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CNC

MELDAS C6/C64/C64T

PROGRAMMING MANUAL
(LATHE TYPE)

BNP-B2264D(ENG)

Introduction

This manual is a guide for using the MELDAS C6/C64/C64T.
Programming is described in this manual, so read this manual thoroughly before starting programming. Thoroughly study the "Precautions for Safety" on the following page to ensure safe use of this NC unit.

Details described in this manual

⚠ CAUTION

- ⚠ For items described as "Restrictions" or "Usable State" in this manual, the instruction manual issued by the machine manufacturer takes precedence over this manual.
- ⚠ Items not described in this manual must be interpreted as "not possible".
- ⚠ This manual is written on the assumption that all option functions are added.
  Refer to the specifications issued by the machine manufacturer before starting use.
- ⚠ Refer to the Instruction Manual issued by each machine manufacturer for details on each machine tool.
- ⚠ Some screens and functions may differ depending on the NC system (or its version), and some functions may not be possible. Please confirm the specifications before use.

General precautions

(1) Refer to the following documents for details on handling
MELDAS C6/C64/C64T Instruction Manual BNP-B2259

Precautions for Safety

Always read the specifications issued by the machine maker, this manual, related manuals and attached documents before installation, operation, programming, maintenance or inspection to ensure correct use.
Understand this numerical controller, safety items and cautions before using the unit.
This manual ranks the safety precautions into "**DANGER**", "**WARNING**" and "**CAUTION**".

⚠ **DANGER**	When the user may be subject to imminent fatalities or major injuries if handling is mistaken.
⚠ **WARNING**	When the user may be subject to fatalities or major injuries if handling is mistaken.
⚠ **CAUTION**	When the user may be subject to injuries or when physical damage may occur if handling is mistaken.

Note that even items ranked as " ⚠ **CAUTION**", may lead to major results depending on the situation. In any case, important information that must always be observed is described.

⚠ DANGER

Not applicable in this manual.

⚠ WARNING

Not applicable in this manual.

⚠ CAUTION

1. Items related to product and manual

⚠ For items described as "Restrictions" or "Usable State" in this manual, the instruction manual issued by the machine manufacturer takes precedence over this manual.

⚠ Items not described in this manual must be interpreted as "not possible".

⚠ This manual is written on the assumption that all option functions are added. Refer to the specifications issued by the machine manufacturer before starting use.

⚠ Refer to the Instruction Manual issued by each machine manufacturer for details on each machine tool.

⚠ Some screens and functions may differ depending on the NC system (or its version), and some functions may not be possible. Please confirm the specifications before use.

⚠ CAUTION

2. Items related to operation

⚠ Before starting actual machining, always carry out dry run operation to confirm the machining program, tool offset amount and workpiece offset amount, etc.

⚠ If the workpiece coordinate system offset amount is changed during single block stop, the new setting will be valid from the next block.

⚠ Turn the mirror image ON and OFF at the mirror image center.

⚠ If the tool offset amount is changed during automatic operation (including during single block stop), it will be validated from the next block or blocks onwards.

⚠ Do not make the synchronous spindle rotation command OFF with one workpiece chucked by the basic spindle and synchronous spindle during the spindle synchronous control mode.
Failure to observe this may cause the synchronous spindle stop, and hazardous situation.

3. Items related to programming

⚠ The commands with "no value after G" will be handled as "G00".

⚠ ";" "EOB" and "%" "EOR" are expressions used for explanation. The actual codes are: For ISO: "CR, LF", or "LF" and "%".
Programs created on the Edit screen are stored in the NC memory in a "CR, LF" format, but programs created with external devices such as the FLD or RS-232C may be stored in an "LF" format.
The actual codes for EIA are: "EOB (End of Block)" and "EOR (End of Record)".

⚠ When creating the machining program, select the appropriate machining conditions, and make sure that the performance, capacity and limits of the machine and NC are not exceeded. The examples do not consider the machining conditions.

⃠ Do not change fixed cycle programs without the prior approval of the machine manufacturer.

⚠ When programming the multi-part system, take special care to the movements of the programs for other part systems.

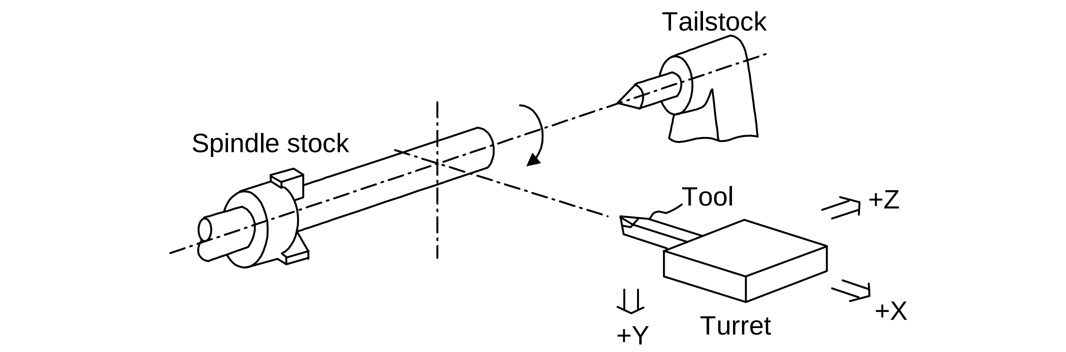
Contents

1. Control Axes

1.1 Coordinate word and control axis

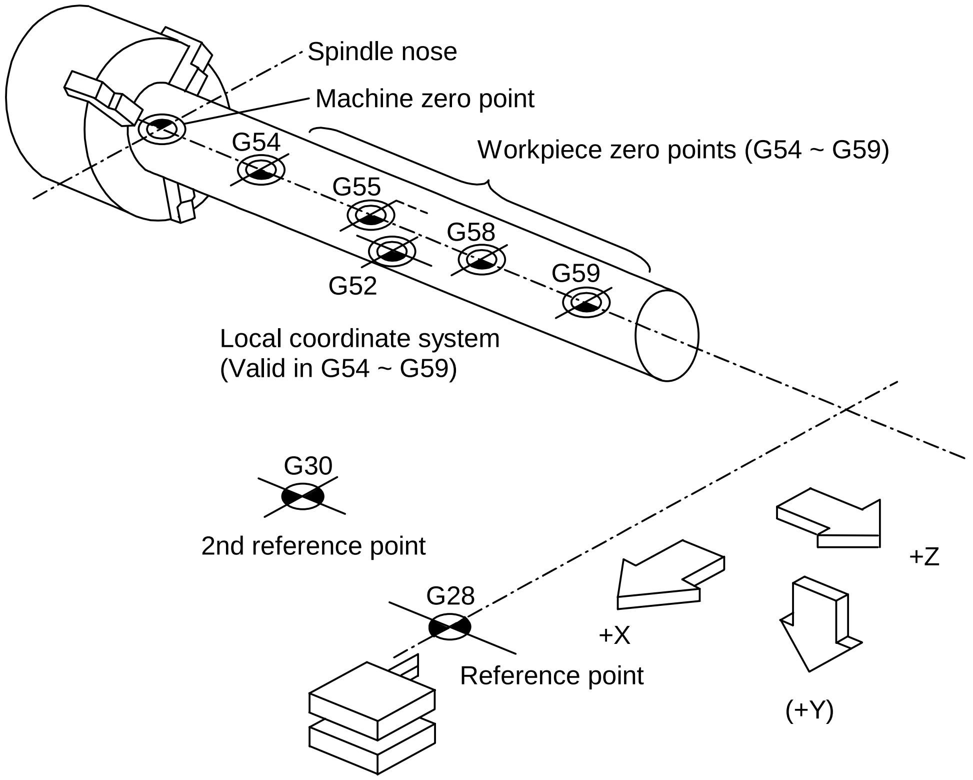
Function and purpose

In the case of a lathe, the axis parallel to the spindle is known as the Z axis and its forward direction is the direction in which the turret moves away from the spindle stock while the axis at right angles to the Z axis is the X axis and its forward direction is the direction in which it moves away from the Z axis, as shown in the figure below.



Coordinate axes and polarities

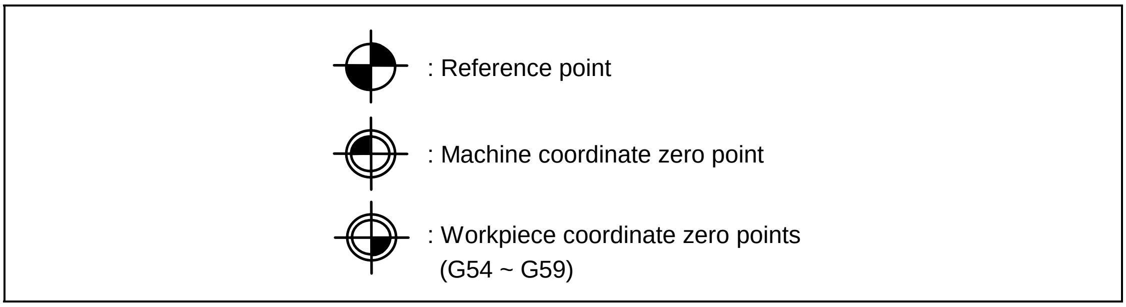
Since coordinates based on the right hand rule are used with a lathe, the forward direction of the Y axis in the above figure which is at right angles to the X-Z plane is downward. It should be borne in mind that an arc on the X-Z plane is expressed as clockwise or counterclockwise as seen from the forward direction of the Y axis. (Refer to the section on circular interpolation.)



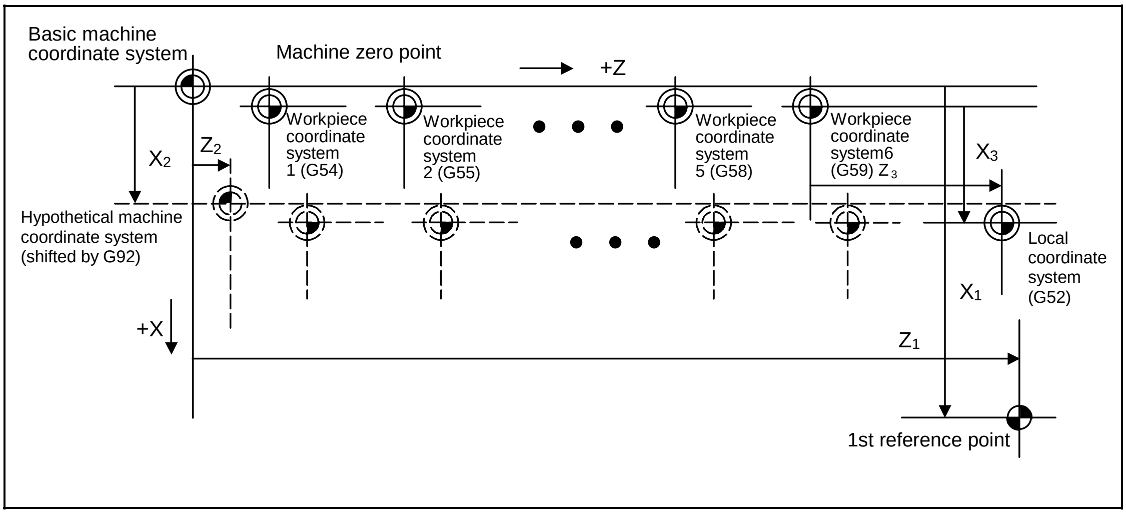
Relationship between coordinates

1.2 Coordinate systems and coordinate zero point symbols

Function and purpose


: Reference point
: Machine coordinate zero point
: Workpiece coordinate zero points
(G54 ~ G59)

Upon completion of the reference point return, the parameters are referred to and automatically set for the basic machine coordinate system and workpiece coordinate systems (G54 ~ G59).
The basic machine coordinate system is set so that the first reference point is at the position designated by the parameter from the basic machine coordinate zero point (machine zero point).


Basic machine coordinate system
Machine zero point
+Z
Workpiece coordinate system 1 (G54)
Workpiece coordinate system 2 (G55)
Workpiece coordinate system 5 (G58)
Workpiece coordinate system6 (G59) Z3
X3
X2
Z2
Hypothetical machine coordinate system (shifted by G92)
Local coordinate system (G52)
X1
+X
Z1
1st reference point

The local coordinate system (G52) is valid on the coordinate systems designated by the commands for the workpiece coordinate systems 1 to 6.
Using the G92 command, the basic machine coordinate system can be shifted and made the hypothetical machine coordinate system. At the same time, workpiece coordinate systems 1 to 6 are also shifted.

2. Input Command Units

2.1 Input command units

Function and purpose

These are the units used for the movement amounts in the program. They are expressed in millimeters, inches or degrees (°).

2.2 Input setting units

Function and purpose

These are the units of setting data which are used, as with the compensation amounts, in common for all axes.
The input command units can be selected from the following types for each axis with the parameters. The input setting units can be selected from the following types common to axes. (For further details on settings, refer to the Instruction Manual.)

	Input unit parameters	Linear axis				Rotation axis (°)
		Millimeter		Inch		
		Diameter command	Radius command	Diameter command	Radius command	
Input command unit	#1015 cunit = 10	0.001	0.001	0.0001	0.0001	0.001
	= 1	0.0001	0.0001	0.00001	0.00001	0.0001
Min. movement unit	#1003 iunit = B	0.0005	0.001	0.00005	0.0001	0.001
	= C	0.00005	0.0001	0.000005	0.00001	0.0001
Input setting unit	#1003 iunit = B	0.001	0.001	0.0001	0.0001	0.001
	= C	0.0001	0.0001	0.00001	0.00001	0.0001

(Note 1) Inch/metric conversion is performed in either of 2 ways: conversion from the parameter screen (#1041 I_inch: valid only when the power is turned ON) and conversion using the G command (G20 or G21).
However, when a G command is used for the conversion, the conversion applies only to the input command units and not to the input setting units.
Consequently, the tool offset amounts and other compensation amounts as well as the variable data should be preset to correspond to inches or millimeters.

(Note 2) The millimeter and inch systems cannot be used together.

(Note 3) During circular interpolation on an axis where the input command units are different, the center command (I, J, K) and the radius command (R) can be designated by the input setting units. (Use a decimal point to avoid confusion.)

3. Data Formats

3.1 Tape codes

Function and purpose

The tape command codes used for this controller are combinations of alphabet letters (A, B, C, ... Z), numbers (0, 1, 2, ... 9) and signs (+, –, /, ...). These alphabet letters, numbers and signs are referred to as characters. Each character is represented by a combination of 8 holes which may, or may not, be present.
These combinations make up what is called codes.
This controller uses the ISO code (R-840).

(Note 1) If a code not given in the "Table of tape codes" is assigned during operation, a program error (P32) will result.

(Note 2) For the sake of convenience, a " ; " has been used in the CNC display to indicate the End of Block (EOB/LF) which separates one block from another. Do not use the " ; " key, however, in actual programming but use the keys in the following table instead.

⚠ CAUTION

⚠ " ; " "EOB" and " % " "EOR" are explanatory notations. The actual code is "Line feed" and "%". (ISO code (R-840)

Detailed description

(1) Use the keys in the following table for programming.

EOB/EOR keys and displays

Code used **Key used**	**ISO**	**Screen display**
End of Block	LF or NL	;
End of Record	%	%

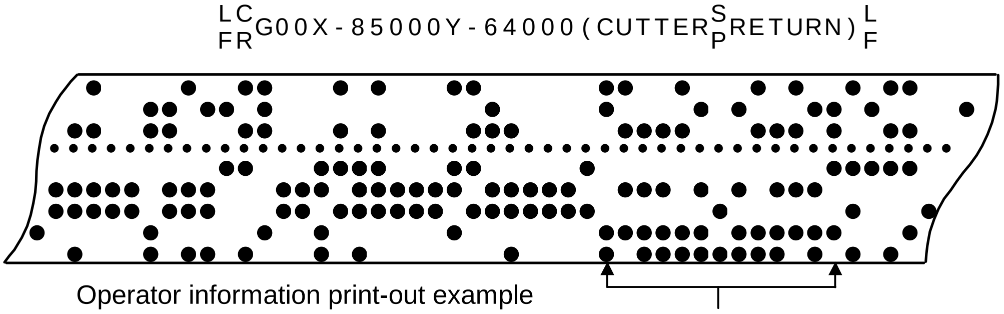
(2) Significant data section (label skip function)

All data up to the first EOB (;), after the power has been turned ON or after operation has been reset, are ignored during automatic operation based on tape, memory loading operation or during a search operation. In other words, the significant data section of a tape extends from the character or number code after the initial EOB (;) code after resetting to the point where the reset command is issued.

(3) Control out, control in

When the ISO code is used, all data between control out "(" and control in ")" (or ";") are ignored, although these data appear on the setting and display unit. Consequently, the command tape name, number and other such data not directly related to control can be inserted in this section.
This information (except (B) in the "Table of tape codes") will also be loaded, however, during tape loading. The system is set to the "control in" mode when the power is turned ON.

