>
<td>Replace the cooling fan.</td>
<td>Stopped cooling fan of the converter radiator (PSM indication = A)</td>
</tr>
<tr>
<td>9120</td>
<td>SPN_n_ : COMMUNICATION DATA ERROR</td>
<td>C0</td>
<td>1 Replace the communication cable between CNC and SPM.</td>
<td>Communication data alarm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2 Replace the SPM control printed circuit board.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3 Replace the CNC side spindle interface printed circuit board.</td>
<td></td>
</tr>
<tr>
<td>9121</td>
<td>SPN_n_ : COMMUNICATION DATA ERROR</td>
<td>C1</td>
<td>1 Replace the communication cable between CNC and SPM.</td>
<td>Communication data alarm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2 Replace the SPM control printed circuit board.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3 Replace the CNC side spindle interface printed circuit board.</td>
<td></td>
</tr>
<tr>
<td>9122</td>
<td>SPN_n_ : COMMUNICATION DATA ERROR</td>
<td>C2</td>
<td>1 Replace the communication cable between CNC and SPM.</td>
<td>Communication data alarm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2 Replace the SPM control printed circuit board.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3 Replace the CNC side spindle interface printed circuit board.</td>
<td></td>
</tr>
</tbody>
</table>
ERROR CODES (SERIAL SPINDLE)

**NOTE**

Note that the meanings of the SPM indications differ depending on which LED, the red or yellow LED, is on. When the yellow LED is on, an error code is indicated with a 2-digit number. The error code is not displayed on the CNC screen.

When the red LED is on, the SPM indicates the number of an alarm generated in the serial spindle.

→ See Item, “Alarm List (Serial Spindle).”