Example of ISO code



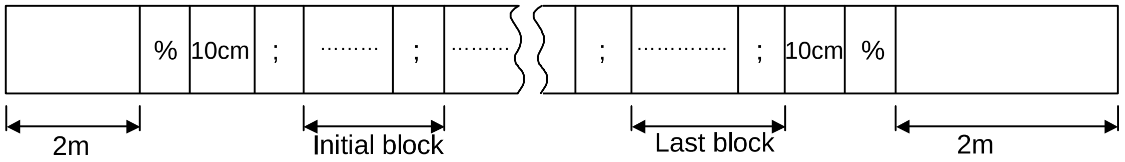
Operator information print-out example

Information in this section is ignored and nothing is executed.

(4) EOR (%) code

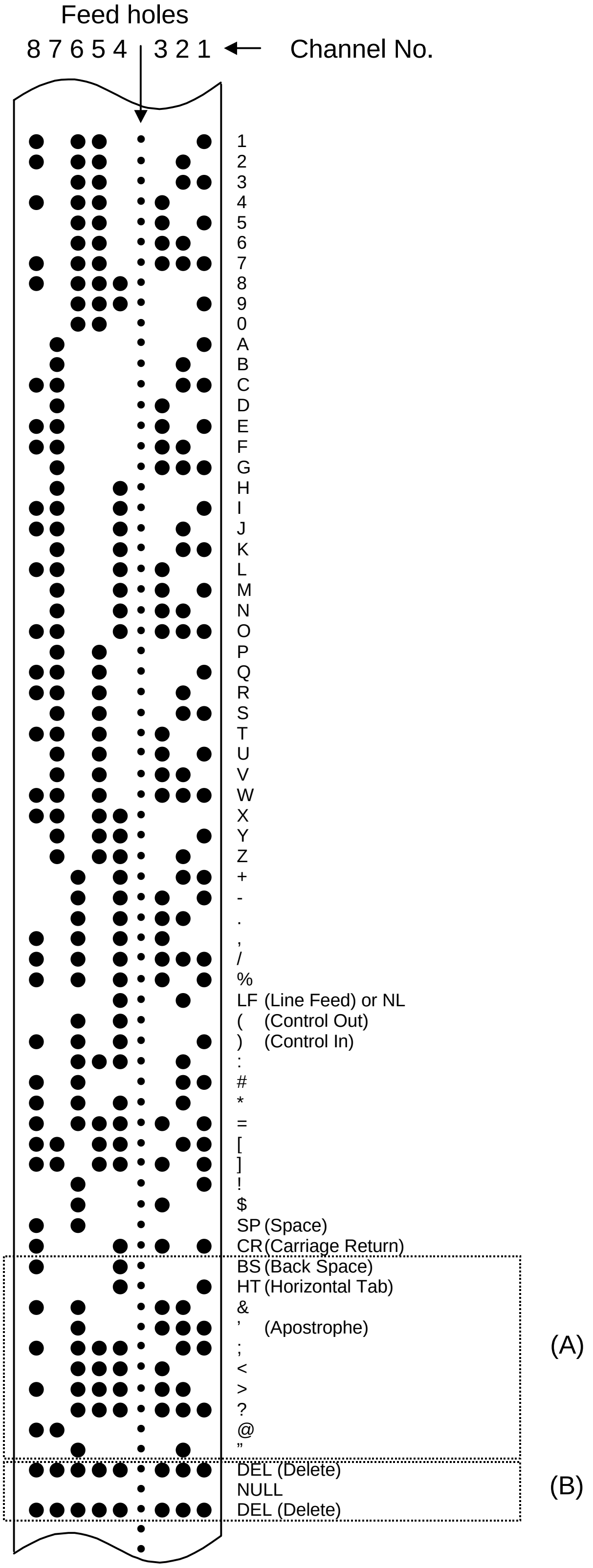
Generally, the End of Record code is punched at both ends of the tape. It has the following functions:
(a) Rewind stop when rewinding tape (with tape rewinder)
(b) Rewind start during tape search (with tape rewinder)
(c) Completion of loading during tape loading into memory

(5) Tape preparation for tape operation (with tape rewinder)



If a tape rewinder is not used, there is no need for the 2-meter dummy at both ends of the tape and for the head EOR (%) code.

ISO code (R-840)



Under the ISO code, LF or NL is EOB and % is EOR.

The (A) codes are stored on tape but an error results (except when they are used in the comment section) during operation.

The (B) codes are non-working codes and are always ignored. (Parity V check is not executed.)

Table of tape codes

3.2 Program formats

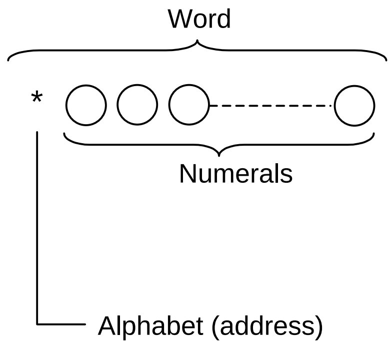
Function and purpose

The prescribed arrangement used when assigning control information to the controller is known as the program format, and the format used with this controller is called the "word address format".

Detailed description

(1) Word and address

A word is a collection of characters arranged in a specific sequence. This entity is used as the unit for processing data and for causing the machine to execute specific operations. Each word used for this controller consists of an alphabet letter and a number of several digits (sometimes with a "–" sign placed at the head of the number).



Word configuration

The alphabet letter at the head of the word is the address. It defines the meaning of the numerical information which follows it.
For details of the types of words and the number of significant digits of words used for this controller, refer to "Format details".

(2) Blocks

A block is a collection of words. It includes the information which is required for the machine to execute specific operations. One block unit constitutes a complete command. The end of each block is marked with an EOB (End of Block) code.

(3) Programs

A program is a collection of several blocks.

(Note 1) When there is no number following the alphabetic character in the actual program, the numeric value following the alphabetic character is handled as a 0.

(Example) G28XYZ; → G28X0Y0Z0;

Item			Metric command	Inch command
Program number			O8	
Sequence number			N5	
Preparatory function			G3/G21	
Movement axis	Input setting unit	0.001°, mm/ 0.0001 inch	X+53 Z+53 α +53	X+44 Z+44 α +44
	Input setting unit	0.0001°, mm/ 0.00001 inch	X+44 Z+44 α +44	X+35 Z+35 α +35
Additional axis	Input setting unit	0.001°, mm/ 0.0001 inch	I+53 K+53	I+44 K+44
	Input setting unit	0.0001°, mm/ 0.00001 inch	I+44 K+44	I+35 K+35
Dwell	Input setting unit	0.001°, mm/ 0.0001 inch	X+53 P53	X+53 P53
	Input setting unit	0.0001°, mm/ 0.00001 inch	X+53 P53	X+53 P53
Feed function	Input setting unit	0.001°, mm/ 0.0001 inch	F73 (Feed per min.) F34 (Feed per rotation)	F54 (Feed per min.) F26 (Feed per rotation)
	Input setting unit	0.0001°, mm/ 0.00001 inch	F64 (Feed per min.) F25 (Feed per rotation)	F45 (Feed per min.) F17 (Feed per rotation)
Fixed cycle	Input setting unit	0.001°, mm/ 0.0001 inch	R+53 Q53 P8 L4	R+44 Q44 P8 L4
	Input setting unit	0.0001°, mm/ 0.00001 inch	R+44 Q44 P8 L4	R+35 Q35 P8 L4
Tool offset			T1/T2	
Miscellaneous function			M8	
Spindle function			S6/S8	
Tool function			T8	
2nd miscellaneous function			A8/B8/C8	
Subprogram			P8H5L4	

(Note 1) α is A, B, C, or Y.

(Note 2) The No. of digits check for a word is carried out with the maximum number of digits of that address.

(Note 3) The basic format is the same for any of the numerals input from the memory, MDI or setting display unit.

(Note 4) Numerals can be used without the leading zeros.

(Note 5) The program number is commanded with single block. It's necessary to command the program number in the head block of each program.

(Note 6) The meanings of the details are as follows :

Example 1 : 08 :8-digit program number

Example 2 : G21 :Dimension G is 2 digits to the left of the decimal point, and 1 digit to the right.

Example 3 : X+53 :Dimension X uses + or - sign and represents 5 digits to the left of the decimal point and 3 digits to the right.

For example, the case for when the X axis is positioned (G00) to the 45.123 mm position in the absolute value (G90) mode is as follows:

```
G00 X45.123 ;
 |    |   |__3 digits below the decimal point
 |    |______5 digits above the decimal point, so it's +00045, but the leading zeros and the mark
 |           (+) have been omitted.
 |___________G0 is possible, too.
```

3.3 Program address check function

Function and purpose

The program can be checked in word units when operating machining programs.

Detailed description

(1) Address check

This function enables simple checking of program addresses in word units. If the alphabetic characters are continuous, the program error (P32) will occur. Availability of this function is selected by the parameter "#1227 aux11/bit4".
Note that an error will not occur for the following:

- Reserved words
- Comment statements

Example of program

(1) Example of program for address check

(Example 1) When there are no numbers following an alphabetic character.
G28 X ; → An error will occur. Change to "G28 X0;", etc.

(Example 2) When a character string is illegal.
TEST ; → An error will occur. Change to "(TEST);", etc.

3.4 Tape memory format

Function and purpose

(1) Storage tape and significant sections (ISO, EIA automatic judgment)

Both ISO and EIA tape codes can be stored in the memory in the same way as tape operation. After resetting, ISO/EIA is automatically judged by the EOB code at the head.
The interval to be stored in the memory is from the next character after the head EOB to the EOR code after resetting.
The significant codes listed in the "Table of tape code" in Section 3.1 "Tape codes", in the above significant section are actually stored into the memory. All other codes are ignored and are not stored.
The data between control out "(" and control in ")" are stored into the memory.

3.5 Optional block skip ; /

Function and purpose

This function selectively ignores specific blocks in a machining program which starts with the "/" (slash) code.

Detailed description

(1) Provided that the optional block skip switch is ON, blocks starting with the "/" code are ignored. They are executed if the switch is OFF.
Parity check is valid regardless of whether the optional block skip switch is ON or OFF.
When, for instance, all blocks are to be executed for one workpiece but specific block are not to be executed for another workpiece, the same command tape can be used to machine different parts by inserting the "/" code at the head of those specific blocks.

Precautions for using optional block skip

(1) Put the "/" code for optional block skip at the beginning of a block. If it is placed inside the block, it is assumed as a user macro, a division instruction.

```
(Example)   N20 G1 X25. /Z25. ; .......... NG (User macro, a division instruction;
                                               a program error results.)
            /N20 G1 X25. Z25. ; .......... OK
```

(2) Parity checks (H and V) are conducted regardless of the optional block skip switch position.

(3) The optional block skip is processed immediately before the pre-read buffer.
Consequently, it is not possible to skip up to the block which has been read into the pre-read buffer.

(4) This function is valid even during a sequence number search.

(5) All blocks with the "/" code are also input and output during tape storing and tape output, regardless of the position of the optional block skip switch.

3.6 Program/sequence/block numbers; O, N

Function and purpose

These numbers are used for monitoring the execution of the machining programs and for calling both machining programs and specific stages in machining programs.

(1) Program numbers are classified by workpiece correspondence or by subprogram units, and they are designated by the address "O" followed by a number with up to 8 digits.

(2) Sequence numbers are attached where appropriate to command blocks which configure machining programs, and they are designated by the address "N" followed by a number with up to 5 digits.

(3) Block numbers are automatically provided internally. They are preset to zero every time a program number or sequence number is read, and they are counted up one at a time unless program numbers or sequence numbers are commanded in blocks which are subsequently read.
Consequently, all the blocks of the machining programs given in the table below can be determined without further consideration by combinations of program numbers, sequence numbers and block numbers.

Machining program	Monitor display		
	Program No.	Sequence No.	Block No.
O12345678 (DEMO, PROG) ;	12345678	0	0
N100 G00 G90 X120. Z100. ;	12345678	100	0
G94 S1000 ;	12345678	100	1
N102 G71 P210 Q220 I0.2 K0.2 D0.5 F600 ;	12345678	102	0
N200 G94 S1200 F300 ;	12345678	200	0
N210 G01 X0 Z95. ;	12345678	210	0
G01 X20. ;	12345678	210	1
G03 X50. Z80. K–15. ;	12345678	210	2
G01 Z55. ;	12345678	210	3
G02 X80. Z40. I15. ;	12345678	210	4
G01 X100. ;	12345678	210	5
G01 Z30. ;	12345678	210	6
G02 Z10. K–15. ;	12345678	210	7
N220 G01 Z0 ;	12345678	220	0
N230 G00 X120. Z150. ;	12345678	230	0
N240 M02 ;	12345678	240	0
%	12345678	240	0

3.7 Parity H/V

Function and purpose

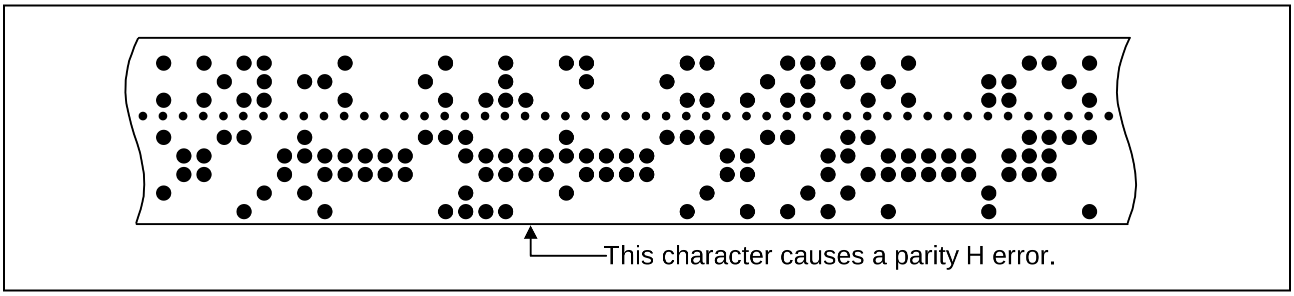
Parity check provides a mean of checking whether the tape has been correctly perforated or not. This involves checking for perforated code errors or, in other words, for perforation errors. There are two types of parity check: Parity H and Parity V.

(1) Parity H

Parity H checks the number of holes configuring a character and it is done during tape operation, tape input and sequence number search.
A parity H error is caused in the following cases.

(a) ISO code

When a code with an odd number of holes in a significant data section has been detected.
(Example 1) Parity H error example (For ISO codes)



When a parity H error occurs, the tape stops following the alarm code.

(2) Parity V

A parity V check is done during tape operation, tape input and sequence number search when the I/O PARA #9n15 (n is the unit No.1 to 5) parity V check function is set to "1". It is not done during memory operation.
A parity V error occurs in the following case: when the number of codes from the first significant code to the EOB (;) in the significant data section in the vertical direction of the tape is an odd number, that is, when the number of characters in one block is odd.
When a parity V error is detected, the tape stops at the code following the EOB (;).

(Note 1) Among the tape codes, there are codes which are counted as characters for parity and codes which are not counted as such. For details, refer to the "Table of tape code" in Section 3.1 "Tape codes".

(Note 2) Any space codes which may appear within the section from the initial EOB code to the address code or "/" code are counted for parity V check.

3.8 G code lists

Function and purpose

G codes include the two G code lists 2 and 3. One list is selected by setting in parameter "#1037 cmdtyp".

cmdtyp	G code list
3	List 2
4	List 3

G functions are explained using the G code list 3.

(Note 1) A program error (P34) will result if a G code that is not in the Table of G code lists is commanded.

(Note 2) An alarm will result if a G code without additional specifications is commanded.

Table of G code lists

G code list		Group	Function
2	3		
ΔG00	ΔG00	01	Positioning
ΔG01	ΔG01	01	Linear interpolation
G02	G02	01	Circular interpolation CW
G03	G03	01	Circular interpolation CCW
G04	G04	00	Dwell
G09	G09	00	Exact stop check
G10	G10	00	Program parameter input/Compensation input / Tool life management data registration
G11	G11	00	Program parameter input mode cancel / Tool life management data registration mode cancel
*G14	*G14	18	• Balance cut OFF
G15	G15	18	• Balance cut ON
ΔG17	ΔG17	02	Plane selection X-Y
ΔG18	ΔG18	02	Plane selection Z-X
ΔG19	ΔG19	02	Plane selection Y-Z
ΔG20	ΔG20	06	Inch command
ΔG21	ΔG21	06	Metric command
G22	G22	04	Barrier check ON
*G23	*G23	04	Barrier check OFF
G27	G27	00	Reference point return check
G28	G28	00	Reference point return
G29	G29	00	Return from reference point
G30	G30	00	2nd, 3rd and 4th reference point return
G30.1	G30.1	00	Tool change position return 1

G code list		Group	Function
2	3		
G30.2	G30.2	00	Tool change position return 2
G30.3	G30.3	00	Tool change position return 3
G30.4	G30.4	00	Tool change position return 4
G30.5	G30.5	00	Tool change position return 5
G31	G31	00	Skip function / Multi-step skip function 2
G31.1	G31.1	00	Multi-step skip function 1-1
G31.2	G31.2	00	Multi-step skip function 1-2
G31.3	G31.3	00	Multi-step skip function 1-3
G32	G33	01	Thread cutting
G34	G34	01	Variable lead thread cutting
G37	G37	00	Automatic tool length measurement
*G40	*G40	07	Tool nose R compensation cancel
G41	G41	07	Tool nose R compensation left
G42	G42	07	Tool nose R compensation right
G46	G46	07	Tool nose R compensation (direction automatically selected) ON
G43.1	G43.1	20	Selected spindle control mode (n: selected with parameter)
G44.1	G44.1	20	2nd spindle control mode
G50	G92	00	Coordinate system setting/Spindle clamp speed setting
G50.1	G50.1	19	G command mirror image cancel
G51.1	G51.1	19	G command mirror image ON
G52	G52	00	Local coordinate system setting
G53	G53	00	Machine coordinate system selection
*G54	*G54	12	Workpiece coordinate system selection 1
G55	G55	12	Workpiece coordinate system selection 2
G56	G56	12	Workpiece coordinate system selection 3
G57	G57	12	Workpiece coordinate system selection 4
G58	G58	12	Workpiece coordinate system selection 5
G59	G59	12	Workpiece coordinate system selection 6
G61	G61	13	Exact stop check mode
G62	G62	13	Automatic corner override
G63	G63	13	Tapping mode
*G64	*G64	13	Cutting mode

G code list		Group	Function
2	3		
G65	G65	00	User macro call
G66	G66	14	User macro modal call A
G66.1	G66.1	14	User macro modal call B
*G67	*G67	14	User macro modal call cancel
G68	G68	15	Double-turret mirror image ON
*G69	*G69	15	Double-turret mirror image OFF
G70	G70	09	Finish cycle
G71	G71	09	Longitudinal rough cutting cycle
G72	G72	09	Face rough cutting cycle
G73	G73	09	Formed material rough cutting cycle
G74	G74	09	Face cut-off cycle
G75	G75	09	Longitudinal cut-off cycle
G76	G76	09	Compound type thread cutting cycle
G76.1	G76.1	09	• 2-part system simultaneous thread cutting cycle (1)
G76.2	G76.2	09	• 2-part system simultaneous thread cutting cycle (2)
*G80	*G80	09	Hole drilling cycle cancel
G90	G77	09	Longitudinal cutting fixed cycle
G92	G78	09	Thread cutting fixed cycle
G94	G79	09	Face cutting fixed cycle
G79	G83.2	09	Deep hole drilling cycle 2
G83	G83	09	Deep hole drilling cycle1 (Z axis)
G84	G84	09	Tap cycle (Z axis)
G85	G85	09	Boring cycle (Z axis)
G87	G87	09	Deep hole drilling cycle 1 (X axis)
G88	G88	09	Tap cycle (X axis)
G89	G89	09	Boring cycle (X axis)
ΔG96	ΔG96	17	Constant surface speed control ON
ΔG97	ΔG97	17	Constant surface speed control OFF
ΔG98	ΔG94	05	Asynchronous feed (Feed per minute)
ΔG99	ΔG95	05	Synchronous feed (Feed per rotation)
–	ΔG90	03	Absolute value command
–	ΔG91	03	Incremental value command
–	*G98	10	Fixed cycle initial return
–	G99	10	Fixed cycle R point return
G113	G113	00	Spindle synchronous control OFF
G114.1	G114.1	00	Spindle synchronous control ON

G code list		Group	Function
2	3		
G115	G115	00	• Start point designation synchronizing Type 1
G116	G116	00	• Start point designation synchronizing Type 2
G117	G117	00	• Miscellaneous function output during axis movement

(Note 1) A (∗) symbol indicates the G code to be selected in each group when the power is turned ON or when a reset is executed to initialize the modal.

(Note 2) A (∆) symbol indicates the G code for which parameters selection is possible as an initialization status when the power is turned ON or when a reset is executed to initialize the modal. Note that inch/metric changeover can only be selected when the power is turned ON.

(Note 3) A (•) symbol indicates a function dedicated for multi-part system.

(Note 4) If two or more G codes from the same group are commanded, the last G code will be valid.

(Note 5) This G code list is a list of conventional G codes. Depending on the machine, movements that differ from the conventional G commands may be included when called by the G code macro. Refer to the Instruction Manual issued by the machine manufacturer.

(Note 6) Whether the modal is initialized differs for each reset input.

(1) "Reset 1"
The modal is initialized when the reset initialization parameter (#1151 rstinit) is ON.

(2) "Reset 2 "and "Reset and Rewind"
The modal is initialized when the signal is input.

(3) Reset at emergency stop release
Conforms to "Reset 1".

(4) When an automatic reset is carried out at the start of individual functions, such as reference point return.
Conforms to "Reset and Rewind".

⚠ CAUTION

⚠ The commands with "no value after G" will be handled as "G00".

3.9 Precautions before starting machining

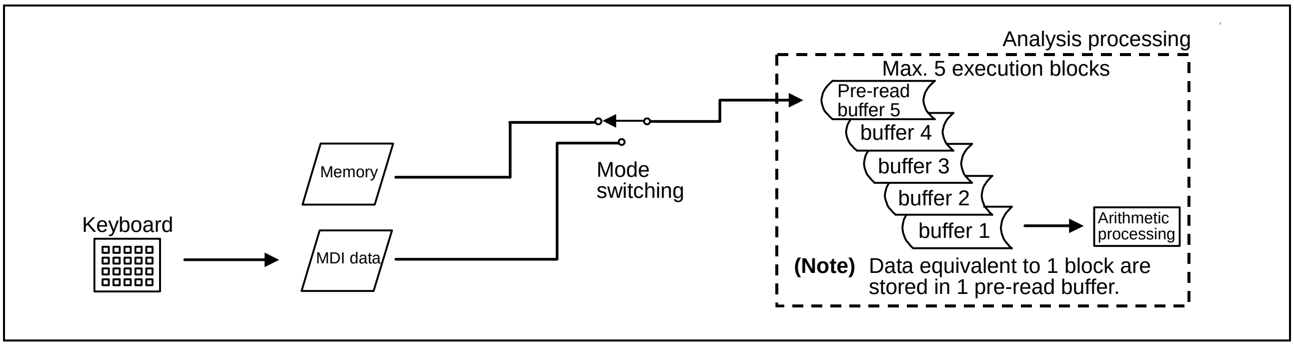
Precautions before machining

⚠ CAUTION

⚠ When creating the machining program, select the appropriate machining conditions, and make sure that the performance, capacity and limits of the machine and NC are not exceeded. The examples do not consider the machining conditions.

⚠ Before starting actual machining, always carry out dry run operation to confirm the machining program, tool offset amount and workpiece offset amount, etc.

4. Buffer Register



4.1 Pre-read buffers

Function and purpose

During automatic processing, the contents of 1 block are normally pre-read so that program analysis processing is conducted smoothly. However, during nose R compensation, a maximum of 5 blocks are pre-read for the intersection point calculation including interference check.
The specifications of the data in 1 block are as follows:

(1) The data of 1 block are stored in this buffer.

(2) Only the significant codes in the significant data section are read into the pre-read buffer.

(3) When codes are sandwiched in the control in and control out, and the optional block skip function is ON, the data extending from the "/" (slash) code up to the EOB code are not read into the pre-read buffer.

(4) The pre-read buffer contents are cleared with resetting.

(5) When the single block function is ON during continuous operation, the pre-read buffer stores the following block data and then stops operation.

Precautions

(1) Depending on whether the program is executed continuously or by single blocks, the timing of the valid/invalid for the external control signals for the optional block skip and others will differ.

(2) If the external control signal such as optional block skip is turned ON/OFF with the M command, the external control operation will not be effective on the program pre-read with the buffer register.

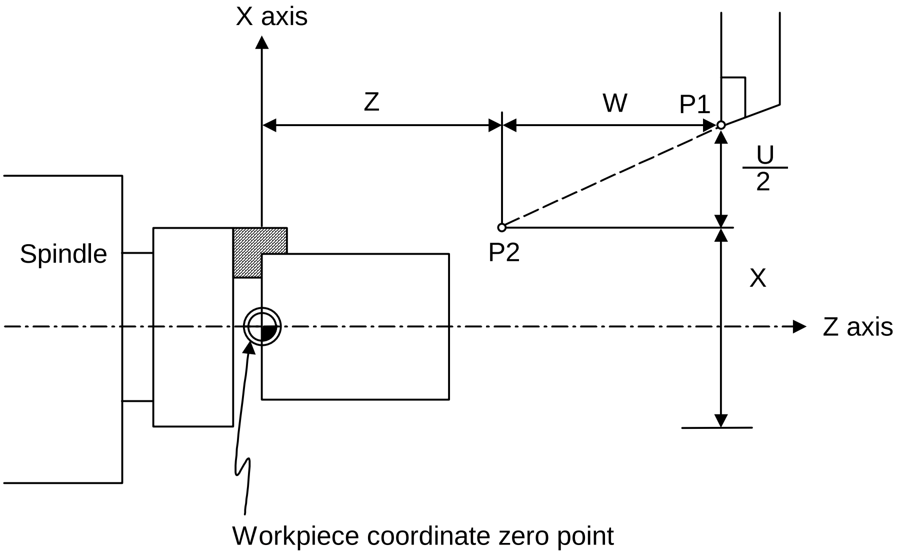
(3) According to the M command that operates the external controls, it prohibits pre-reading, and the recalculation is as follows:
The M command that commands the external controls is distinguished at the PLC, and the "recalculation request" for PLC → NC interface table is turned ON.
(When the "recalculation request" is ON, the program that has been pre-read is reprocessed.)

5. Position Commands

5.1 Incremental/absolute value commands

Function and purpose

There are 2 methods of issuing tool movement amount commands: the incremental value method and the absolute value method.
The incremental value method applies for coordinates of a point which is to be moved and it issues a command using the distance from the present point; on the other hand, the absolute value system issues a command using the distance from the coordinate zero point. The following figure shows what happens when the tool is moved from point P1 to point P2.



Incremental and absolute value commands

Incremental value commands and absolute value commands for the X axis and Z axis are identified by address when parameter "#1076 AbsInc" is set to 1, and identified by G code (G90/G91) when set to 0. Similarly, even with additional axes (C axis or Y axis), they are differentiated by addresses, or G code.

		Command system	Remarks
Absolute value	X axis	Address X	• Set the correspondence between addresses and axes into "#1013 axname" and "#1014 incax". • Absolute and incremental values can be used together in the same block.
	Z axis	Address Z	
	C/Y axis	Address C/Y	
Incremental value	X axis	Address U	
	Z axis	Address W	
	C/Y axis	Address H/V	

(Example)

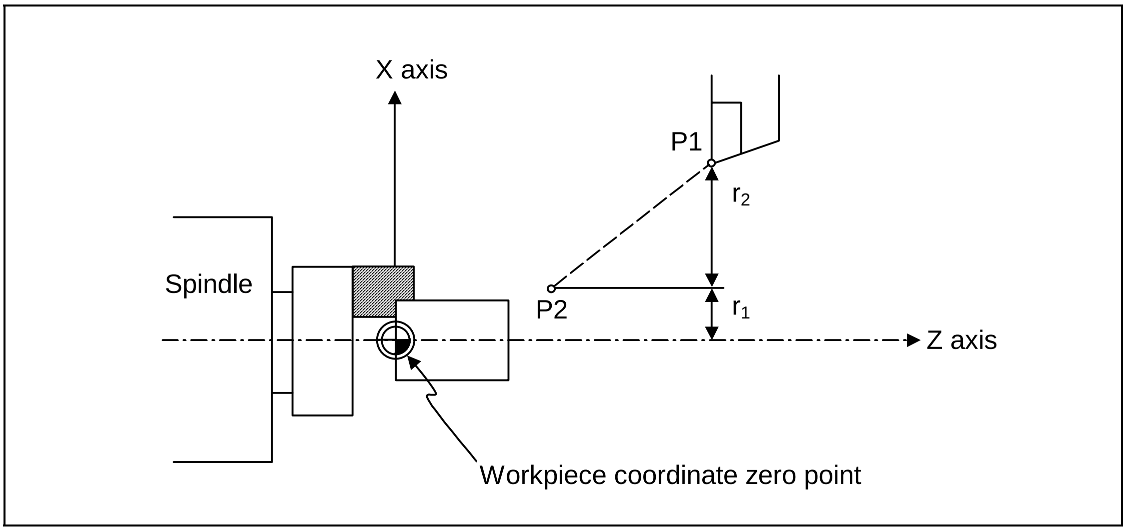
X_____ W _____ ;
Incremental value command for Z axis
Absolute value command for X axis

(Note 1) When parameter "#1076 AbsInc" is 1, and H is used for the incremental command address, address H of blocks in M98 and G10 L50 modal will be handled as the parameter of each command, and the axis will not be moved.

5.2 Radius/diameter commands

Function and purpose

The cross sections of workpieces machined on a lathe are circular, and the diameter or radius value of those circles can be used for movement commands in the X-axis direction. A radius command will move the tool by the commanded amount only, but a diameter command will move the tool both in the X-axis direction by an amount equivalent to one-half the commanded amount only and in the Z-axis direction by the commanded amount only.
This system permits radius or diameter commands to be issued, depending on the parameter (#1019 dia) setting. The figure below shows the command procedure when the tool is to be moved from point P1 to point P2.



X command		U command		Remarks
Radius	Diameter	Radius	Diameter	Even when a diameter command has been selected, only the U command can be made a radius command by parameter "#1077 radius".
X = r_1	X = $2r_1$	U = r_2	U = $2r_2$	

Radius and diameter commands

Precautions and Restrictions

(1) In the above example, the tool moves from P1 to P2 in the minus direction of the X axis and so when an incremental value is issued, the minus sign is given to the numerical value being commanded.

(2) In this manual, diameter commands are used in descriptions of both the X and U axes for the sake of convenience.

5.3 Inch/metric conversion; G20, G21

Function and purpose

The commands can be changed between inch and metric with the G20/G21 command.

Command format

G20/G21;
G20 Inch command
G21 Metric command

Detailed description

The G20 and G21 commands merely select the command units. They do not select the Input units. G20 and G21 selection is meaningful only for linear axes and it is meaningless for rotation axes.

(Example) Relationship between input command units and G20/G21 commands (with decimal point input type I)

Axis	Input command cunit	Command example	mm output (#1016 iout=0)		inch output (#1016 iout=1)	
			G21	G20	G21	G20
X	10	X100 ;	0.100mm	0.254mm	0.0039inch	0.0100inch
Z	10	Z100 ;	0.100mm	0.254mm	0.0039inch	0.0100inch
X	1	X100 ;	0.0100mm	0.0254mm	0.00039inch	0.00100inch
Z	1	Z100 ;	0.0100mm	0.0254mm	0.00039inch	0.00100inch

5.4 Decimal point input

Function and purpose

This function enables the decimal point to be input. It assigns the decimal point in millimeter or inch units for the machining program input information that defines the tool paths, distances and speeds.
A parameter "#1078 Decpt2" selects whether minimum input command unit (type I) or zero point (type II) is to apply for the least significant digit of data without a decimal point.

Command format

○○○○○.○○○	Metric system
○○○○.○○○○	Inch system

Detailed description

(1) The decimal point command is valid for the distances, angles, times and speeds in machining programs.

(2) Refer to the table rising the "Addresses used and valid/invalid decimal point commands" for details on the valid addresses for the decimal point commands.

(3) The number of significant digits in a decimal point command is shown below (for input command unit cunit=10).

	Movement command (linear)		**Movement command (rotation)**		**Feedrate**		**Dwell (X)**	
	Integer	**Decimal part**	**Integer**	**Decimal part**	**Integer**	**Decimal part**	**Integer**	**Decimal part**
MM (millimeter)	0 ~ 99999.	.000 ~ .999	0 ~ 99999.	.000 ~ .999	0 ~ 60000.	.000 ~ .999	0 ~ 99999.	.000 ~ .999
					0 ~ 999.	.0000 ~ .9999		
INCH (inch)	0 ~ 9999.	.0000 ~ .9999	99999. (359.)	.0 ~ .999	0 ~ 2362.	.0000 ~ .9999	0 ~ 99.	.000 ~ .999
					0 ~ 99.	.000000 ~ .999999		

(Note) The top row gives the feedrate as a per-minute rate and the bottom row as a per-rotation rate.

(4) The decimal point command is valid even for commands defining the variable data used in subprograms.