### Errors Displayed on the Spindle Amplifier

<table>
<thead>
<tr>
<th>SPM indication(*1)</th>
<th>Faulty location and remedy</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>Check the *ESP and MRDY sequence. (For MRDY, pay attention to the parameter setting regarding the use of the MRDY signal (bit 0 of parameter No. 4001).)</td>
<td>Although neither *ESP (emergency stop signal; there are two types of signals including the PMC signal and PSM contact signal(2)) nor MRDY (machine ready signal) is input, SFR (forward rotation signal)/SRF (reverse rotation signal)/ORCM (orientation command) is input.</td>
</tr>
<tr>
<td>02</td>
<td>Check the spindle motor speed detector parameter (bits 2, 1, and 0 of parameter No. 4011).</td>
<td>When the spindle motor has a high-resolution magnetic pulse coder (Cs sensor) (bits 6 and 5 of parameter No. 4001 are set to 0 and 1, respectively), 128 /rev is to be set for the speed detector (bits 2, 1, and 0 of parameter No. 4011 are set to 0, 0, and 1, respectively). However, a value other than 128 /rev is set. In this case, the motor is not excited.</td>
</tr>
<tr>
<td>03</td>
<td>Check the parameters for the detector for Cs contour control (bit 5 of parameter No. 4001 and bit 4 of parameter No. 4018).</td>
<td>Although use of a high-resolution magnetic pulse coder (bit 5 of parameter No. 4001 = 1) or use of the Cs contour control function by the sensor (bit 4 of parameter No. 4018 = 1) is not set, a Cs control command is input. In this case, the motor is not excited.</td>
</tr>
<tr>
<td>04</td>
<td>Check the position coder signal parameter (bit 2 of parameter No. 4001).</td>
<td>Although use of the position coder signal (bit 2 of parameter No. 4001 = 1) is not set, a servo mode (rigid tapping, spindle positioning) or spindle synchronization command is input. In this case, the motor is not excited.</td>
</tr>
<tr>
<td>05</td>
<td>Check the orientation software option.</td>
<td>Although the orientation option is not set, an orientation command (ORCM) is input.</td>
</tr>
<tr>
<td>06</td>
<td>Check the spindle output switching software option and power line status signal (RCH).</td>
<td>Although the output switching option is not set, the low-speed winding is selected (RCH = 1).</td>
</tr>
<tr>
<td>07</td>
<td>Check the sequence (CON, SFR, SRV).</td>
<td>Although the Cs contour control mode is specified, SFR/SRV is not input.</td>
</tr>
<tr>
<td>08</td>
<td>Check the sequence (SFR, SRV).</td>
<td>Although the servo mode (rigid tapping, spindle positioning) is specified, SFR/SRV is not input.</td>
</tr>
<tr>
<td>09</td>
<td>Check the sequence (SPSYNC, SFR, SRV)</td>
<td>Although spindle synchronization mode is specified, SFR/SRV is not input.</td>
</tr>
<tr>
<td>10</td>
<td>During execution of the C-axis control command, do not specify another operation mode. Before entering another mode, cancel the Cs contour control command.</td>
<td>Although Cs contour control mode is set, another operation mode (servo mode, spindle synchronization, or orientation) is specified.</td>
</tr>
<tr>
<td>11</td>
<td>During execution of the servo mode command, do not specify another operation mode. Before entering another mode, cancel the servo mode.</td>
<td>Although servo mode (rigid tapping, or spindle positioning) is set, another operation mode (Cs contour control, spindle synchronization, or orientation) is specified.</td>
</tr>
<tr>
<td>SPM indication(*1)</td>
<td>Faulty location and remedy</td>
<td>Description</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>12</td>
<td>During execution of the spindle synchronization command, do not specify another operation mode. Before entering another mode, cancel the spindle synchronization command.</td>
<td>Although spindle synchronization is being performed, another operation mode (Cs contour control, servo mode, or orientation) is specified.</td>
</tr>
<tr>
<td>13</td>
<td>During execution of the orientation command, do not specify another operation mode. Before entering another mode, cancel the orientation command.</td>
<td>Although the orientation command is being executed, another operation mode (Cs contour control, servo mode, or synchronization) is specified.</td>
</tr>
<tr>
<td>14</td>
<td>Input the SFT or SRV signal.</td>
<td>The SFT and SRV signals are both input at the same time.</td>
</tr>
<tr>
<td>15</td>
<td>Check bit 5 of parameter No. 4000 and PMC signal (CON).</td>
<td>When bit 5 of parameter No. 4000 is set to 1 to indicate the presence of the differential speed mode function, Cs contour control is specified.</td>
</tr>
<tr>
<td>16</td>
<td>Check bit 5 of parameter No. 4000 and PMC signal (DEFMD).</td>
<td>When bit 5 of parameter No. 4000 is set to 0 to indicate the absence of the differential speed mode function, the differential speed mode command (DEFMD) is input.</td>
</tr>
<tr>
<td>17</td>
<td>Check bits 2, 1, and 0 of parameter No. 4011.</td>
<td>Setting of the speed detector parameter (bits 2, 1, and 0 of parameter No. 4011) is invalid. (The corresponding speed detector is not present.)</td>
</tr>
<tr>
<td>18</td>
<td>Check bit 2 of parameter No. 4001 and PMC signal (ORCM).</td>
<td>Although bits 2 of parameter No. 4001 is set to 0 not to use the position coder signal, a command for orientation by a position coder (ORCMA) is input.</td>
</tr>
<tr>
<td>19</td>
<td>During execution of the orientation command, do not specify another operation mode. Before entering another mode, cancel the orientation command.</td>
<td>Although orientation by a magnetic sensor is being performed, another operation mode is specified.</td>
</tr>
<tr>
<td>20</td>
<td>Check bit 5 of parameter No. 4014, and bit 4 of parameter No. 4018.</td>
<td>When the use of the slave operation mode function is set (bit 5 of parameter No. 4014 = 1), the use of a high-resolution magnetic pulse coder (bit 5 of parameter No. 4018 = 1) or the use of the Cs contour control function by the sensor (bit 4 of parameter No. 4018 = 1) is specified. These items cannot be set at the same time.</td>
</tr>
<tr>
<td>21</td>
<td>Input the slave operation mode command (SLV) in normal operation mode.</td>
<td>Although position control (such as servo mode or orientation) is being performed, a slave operation mode command (SLV) is input.</td>
</tr>
<tr>
<td>22</td>
<td>Input the position control command in normal operation mode.</td>
<td>Although slave operation mode is set (SLVS = 1), a position control command (such as servo mode or orientation) is input.</td>
</tr>
<tr>
<td>23</td>
<td>Check bit 5 of parameter No. 4014 and PMC signal (SLV).</td>
<td>Although bit 5 of parameter No. 4014 is set to 0 not to use the slave operation mode function, a slave operation mode command (SLV) is input.</td>
</tr>
<tr>
<td>24</td>
<td>Check the PMC signal (INCMD). Perform orientation by specifying an absolute position first.</td>
<td>Orientation is performed in incremental operation mode (INCMD = 1) first, then the absolute position command (INCMD = 0) is input.</td>
</tr>
<tr>
<td>25</td>
<td>Check the spindle amplifier specifications and parameter setting (bit 4 of parameter No. 4018).</td>
<td>Although the spindle amplifier SPM type 4 is not used, the use of the Cs contour control function by the sensor is set (bit 4 of parameter No. 4018 = 1).</td>
</tr>
</tbody>
</table>

**NOTE**

PSM contact signal
Between ESP1 and ESP2 on the PSM

| Contact open | Emergency stop |
| Contact closed | Normal operation |
## 12) System alarms

(These alarms cannot be reset with reset key.)