(5) As for the minimum unit when a value is commanded without a decimal point though the decimal point designation is valid, select the minimum input command unit determined by specifications (1μm, 10μm, etc.) or "mm".
Select which to use by setting the parameter "#1078 Decpt2".

(6) Decimal point commands for decimal point invalid addresses are processed as integer data only and everything below the decimal point is ignored. Addresses which are invalid for the decimal point are D, H, L, M, N, O, P, S and T.
All variable commands, however, are treated as data with decimal points.

Precautions

(1) If an arithmetic operator is inserted, the data will be handled as data with a decimal point.
(Example1) G00 X123+0 ;
This is the X axis command 123mm command. It will not be 123μm.

Example of program

(1) Example of program for decimal point valid address

Specification division / Program example	Decimal point command 1		Decimal point command 2 When 1 = 1mm
	When 1 = 1μm	When 1 = 10μm	
G0 X123.45 (decimal points are all mm points)	X123.450mm	X123.450mm	X123.450mm
G0 X12345	X12.345mm (last digit is 1μm unit)	X123.450mm	X12345.000mm
#111 = 123, #112 = 5.55 X#111 Z#112	X123.000mm, Z5.550mm	X123.000mm, Z5.550mm	X123.000mm, Z5.550mm
#113 = #111 + #112 (addition)	#113 = 128.550	#113 = 128.550	#113 = 128.550
#114 = #111 – #112 (subtraction)	#114 = 117.450	#114 = 117.450	#114 = 117.450
#115 = #111 ∗ #112 (multiplication)	#115 = 682.650	#115 = 682.650	#115 = 682.650
#116 = #111/#112 #117 = #112/#111 (division)	#116 = 22.162, #117 = 0.045	#116 = 22.162, #117 = 0.045	#116 = 22.162, #117 = 0.045

Decimal point input I, II and decimal point command validity

In the table on the next page, decimal point input I and II result in the following for commands in which a decimal point is not used in an address where a decimal point command is valid.
Both decimal point input I and II become the same for commands using a decimal point.

(1) Decimal point input I
The lowest order digit of command data matches the command unit.
(Example) When "X1" is commanded in 1μm system, the same result occurs as for an "X0.001" command.

(2) Decimal point input II
The lowest order digit of command data matches the command unit.
(Example) When "X1" is commanded in 1μm system, the same result occurs as for an "X1." command.

Addresses used and valid/invalid decimal point commands

Address	Decimal point command	Application	Remarks
A	Valid	Coordinate position data	
	Invalid	2nd miscellaneous function code	
	Valid	Angle data	
	Invalid	MRC program number	
	Invalid	Program parameter input, axis No.	
	Valid	Deep hole drilling cycle (2) Safety distance	
		Compound type thread cutting cycle Thread cutting start shift angle	
	Valid	Spindle synchronous acceleration/deceleration time constant	
B	Valid	Coordinate position data	
	Invalid	2nd miscellaneous function code	
C	Valid	Coordinate position data	
	Invalid	2nd miscellaneous function code	
	Valid	Corner chamfering amount	,C
	Valid	Program tool offset input Nose R compensation amount (incremental)	
	Valid	Chamfering width (slitting cycle)	
D	Valid	Automatic tool length measurement, deceleration range d	
	Invalid	Program parameter input, byte type data	
	Invalid	Synchronous spindle No. at spindle synchronization	
E	Valid	Inch threads Precision thread lead	
	Valid	Corner cutting feedrate	
F	Valid	Feedrate	
	Valid	Thread lead	
G	Valid	Preparatory function code	
H	Valid	Coordinate position data	
	Invalid	Sequence numbers in subprograms	
	Invalid	Subprogram return destination program No.	
	Invalid	Program parameter input, bit type data	
	Invalid	Selection of linear - arc intersection (geometric)	
	Invalid	Basic spindle No. at spindle synchronization	
I	Valid	Circular center coordinates	
	Valid	Nose R compensation/ tool radius compensation vector components	
	Valid	Deep hole drilling (2) First cut amount	
	Valid	G0/G1 in-position width Hole drilling cycle G0 in-position width	,I
J	Valid	Circular center coordinates	
	Valid	Nose R compensation/ tool radius compensation vector components	
	Invalid	Deep hole drilling (2) Dwell time at return point	
	Invalid	Hole drilling cycle G1 in-position width	,J
K	Valid	Circular center coordinates	
	Valid	Nose R compensation/tool radius compensation vector components	
	Invalid	Hole machining cycle Number of repetitions	
	Valid	Deep hole drilling cycle (2) Second and subsequent cut amounts	
	Valid	Thread lead increase/ decrease amount (variable lead thread cutting)	
L	Invalid	Subprogram Number of repetitions	
	Invalid	Program tool compensation input type selection	L2 L10 L11
	Invalid	Program parameter input, selection	L50
	Invalid	Program parameter input, two-word type data	4 bytes
	Invalid	Part system No. to wait in sunchronization	
M	Invalid	Miscellaneous function codes	
N	Invalid	Sequence numbers	
	Invalid	Program parameter input, data No.	
O	Invalid	Program numbers	
P	Valid	Dwell time	
	Invalid	Subprogram call program numbers	
	Invalid	2nd, 3rd and 4th reference point number	
	Invalid	Constant surface speed control, axis number	
	Invalid	MRC finishing shape start sequence number	
	Valid	Cut-off cycle shift amount/cut amount	
	Invalid	Compound type thread cutting cycle Number of cutting passes, chamfering, tool nose angle	

(Note 1) Decimal points are all valid in user macro arguments.

Address	Decimal point command	Application	Remarks
P	Valid	Compound type thread cutting cycle Thread height	
	Invalid	Program tool compensation input compensation No.	
	Invalid	Program parameter input, section No.	
	Valid	Coordinate position data	
	Invalid	Skip signal command for multi-step skip function 2	
	Valid	Arc center coordinates (absolute value) (geometric)	
	Invalid	Subprogram return destination sequence No.	
Q	Invalid	Minimum spindle clamp rotation speed	
	Invalid	MRC finishing shape end sequence number	
	Valid	Cut-off cycle Cut amount/shift amount	
	Valid	Compound type thread cutting cycle Minimum cut amount	
	Valid	Compound type thread cutting cycle First cut amount	
	Valid	Deep hole drilling cycle 1 Cut amount of each pass	
	Invalid	Program tool compensation input Hypothetical tool nose point number	
	Invalid	Deep hole drilling cycle (2) Dwell time at cut point	
	Valid	Arc center coordinates (absolute value) (geometric)	
	Valid	Thread cutting start shift angle	
R	Valid	R-designated arc radius	
	Valid	Corner rounding circular radius	,R
	Valid	Automatic tool length measurement, deceleration range r	
	Valid	MRC longitudinal/face escape amount	
	Invalid	MRC shaping division number	
	Valid	Cut-off cycle, return amount	
	Valid	Cut-off cycle, escape amount	
	Valid	Compound type thread cutting cycle, finishing allowance	
	Valid	Compound type thread cutting cycle/turning cycle, taper difference	
	Valid	Hole drilling cycle/deep hole drilling cycle (2), distance to reference point	
R	Valid	Program tool compensation input/nose R compensation amount	
	Valid	Coordinate position data	
	Valid	Rough cutting cycle (longitudinal) (face) pull amount	
	Valid	Synchronous tap/ asynchronous tap changeover	,R
	Valid	Synchronous spindle phase shift amount	
S	Invalid	Spindle function codes	
	Invalid	Maximum spindle clamp rotation speed	
	Invalid	Constant surface speed control, surface speed	
	Invalid	Program parameter input, word type data	2 bytes
T	Invalid	Tool function codes	
U	Valid	Coordinate position data	
	Valid	Program tool compensation input	
	Valid	Rough cutting cycle (longitudinal) cutting amount	
	Valid	Dwell time	
V	Valid	Coordinate position data	
	Valid	Program tool compensation input	
W	Valid	Coordinate position data	
	Valid	Program tool compensation input	
	Valid	Rough cutting cycle (face) cutting amount	
X	Valid	Coordinate position data	
	Valid	Dwell	
	Valid	Program tool compensation input	
Y	Valid	Coordinate position data	
	Valid	Program tool compensation input	
Z	Valid	Coordinate position data	
	Valid	Program tool compensation input	

6. Interpolation Functions

6.1 Positioning (Rapid Traverse); G00

Function and purpose

This command is accompanied by coordinate words. It positions the tool along a linear or non-linear path from the present point as the start point to the end point which is specified by the coordinate words.

Command format

G00 Xx/Uu Zz/Ww ,Ii ;	
x, u, z, w	Coordinate values
i	In-position width. A decimal point command will result in a program error. This is valid only in the commanded block. A block that does not contain this address will follow the parameter "#1193 inpos" settings. The range is 1 to 999999 (μm).

The command addresses are valid for all additional axes.

Detailed description

(1) Once this command has been issued, the G00 mode is retained until it is changed by another G function or until the G01, G02, G03, G33 or G34 command in the 01 group is issued. If the next command is G00, all that is required is simply that the coordinate words be specified.

(2) In the G00 mode, the tool is always accelerated at the start point of the block and decelerated at the end point. Refer to (Note4) of "Example of program".

(3) If multiple axes are controlled, the next block will be executed after confirming that the position error amounts of all the moving axes become within the specified in-position width for each part system.

(4) Any G command (G83 ~ G89) in the 09 group is cancelled (G80) by the G00 command.

(5) Whether the tool moves along a linear or non-linear path is determined by parameter, but the positioning time does not change.

  (a) Linear path................. This is the same as linear interpolation (G01), and the speed is limited by the rapid traverse rate of each axis.

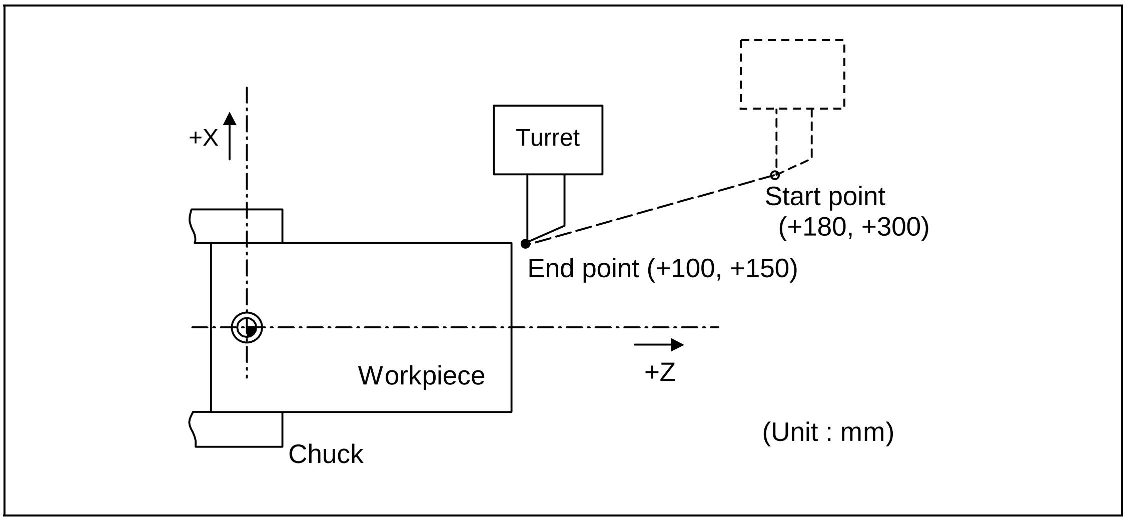
  (b) Non-linear path.......... The tool is positioned at the rapid traverse rate independently for each axis.

(6) Refer to "Operation during in-position check" for the programmable in-position check positioning command.

⚠ **CAUTION**

⚠ The commands with "no value after G" will be handled as "G00".

Example of program

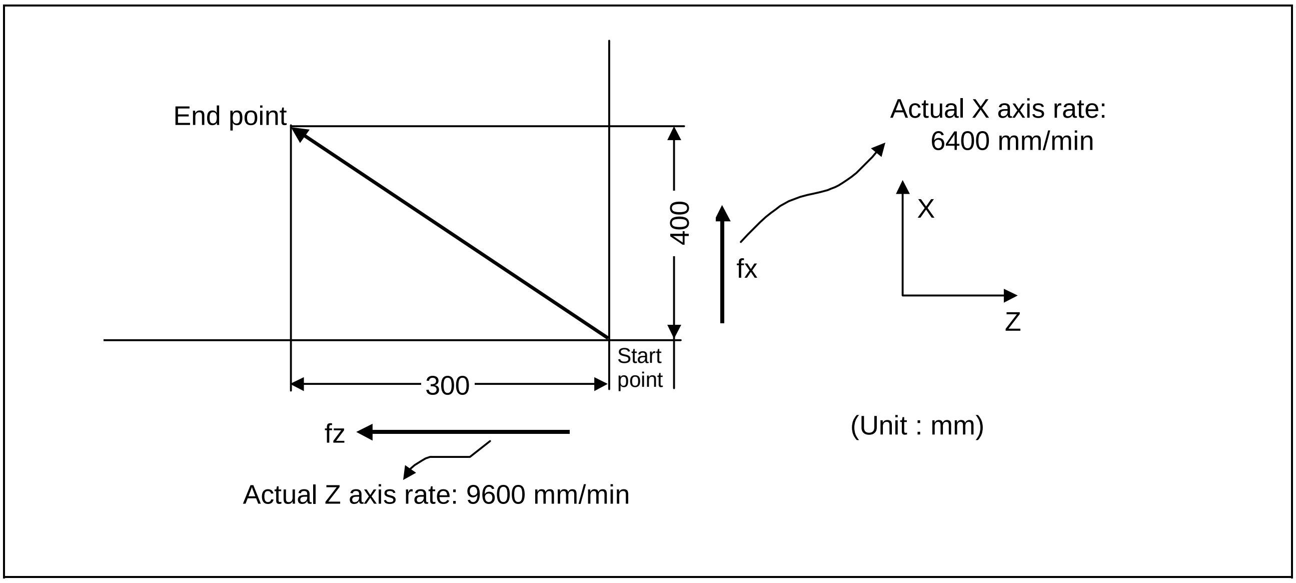


G00 X100000 Z150000 ;	Absolute value command
G00 U-80000 W-150000 ;	Incremental value command (With an input setting unit of 0.001mm)

Precautions

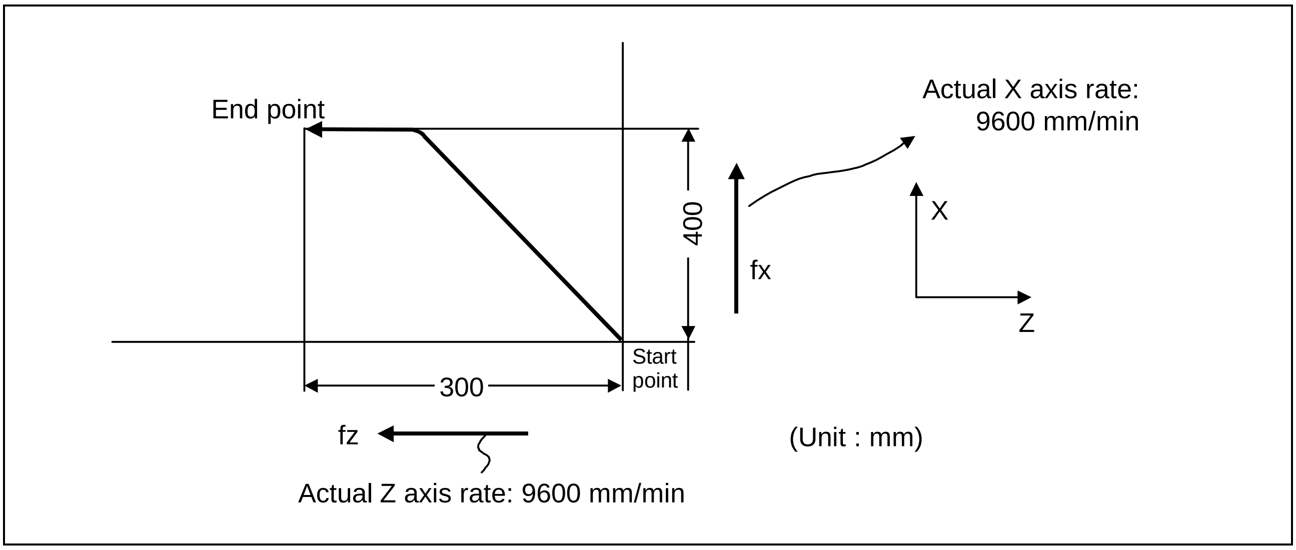
(1) When the parameter "#1086 G0Intp" is 0, the path along which the tool is positioned is the shortest path connecting the start and end points. The positioning speed is automatically calculated so that the shortest distribution time is obtained in order that the commanded speeds for each axis do not exceed the rapid traverse rate.
When, for instance, the X-axis and Z-axis rapid traverse rates are both 9600mm/min, the tool will follow the path in the figure below if the following is programmed:

G00 Z–300000 X400000 ; (With an input setting unit of 0.001mm)



(2) When parameter "#1086 G0Intp" is 1, the tool will move along the path from the start point to the end point at the rapid traverse rate of each axis.
When, for instance, the X-axis and Z-axis rapid traverse rates are both 9600 mm/min, the tool will follow the path in the figure below if the following is programmed:

G00 Z – 300000 X400000 ; (With an input setting unit of 0.001mm)


End point
Actual X axis rate: 9600 mm/min
400
X
fx
Z
Start point
300
fz
(Unit : mm)
Actual Z axis rate: 9600 mm/min

(3) The rapid traverse rate for each axis with the G00 command differs according to the individual machine and so reference should be made to the machine specifications manual.

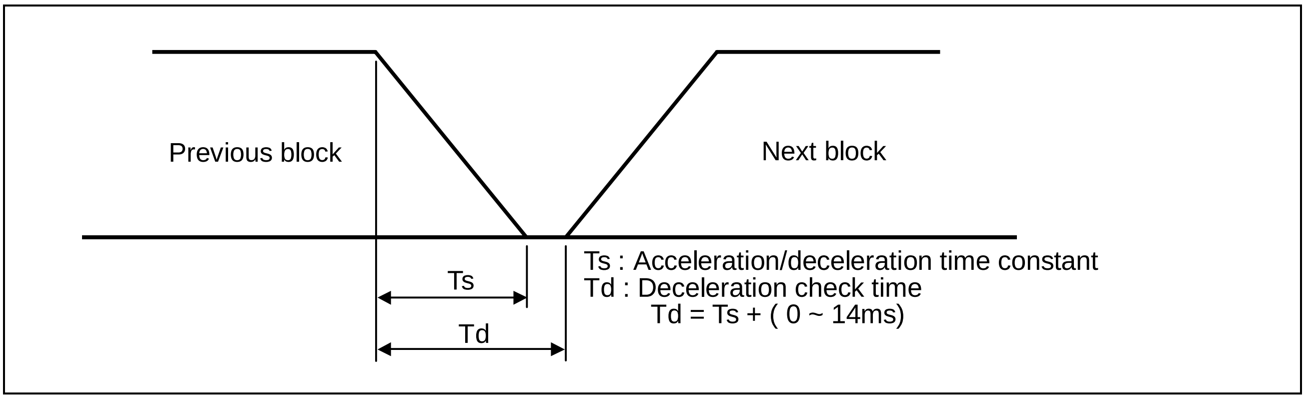
(4) Rapid traverse (G00) deceleration check
There are two methods for the deceleration check at rapid traverse; commanded deceleration method and in-position check method. Select a method with the parameter "#1193 inpos".

■ When "inpos" = "1"
Upon completion of the rapid traverse (G00), the next block will be executed after confirming that the remaining distances for each axis are below the fixed amounts. (Refer to the following drawing.)
The confirmation of the remaining distance should be done with the imposition width, L_R. L_R is the setting value for the servo parameter "#2224 SV024".

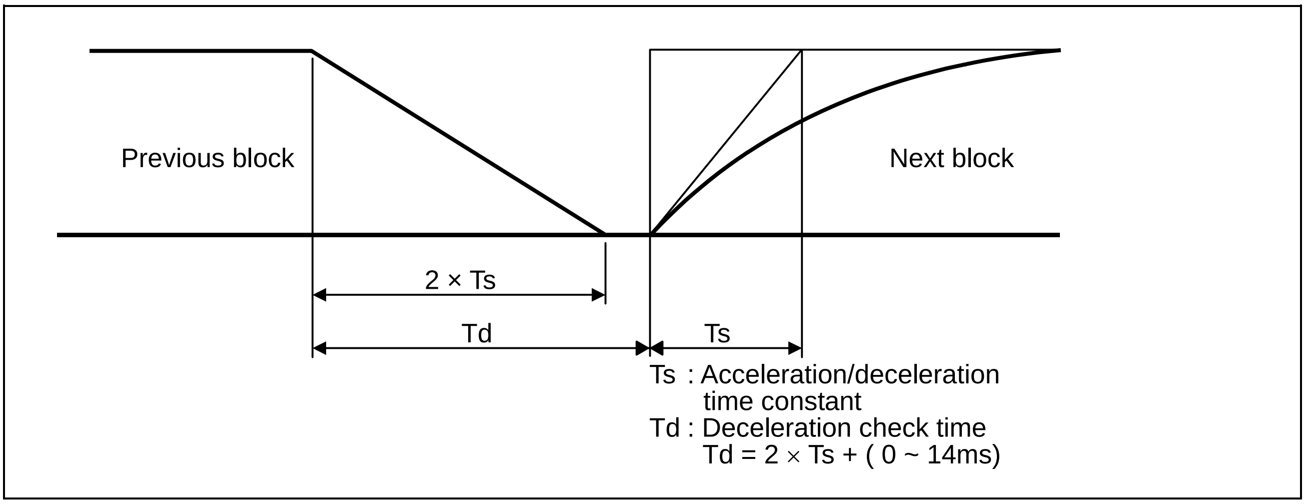
The purpose of checking the rapid traverse deceleration is to minimize the time it takes for positioning. The bigger the setting value for the servo parameter "#2224 SV024", the longer the reduced time is, but the remaining distance of the previous block at the starting time of the next block also becomes larger, and this could become an obstacle in the actual processing work. The check for the remaining distance is done at set intervals. Accordingly, it may not be possible to get the actual amount of time reduction for positioning with the setting value SV024.

- When "inpos" = "0"
  Upon completion of the rapid traverse (G00), the next block will be executed after the deceleration check time (Td) has elapsed. The deceleration check time (Td) is as follows, depending on the acceleration/deceleration type.

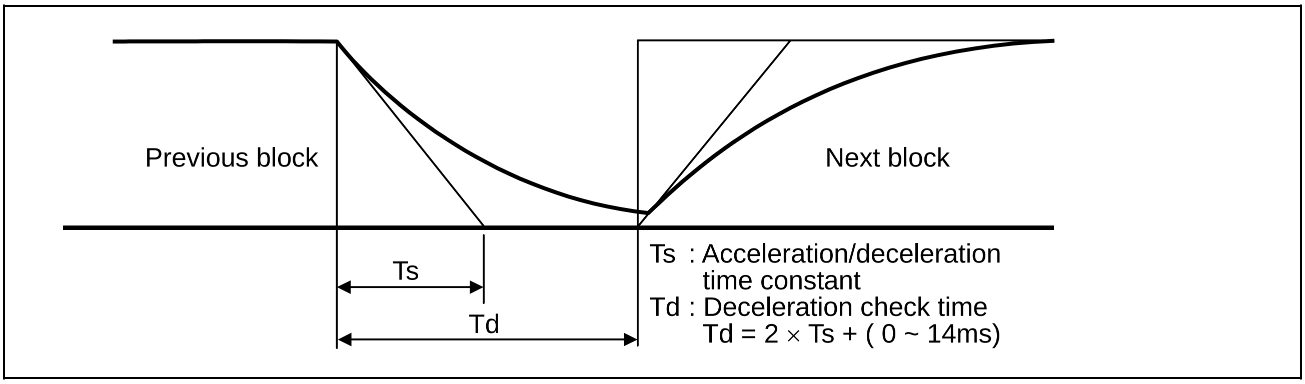
(a) Linear acceleration/linear deceleration Td = Ts + α


Previous block
Next block
Ts
Td
Ts : Acceleration/deceleration time constant
Td : Deceleration check time
Td = Ts + (0 ~ 14ms)

(b) Exponential acceleration/linear deceleration Td = 2 × Ts + α


Previous block
Next block
2 × Ts
Td
Ts
Ts : Acceleration/deceleration time constant
Td : Deceleration check time
Td = 2 × Ts + (0 ~ 14ms)

(c) Exponential acceleration/exponential deceleration Td = 2 × Ts + α

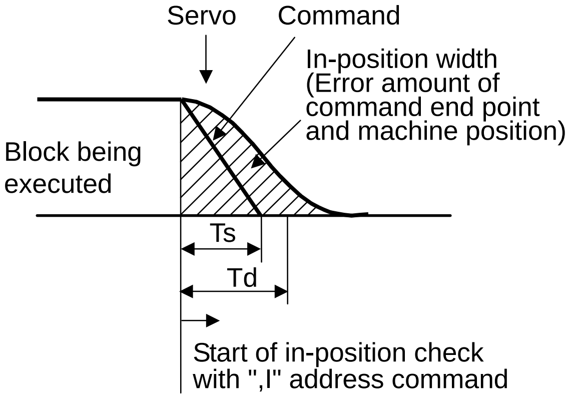
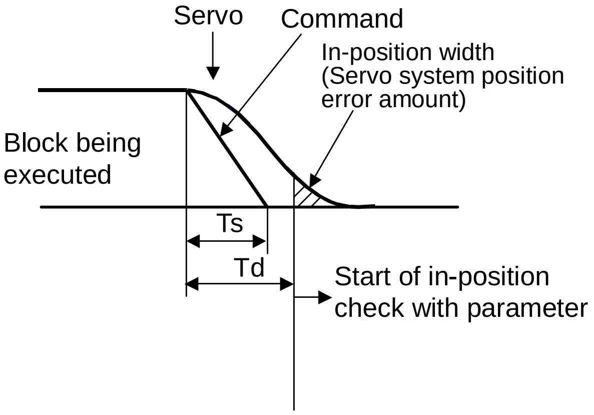

Previous block
Next block
Ts
Td
Ts : Acceleration/deceleration time constant
Td : Deceleration check time
Td = 2 × Ts + (0 ~ 14ms)

Where Ts is the acceleration time constant, α = 0 to 14ms
The time required for the deceleration check during rapid traverse is the longest among the rapid traverse deceleration check times of each axis determined by the rapid traverse acceleration/deceleration time constants and by the rapid traverse acceleration/deceleration mode of the axes commanded simultaneously.

Operation during in-position check

Execution of the next block starts after confirming that the position error amount of the positioning (rapid traverse: G00) command block and the block that carries out deceleration check with the linear interpolation (G01) command is less than the in-position width issued in this command.
The in-position width in this command is valid only in the command block, so the deceleration check method set in base specification parameter "#1193 inpos" is used for blocks that do not have the in-position width command.
When there are several movement axes, the system confirms that the position error amount of each movement axis in each system is less than the in-position width issued in this command before executing the next block.
The differences of when the in-position check is validated with the parameter (base specification parameter "#1193 inpos" set to 1; refer to next page for in-position width) and when validated with this command are shown in the following drawing.

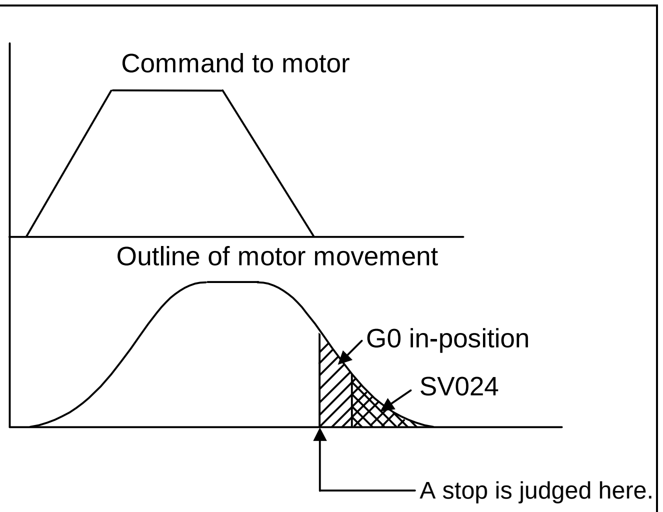
The differences of In-position check with parameter

In-position check with ",I" address command	In-position check with parameter
After starting deceleration of the command system, the position error amount and commanded in-position width are compared.	After starting deceleration of the command system, the servo system's position error amount and the parameter setting value (in-position width) are compared.
 Servo Command In-position width (Error amount of command end point and machine position) Block being executed Ts Td Start of in-position check with ",I" address command	 Servo Command In-position width (Servo system position error amount) Block being executed Ts Td Start of in-position check with parameter
Ts : Acceleration/deceleration time constant Td : Deceleration check time Td = Ts + (0 to 14ms)	

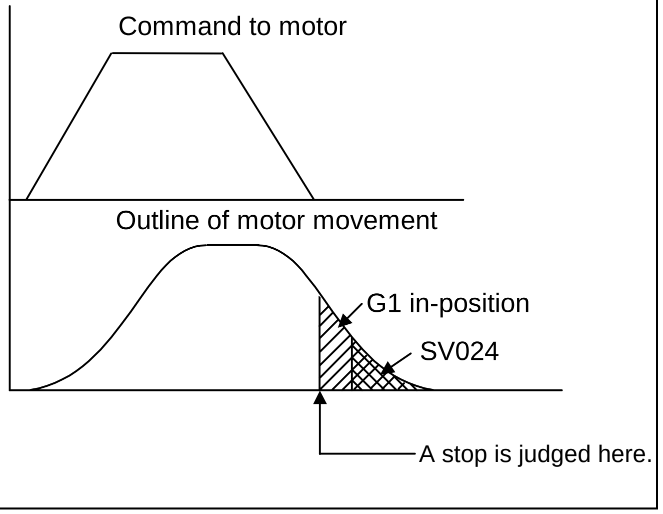
G0/G1 in-position width setting

When the setting value of the servo parameter "#2224 SV024" is smaller than the setting value of the G0 in-position width "#2077 G0inps" and the G1 in-position width "#2078 G1inps", the in-position check is carried out with the G0 in-position width and the G1 in-position width.

In-position check using the "G0inps" value



In-position check using the "G1inps" value



When the SV024 value is larger, the in-position check is completed when the motor position becomes within the specified with SV024.
The in-position check method depends on the method set in the deceleration check parameter.

(Note 1) When the in-position width check is carried out, the in-position width command in the program takes place the in-position width set with the parameters such as SV024, G0inps, or G1inps.

(Note 2) When the SV024 setting value is larger than the G0 in-position width/G1 in-position width, the in-position check is carried out with the SV024 value.

6.2 Linear interpolation; G01

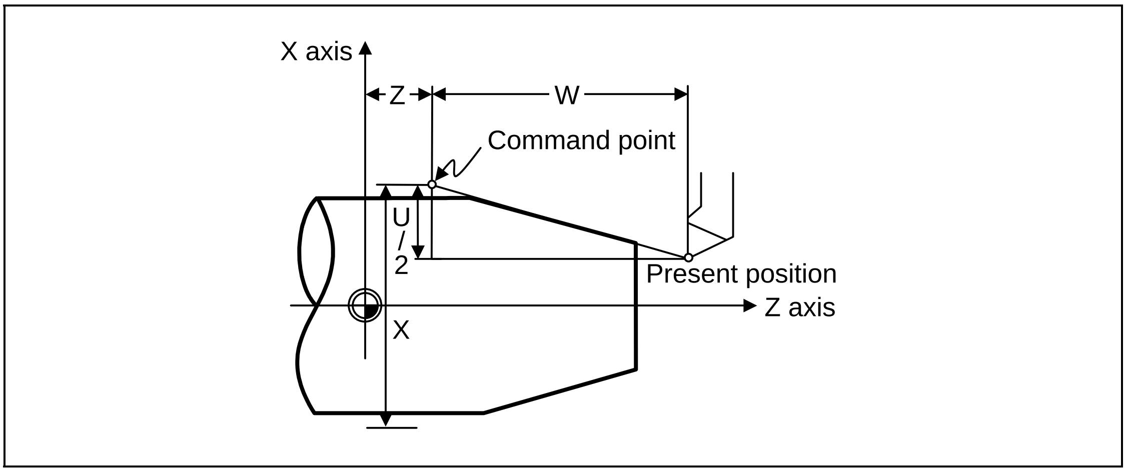
Function and purpose

This command is accompanied by coordinate words and a feedrate command. It makes the tool move (interpolate) linearly from its present position to the end point specified by the coordinate words at the speed specified by address F. In this case, the feedrate specified by address F always acts as a linear speed in the tool nose center advance direction.

Command format

G01 Xx/Uu Zz/Ww αα Ff ,Ii ; ("α" is an additional axis)

x, u, z, w, α	Coordinate values
f	Feedrate (mm/min or °/min)
i	In-position width. A decimal point command will result in a program error. This is valid only in the commanded block. A block that does not contain this address will follow the parameter "#1193 inpos" settings. The range is 1 to 999999 (μm).