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<td>ROM PARITY</td>
<td>A parity error occurred in the CNC, macro, or servo ROM. Correct the contents of the flash ROM having the displayed number.</td>
</tr>
<tr>
<td>910</td>
<td>SRAM PARITY : (BYTE 0)</td>
<td>A RAM parity error occurred in the part program storage RAM. Clear the RAM, or replace the SRAM module or motherboard. Subsequently, re-set the parameters and all other data.</td>
</tr>
<tr>
<td>911</td>
<td>SRAM PARITY : (BYTE 1)</td>
<td></td>
</tr>
<tr>
<td>912</td>
<td>DRAM PARITY : (BYTE 0)</td>
<td>A RAM parity error occurred in the DRAM module. Replace the DRAM module.</td>
</tr>
<tr>
<td>913</td>
<td>DRAM PARITY : (BYTE 1)</td>
<td></td>
</tr>
<tr>
<td>914</td>
<td>DRAM PARITY : (BYTE 2)</td>
<td></td>
</tr>
<tr>
<td>915</td>
<td>DRAM PARITY : (BYTE 3)</td>
<td></td>
</tr>
<tr>
<td>916</td>
<td>DRAM PARITY : (BYTE 4)</td>
<td></td>
</tr>
<tr>
<td>917</td>
<td>DRAM PARITY : (BYTE 5)</td>
<td></td>
</tr>
<tr>
<td>918</td>
<td>DRAM PARITY : (BYTE 6)</td>
<td></td>
</tr>
<tr>
<td>919</td>
<td>DRAM PARITY : (BYTE 7)</td>
<td></td>
</tr>
<tr>
<td>920</td>
<td>SERVO ALARM (1–4 AXIS)</td>
<td>Servo alarm (first to fourth axis). A watchdog alarm condition occurred, or a RAM parity error occurred in the axis control card. Replace the axis control card.</td>
</tr>
<tr>
<td>921</td>
<td>SERVO ALARM (5–8 AXIS)</td>
<td>Servo alarm (fifth to eighth axis). A watchdog alarm condition occurred, or a RAM parity error occurred in the axis control card. Replace the axis control card.</td>
</tr>
<tr>
<td>926</td>
<td>FSSB ALARM</td>
<td>FSSB alarm. Replace the axis control card.</td>
</tr>
<tr>
<td>930</td>
<td>CPU INTERRUPT</td>
<td>CPU error (abnormal interrupt). The motherboard or CPU card may be faulty.</td>
</tr>
<tr>
<td>935</td>
<td>SRAM ECC ERROR</td>
<td>An error occurred in RAM for part program storage. Action: Replace the master printed circuit board (SRAM module), perform all-clear operation, and set all parameter and other data again.</td>
</tr>
<tr>
<td>950</td>
<td>PMC SYSTEM ALARM</td>
<td>An error occurred in the PMC. The PMC control circuit on the motherboard may be faulty.</td>
</tr>
<tr>
<td>951</td>
<td>PMC WATCH DOG ALARM</td>
<td>An error occurred in the PMC. (Watchdog alarm) The motherboard may be faulty.</td>
</tr>
<tr>
<td>972</td>
<td>NMI OCCURRED IN OTHER MODULE</td>
<td>An NMI occurred on a board other than the motherboard. The option board may be faulty.</td>
</tr>
<tr>
<td>973</td>
<td>NON MASK INTERRUPT</td>
<td>An NMI occurred as a result of an unknown cause.</td>
</tr>
<tr>
<td>974</td>
<td>F–BUS ERROR</td>
<td>A bus error occurred on the FANUC bus. The motherboard or option board may be faulty.</td>
</tr>
<tr>
<td>975</td>
<td>BUS ERROR</td>
<td>A bus error occurred on the motherboard. The motherboard may be faulty.</td>
</tr>
<tr>
<td>976</td>
<td>L–BUS ERROR</td>
<td>A bus error occurred on the local bus. The motherboard may be faulty.</td>
</tr>
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