Detailed description

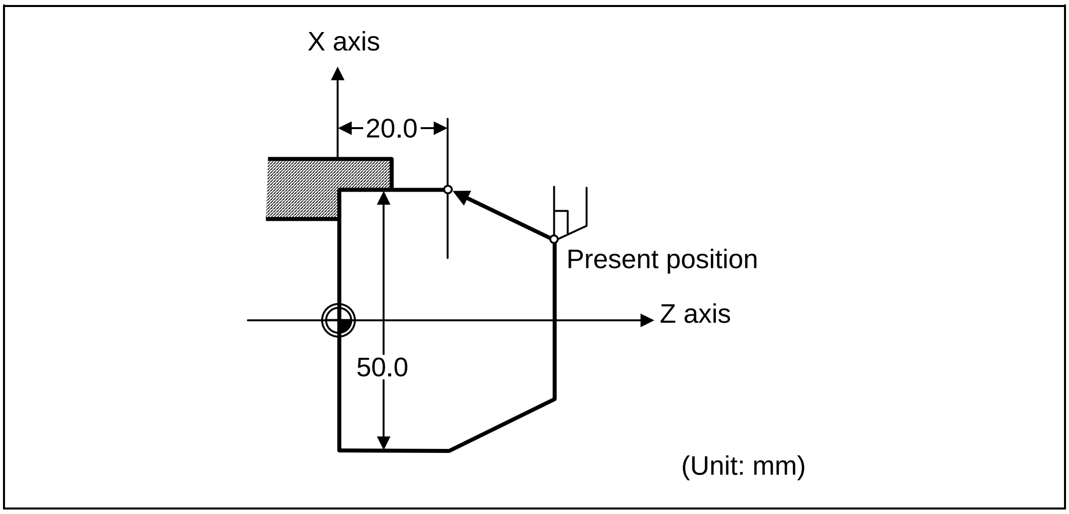
(1) Once this command is issued, the mode is maintained until another G function (G00, G02, G03, G33, G34) in the 01 group which changes the G01 mode is issued. Therefore, if the next command is also G01 and if the feedrate is the same all that is required to be done is to specify the coordinate words. If no F command is given in the first G01 command block, program error (P62) results.

(2) The feedrate for a rotation axis is commanded by °/min (decimal point position unit). (F300 = 300°/min)

(3) The G functions (G70 ~ G89) in the 09 group are cancelled (G80) by the G01 command.

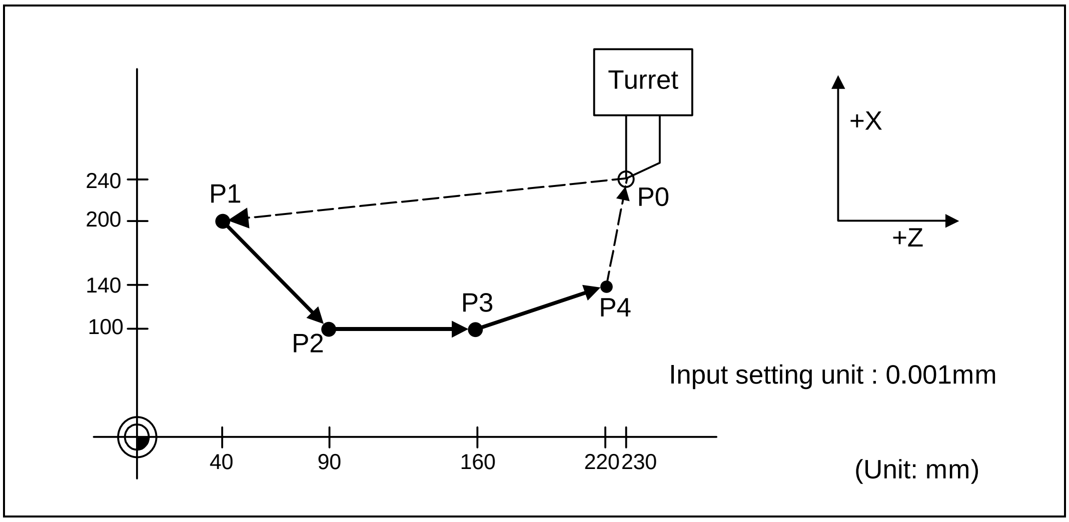
Example of program

(Example 1)



G01 X50.0 Z20.0 F300 ;	

(Example 2) Cutting in the sequence of P1 → P2 → P3 → P4 at 300mm/min feedrate. P0 → P1 , P4 → P0 is for tool positioning.



G00	X200000 Z40000 ;	P0 → P1
G01	X100000 Z90000 F300 ;	P1 → P2
	Z160000 ;	P2 → P3
	X140000 Z220000 ;	P3 → P4
G00	X240000 Z230000 ;	P4 → P0

Programmable in-position width command for linear interpolation

This command commands the in-position width for the linear interpolation command from the machining program.
The commanded in-position width is valid in the linear interpolation command only when carrying out deceleration check.

- When the error detect switch is ON.
- When G09 (exact stop check) is commanded in the same block.
- When G61 (exact stop check mode) is selected.

```
G01  X__   Z__   F__     ,I__ ;
```

In-position width
Feedrate
Linear interpolation coordinate value of each axis

(Note 1) Refer to the section "6.1 Positioning (Rapid Traverse); G00" for details on the in-position check operation.

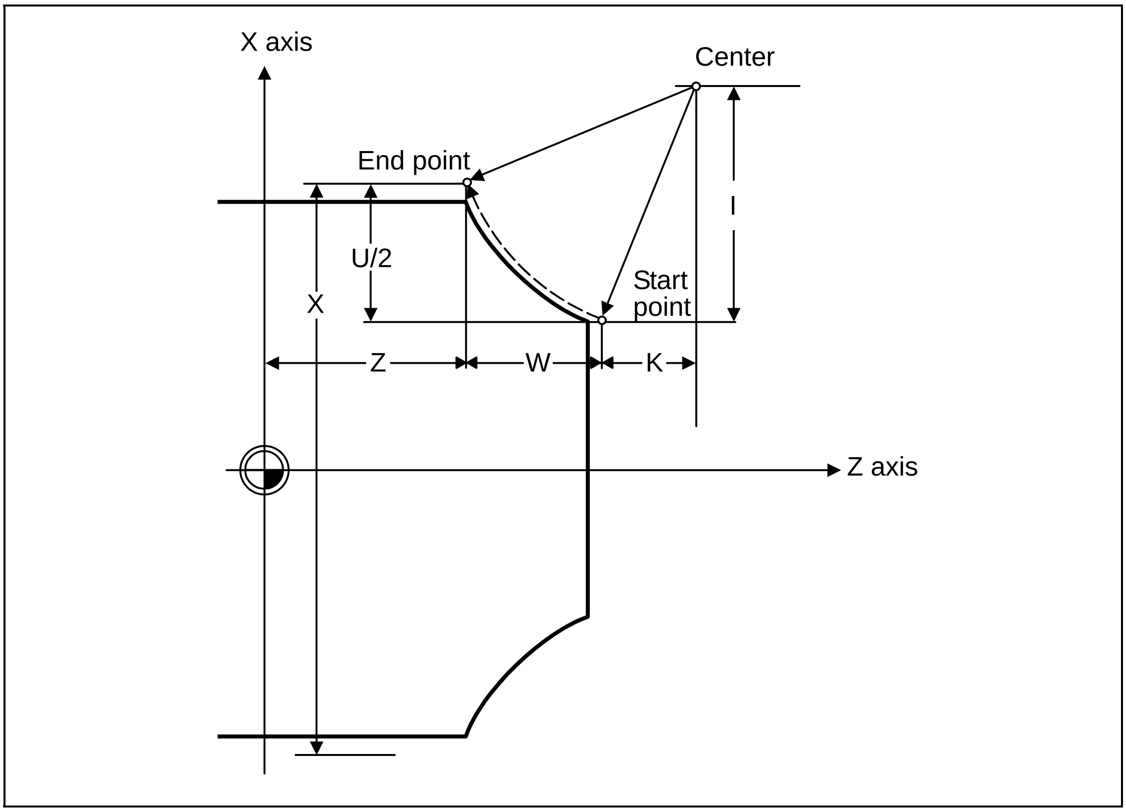
6.3 Circular Interpolation; G02, G03

Function and purpose

These commands serve to move the tool along a circular.

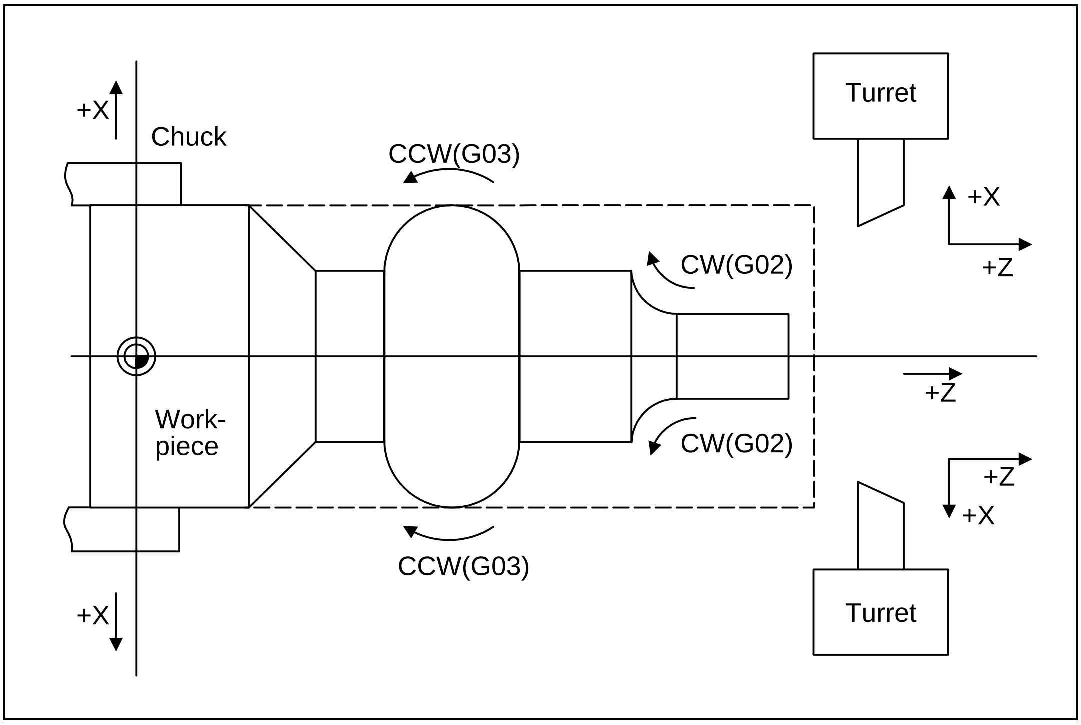
Command format

G02 (G03) Xx/Uu Zz/Ww Ii Kk Ff ;	
G02	Clockwise (CW)
(G03)	Counterclockwise (CCW)
Xx/Uu	Circular end point coordinates, X axis (absolute value of workpiece coordinate system for X, incremental value from present position for U)
Zz/Ww	Circular end point coordinates, Z axis (absolute value of workpiece coordinate system for Z, incremental value from present position for W)
Ii	Circular center, X axis (for I, incremental value of X coordinate at center as seen from start point. Command as "radius command".)
Kk	Circular center, Z axis (for K, incremental value of Z coordinate at center as seen from start point)
Ff	Feedrate



Detailed description

(1) G02 (or G03) is retained until another G command (G00, G01, G33, or G34) in the 01 group that changes its mode is issued.
The direction of the circular rotation is differentiated by G02 and G03:
G02 : Clockwise (CW)
G03 : Counterclockwise (CCW)



(2) An arc which extends for more than one quadrant can be executed with a single block command.

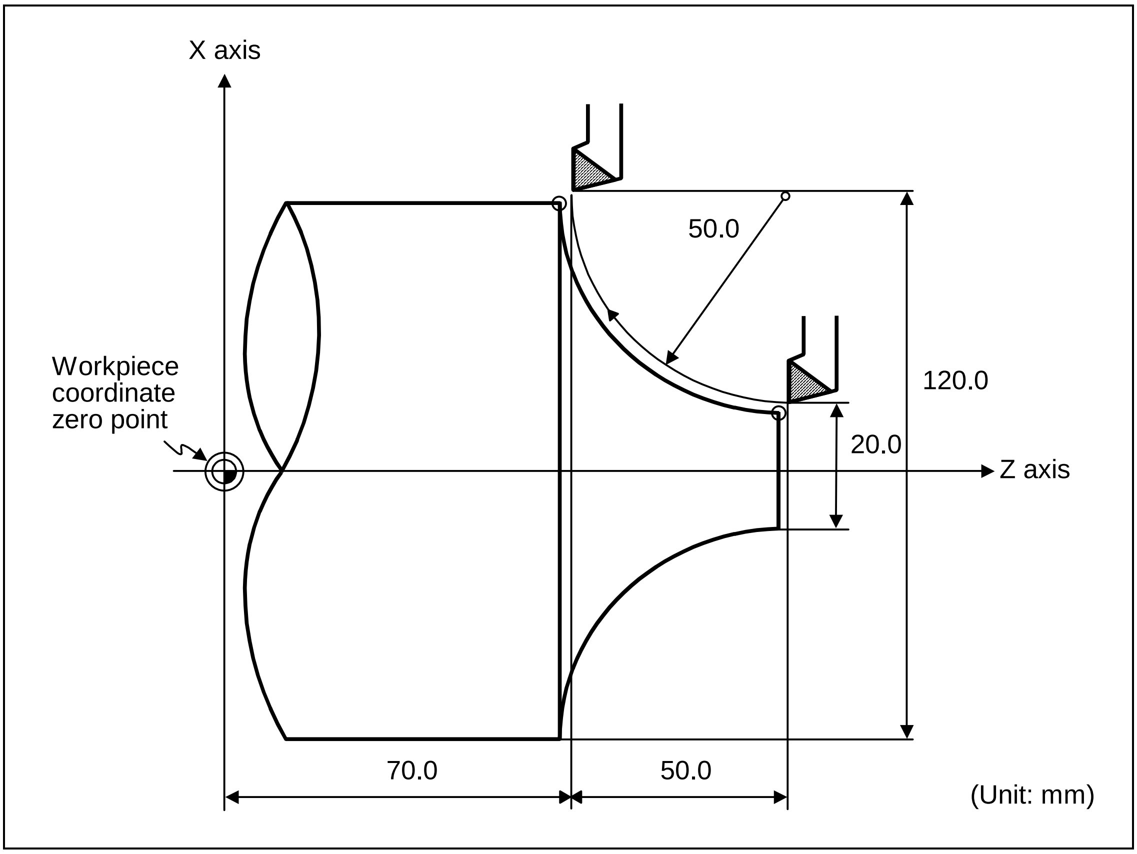
(3) The following information is needed for circular interpolation.

(a) Rotation direction	:Clockwise (G02) or counterclockwise (G03)
(b) Circular end point coordinates	:Given by addresses X, Z, U, W
(c) Circular center coordinates	:Given by addresses I, K (incremental value commands)
(d) Feedrate	:Given by address F

(4) A program error results when I, K or R is not commanded.
Consideration must be given to the sign for I and K since I is the distance in the X-axis direction to the arc center as seen from the start point and K is the distance in the Z-axis direction.

(5) No T commands can be issued in the G2/G3 modal status.
A program error (P151) results if a T command is issued in the G2/G3 modal status.

Example of program



G02 X120.0 Z70.0 I50.0 F200 ;	Absolute value command
G02 U100.0 W-50.0 I50.0 F200 ;	Incremental value command

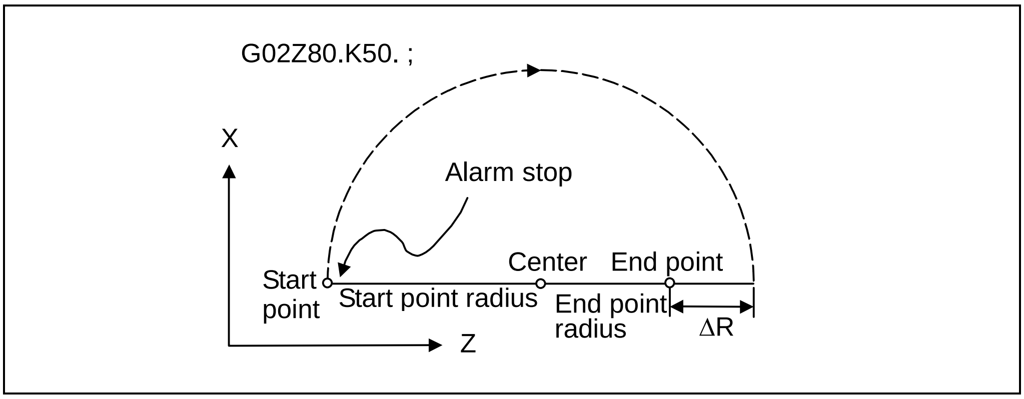
Cautions for circular interpolation

(1) The terms "clockwise" (G02) and "counterclockwise" (G03) used for circular operations are defined as a case where in a right-hand coordinate system, the negative direction is viewed from the positive direction of the coordinate axis which is at right angles to the plane in question.

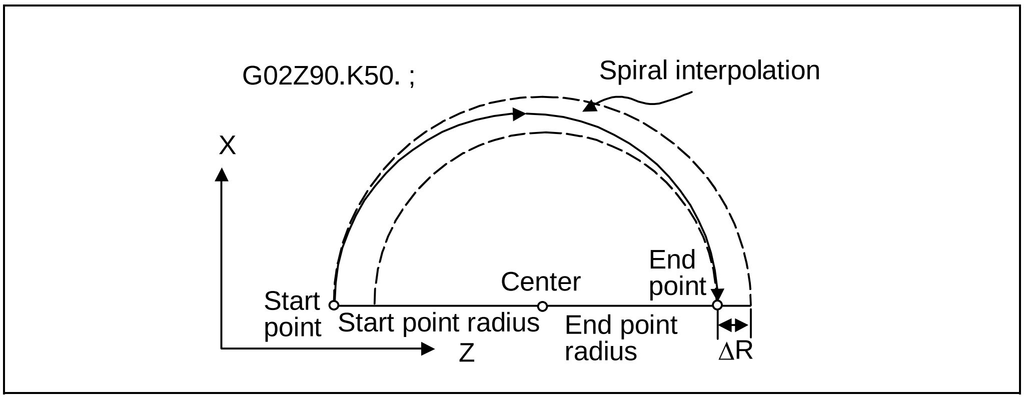
(2) If all the end point coordinates are omitted or the end point is at the same position as the start point, commanding the center using I and K is the same as commanding a 360° arc (perfect circle).

(3) The following occurs when the start and end point radii do not match in a circular command:

(a) Program error (P70) results at the circular start point when error ΔR is greater than the parameter "#1084 RadErr".



(b) Spiral interpolation in the direction of the commanded end point results when error ΔR is less than the parameter value.



6.4 R specification circular interpolation; G02, G03

Function and purpose

Along with the conventional circular interpolation commands based on the circular center coordinate (I, K) designation, these commands can also be issued by directly designating the circular radius R.

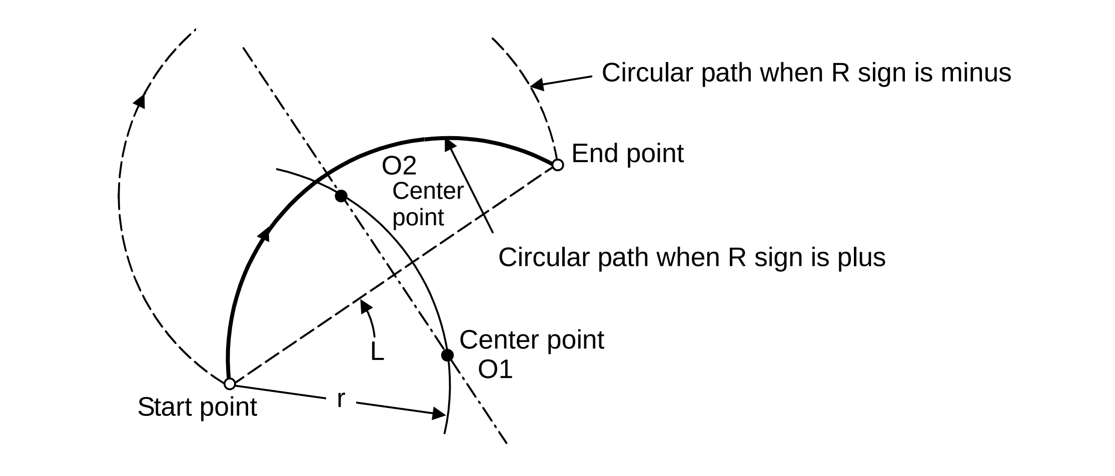
Command format

G02 (G03) Xx/Uu Zz/Ww Rr Ff;

G02	Clockwise (CW)
(G03)	Counterclockwise (CCW)
x/u	Circular end point coordinate, X axis
z/w	Circular end point coordinate, Z axis
r	Circular radius
f	Feedrate

Detailed description

The circular center is on the bisector line which is perpendicular to the line connecting the start and end paints of the circular. The point, where the circular with the specified radius whose start point is the center intersects the perpendicular bisector line, serves as the center coordinates of the circular command.
If the R sign of the commanded program is plus, the circular is smaller than a semicircular; if it is minus, the circular is larger than a semicircular.


Circular path when R sign is minus
End point
O2
Center point
Circular path when R sign is plus
L
Center point
O1
Start point
r

The following condition must be met with an R specification circular interpolation command:

$$\frac{L}{2 \times r} \leq 1$$

When L/2 - r > (parameter : #1084 RadErr), an alarm will occur.

Where L is the line from the start point to end point.
If an R specification and I, K specification are given at the same time in the same block, the circular command with the R specification takes precedence.
In the case of a full-circle command (where the start and end points coincide), an R specification circular command will be completed immediately even if it is issued and no operation will be executed. An I, K specification circular command should therefore be used in such a case.

Example of program

(Example 1)

G03 Zz1 Xx1 Rr1 Ff1 ;	R specification circular on Z-X plane

(Example 2)

G02 Xx1 Zz1 Ii1 Kk1 Rr1 Ff1 ;	R specification circular on X-Z plane (When the R specification and I, K specification are contained in the same block, the R specification has priority in processing.)

6.5 Plane selection; G17, G18, G19

Function and purpose

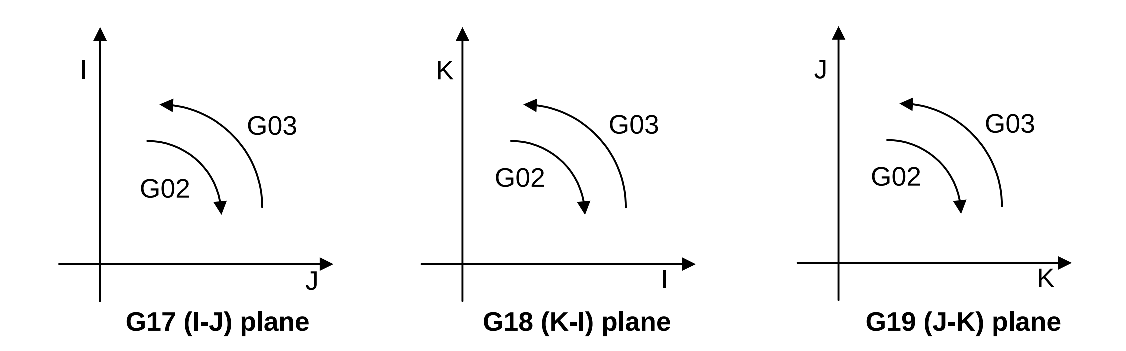
These commands are used to select the control plane and the plane on which the circular exists.
If the 3 basic axes and the parallel axes corresponding to these basic axes are entered as parameters, the commands can select the plane composed of any 2 axes which are not parallel axes. If a rotation axis is entered as a parallel axis, the commands can select the plane containing the rotation axis.
These commands are used to select:

- The plane for circular interpolation
- The plane for nose R compensation

Command format

G17;	**(I-J plane selection)**
G18;	**(K-I plane selection)**
G19;	**(J-K plane selection)**

I, J and K indicate each basic axis or parallel axis.
When the power is turned ON or when the system is reset, the plane set by the parameters "#1025 I_plane" is selected.



G17 (I-J) plane **G18 (K-I) plane** **G19 (J-K) plane**

Parameter entry

	#1026 to 1028 base_I, J, K	#1029 to 1031 aux_I, J, K
I	X	Y
J	Y	
K	Z	

Fig. 1 Examples of plane selection parameter entry

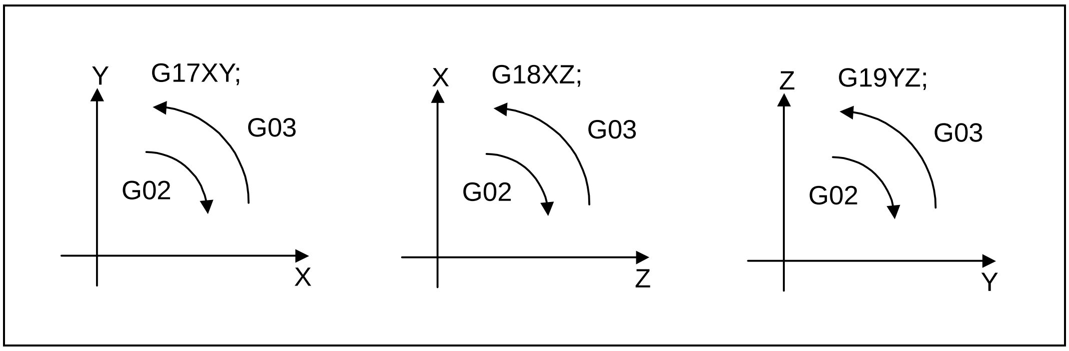
Basic axes and parallel axes can be entered in the parameters. The same axis name can be entered in duplication, but when it is assigned in duplication, the plane is determined as "Plane selection system (4) ".
It is not possible to set axes which have not been entered as control axes.

Plane selection system

This section describes the plane selection for the parameter entry samples shown in Fig. 1.

(1) Axis addresses assigned in the same block as the plane selection (G17, G18, G19) command determine which of the basic axes or parallel axes are to be in the actual plane selected.

(Example)



(2) Plane selection is not performed with blocks in which the plane selection G code (G17, G18, G19) is not assigned.

G18 X_ Z_ ;	Z-X plane
Y_ Z_ ;	Z-X plane (no plane change)

(3) When the axis addresses are omitted in the block containing the plane selection G codes (G17, G18, G19), it is assumed that the axis addresses of the 3 basic axes have been assigned.

G18 ; (Z-X plane = G18 XZ ;)

(4) When the basic axes or their parallel axes are duplicated and assigned in the same block as the plane selection G code (G17, G18, G19), the plane is determined in the order of basic axes, and then parallel axes.

G18 XYZ ; The Z-X plane is selected.
Therefore, the Y movement is unrelated to the selected plane.

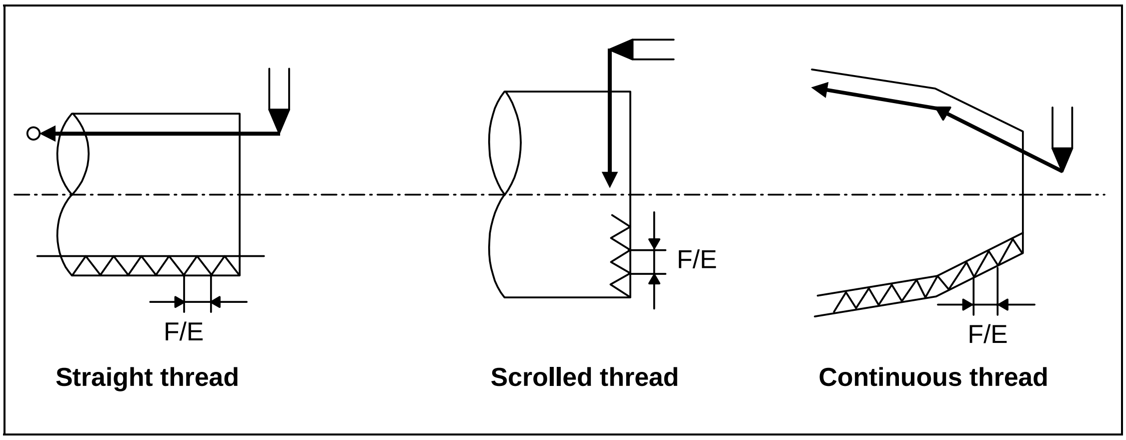
(Note 1) When the "2" in the parameter "#1025 I_plane" is kept ON, the G18 plane is selected when the power is turned ON or when the system is reset.

6.6 Thread cutting

6.6.1 Constant lead thread cutting; G33

Function and purpose

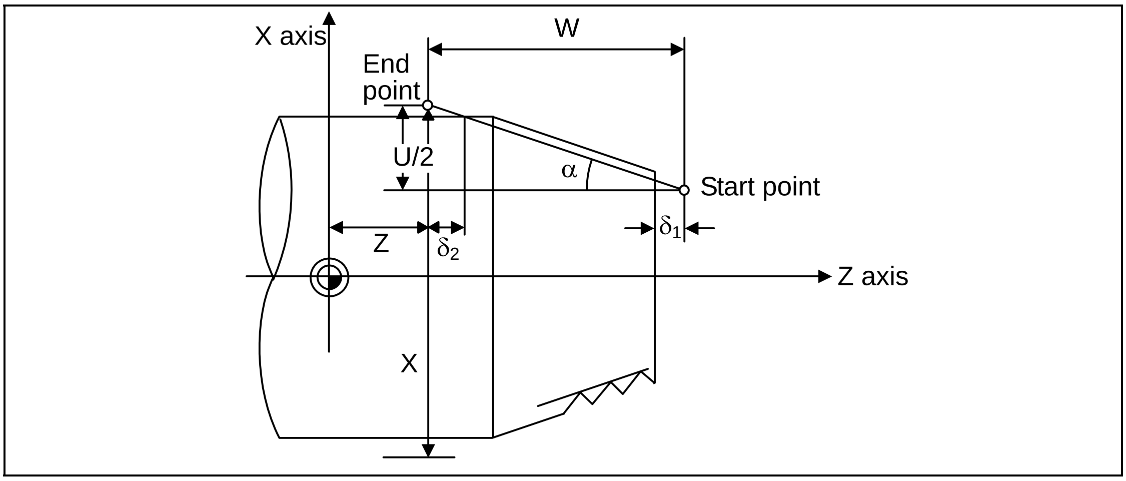
The G33 command exercises feed control over the tool which is synchronized with the spindle rotation and so this makes it possible to conduct constant-lead straight thread-cutting, tapered thread-cutting, and continuous thread-cutting.



Command format

G33 Zz/Ww Xx/Uu Ff Qq ;	(Normal lead thread cutting commands)
Zz, Ww, Xx, Uu	Thread end point coordinates
Ff	Lead of long axis (axis which moves most) direction
Qq	Thread cutting start shift angle, 0.001 to 360.000°

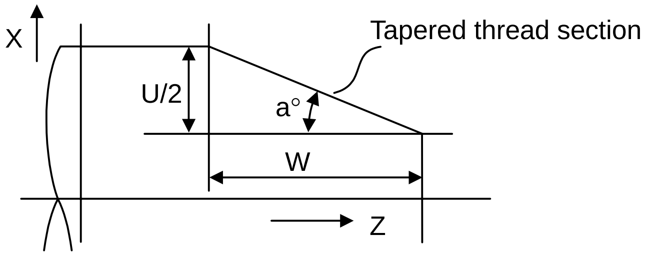
G33 Zz/Ww Xx/Uu Ee Qq ;	(Precision lead thread cutting commands)
Zz, Ww, Xx, Uu	Thread end point coordinates
Ee	Lead of long axis (axis which moves most) direction
Qq	Thread cutting start shift angle, 0.001 to 360.000°



Detailed description

(1) The E command is also used for the number of ridges in inch thread cutting, and whether the ridge number or precision lead is to be designated can be selected by parameter setting.
(Set the parameter "#1229 set 01/bit" to "1" for precision lead designation.)

(2) The lead in the long axis direction is commanded for the taper thread lead.



When a < 45°, the lead is in Z-axis direction.

When a > 45°, the lead is in X-axis direction.

When a = 45°, the lead can be in either Z or X-axis direction.

Thread cutting metric input

Input unit system	B (0.001mm)			C (0.0001mm)		
Command address	F (mm/rev)	E (mm/rev)	E (ridges/inch)	F (mm/rev)	E (mm/rev)	E (ridges/inch)
Minimum command unit	1 (= 0.0001), (1.=1.0000)	1 (= 0.00001), (1.=1.00000)	1 (= 1.00), (1.=1.00)	1 (= 0.00001), (1.=1.00000)	1(=0.000001), (1.=1.000000)	1 (= 1.000), (1.=1.000)
Command range	0.0001 ~ 999.9999	0.00001 ~ 999.99999	0.03 ~ 999.99	0.00001 ~ 99.99999	0.000001 ~ 99.999999	0.255 ~9999.999

Thread cutting inch input

Input unit system	B (0.0001inch)			C (0.00001inch)		
Command address	F (inch/rev)	E (inch/rev)	E (ridges/inch)	F (inch/rev)	E (inch/rev)	E (ridges/inch)
Minimum command unit	1(=0.000001), (1.=1.000000)	1(=0.0000001), (1.=1.0000000)	1 (= 1), (1.=1.0000)	1(=0.0000001), (1.=1.0000000)	1(=0.00000001), (1.=1.00000000)	1(=1), (1.=1.00000)
Command range	0.000001 ~ 99.999999	0.000010 ~ 9.9999999	0.0101 ~ 9999.9999	0.0000001 ~ 9.9999999	0.00000001 ~ 0.99999999	0.10001 ~999.99999

(Note 1) It is not possible to assign a lead where the feedrate as converted into per-minute feed exceeds the maximum cutting feedrate.

(3) The constant surface speed control function should not be used for taper thread cutting commands or scrolled thread cutting commands.

(4) The spindle rotation speed should be kept constant throughout from the rough cutting until the finishing.

(5) If the feed hold function is employed during thread cutting to stop the feed, the thread ridges will lose their shape. For this reason, feed hold does not function during thread cutting.
Note that this is valid from the time the thread cutting command is executed to the time the axis moves.
If the feed hold switch is pressed during thread cutting, block stop will result at the end point of the block following the block in which thread cutting is completed (no longer G33 mode).

(6) The converted cutting feedrate is compared with the cutting feed clamp rate when thread cutting starts, and if it is found to exceed the clamp rate, an operation error will result.

(7) In order to protect the lead during thread cutting, a cutting feedrate which has been converted may sometimes exceed the cutting feed clamp rate.

(8) An illegal lead is normally produced at the start of the thread and at the end of the cutting because of servo system delay and other such factors.
Therefore, it is necessary to command a thread length which is determined by adding the illegal lead lengths $\delta 1$ and $\delta 2$ to the required thread length.

(9) The spindle rotation speed is subject to the following restriction:

$$1 \leq R \leq \frac{\text{Maximum feedrate}}{\text{Thread lead}}$$

Where R ≤ Tolerable speed of encoder (r/min)
R = Spindle rotation speed (r/min)
Thread lead = mm or inches
Maximum feedrate = mm/min or inch/mm
(this is subject to the restrictions imposed by the machine specifications).

(10) Dry run is valid for thread cutting but the feedrate based on dry run is not synchronized with the spindle rotation.
The dry run signal is checked at the start of thread cutting and any switching during thread cutting is ignored.

(11) Synchronous feed applies for the thread cutting commands even with an asynchronous feed command (G94).

(12) Spindle override is invalid and 100% fixed during thread cutting.

(13) When a thread cutting command is programmed during nose R compensation, the compensation is temporarily canceled and the thread cutting is executed.

(14) When the mode is switched to another automatic mode while G33 is executed, the following block which does not contain a thread cutting command is first executed and then the automatic operation stops.

(15) When the mode is switched to the manual mode while G33 is executed, the following block which does not contain a thread cutting command is first executed and then the automatic operation stops. In the case of a single block, the following block which does not contain a thread cutting command (When G33 mode is cancelled) is first executed and then the automatic operation stops. Note that automatic operation is stopped until the G33 command axis starts moving.

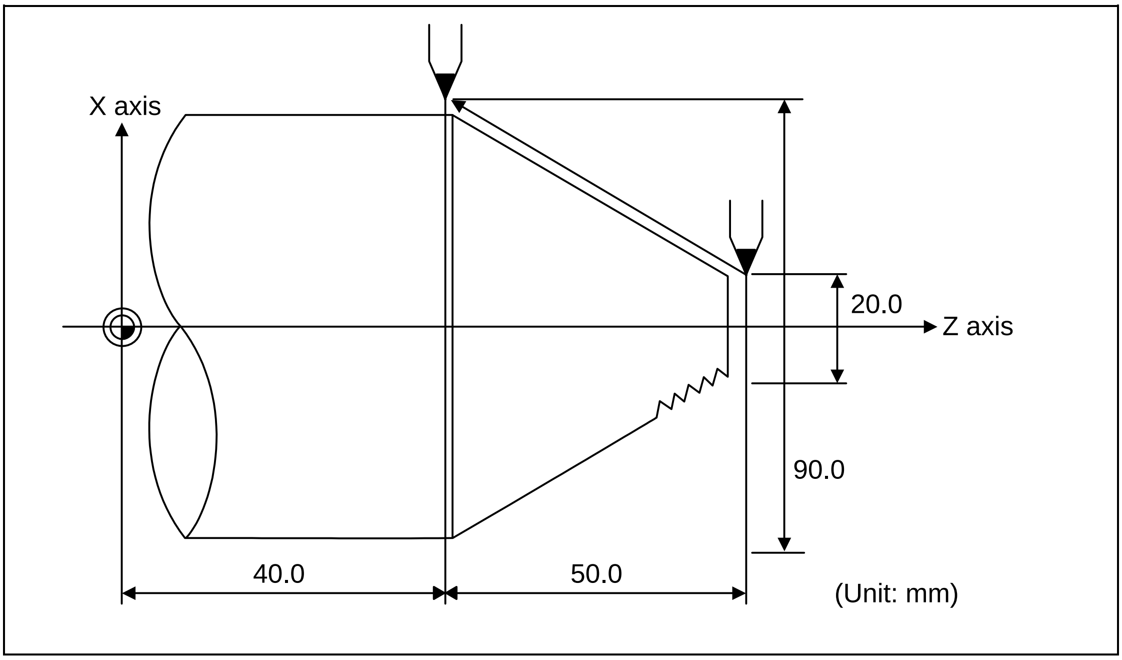
(16) The thread cutting command waits for the single rotation sync signal of the rotary encoder and starts movement.
Note that when using multiple part systems, if one part system issues a thread cutting command during ongoing thread cutting by another part system, the movement will start without waiting for the rotary encoder single rotation sync signal. Therefore, carry out synchronizing between part systems before issuing a thread cutting command with multiple part systems.

(17) The thread cutting start shift angle is not a modal. If there is no Q command with G33, this will be handled as "Q0".

(18) If a value exceeding 360.000 is commanded with G33 Q, this will be handled as "Q360.000".

(19) G33 cuts one row with one cycle. To cut two rows, change the Q value, and issue the same command.

Example of program



G33 X90.0 Z40.0 E12.34567 ;	Absolute value command
G33 U70.0 W-50.0 E12.34567 ;	Incremental value command

6.6.2 Inch thread cutting; G33

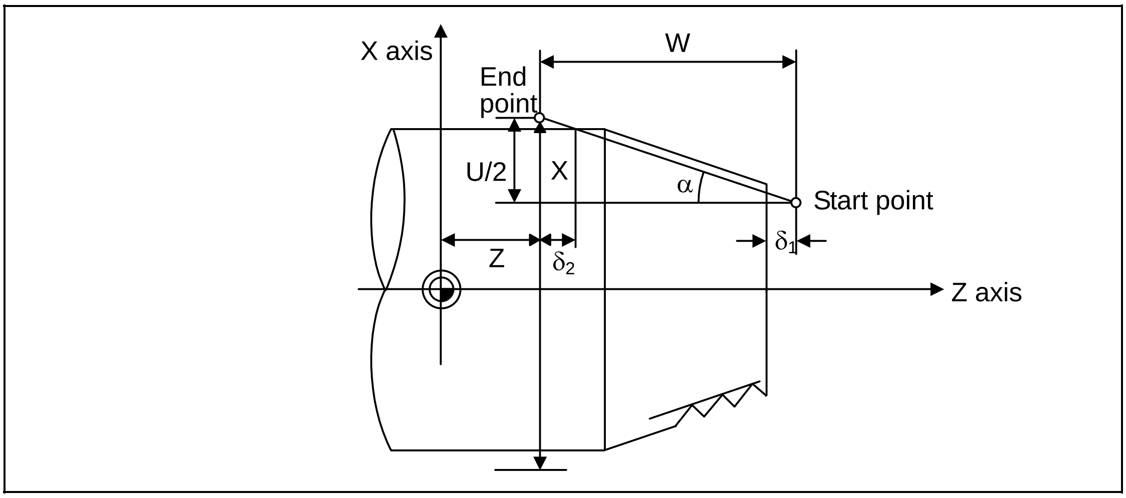
Function and purpose

If the number of ridges per inch in the long axis direction is assigned in the G33 command, the feed of the tool synchronized with the spindle rotation will be controlled, which means that constant-lead straight thread-cutting, tapered thread-cutting, and continuous thread-cutting can be performed.

Command format

G33 Zz/Ww Xx/Uu Ee Qq;

Zz,Ww,Xx,Uu	Thread end point addresses and coordinates
Ee	Number of ridges per inch in direction of long axis (axis which moves most) (decimal point command can also be assigned)
Qq	Thread cutting start shift angle, 0.001 to 360.000°



Detailed description

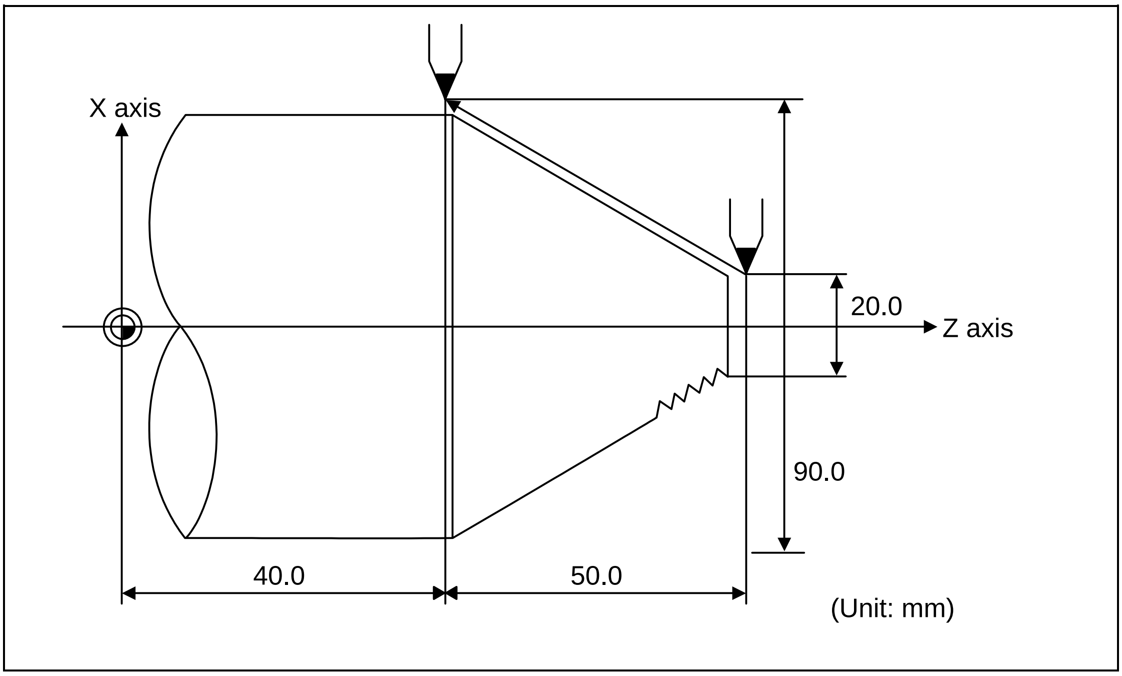
(1) The number of ridges in the long axis direction is assigned as the number of ridges per inch.

(2) The E code is also used to assign the precision lead length, and whether the ridge number or precision lead length is to be designated can be selected by parameter setting. (The number of ridges is designated by setting parameter "#1229 set 01/bit 1" to "0".)

(3) The E command value should be set within the lead value range when the lead is converted.

(4) See Section "6.6.1 Constant lead thread cutting" for other details.

Example of program

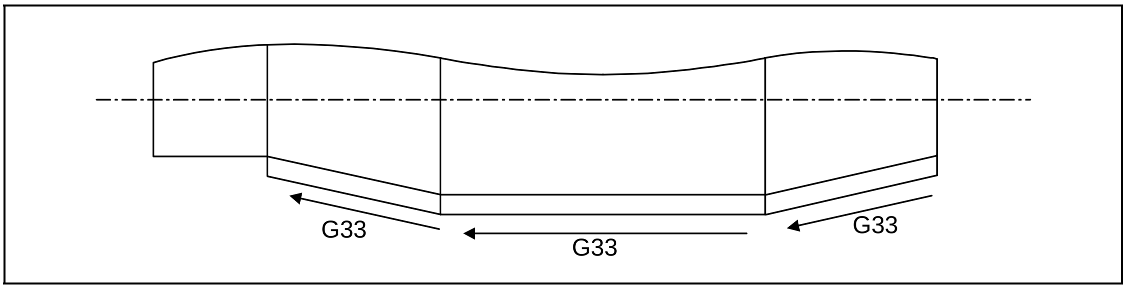


G33 X90.0 Z40.0 E12.0 ;	Absolute value command
G33 U70.0 W-50.0 E12.0 ;	Incremental value command

6.6.3 Continuous thread cutting

Function and purpose

Continuous thread cutting is possible by assigning thread cutting commands continuously.
In this way, it is possible to cut special threads whose lead or shape changes.



6.6.4 Variable lead thread cutting; G34

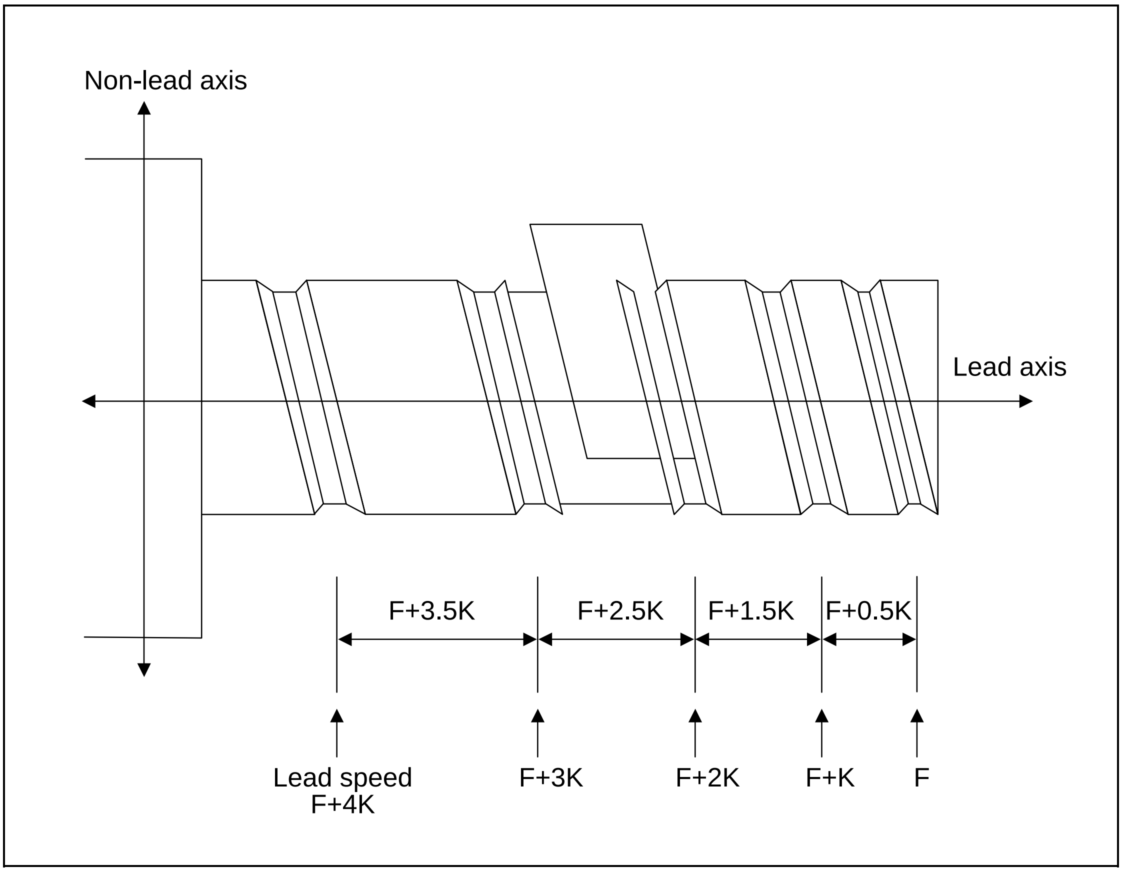
Function and purpose

Variable lead thread cutting is enabled by a command specifying a lead increment or decrement amount per turn of the screw.

Command format

G34 Xx/Uu Zz/Ww Ff/Ee Kk ;

Xx/Uu Zz/Ww	Thread end point coordinates
Ff/Ee	Standard screw lead
Kk	Lead increment or decrement amount per turn of the screw



Detailed description

(1) The command range is as shown below.

Thread cutting metric input

Input unit system	B (0.001mm)		C (0.0001mm)		B/C
Command address	F (mm/rev)	E (mm/rev)	F (mm/rev)	E (mm/rev)	K (n ∗ mm/rev) n: Number of pitches Same as F or E (signed)
Minimum command unit	1 (=0.0001) (1.=1.0000)	1 (=0.00001) (1.=1.00000)	1 (=0.00001) (1.=1.00000)	1 (=0.000001) (1.=1.000000)	
Command range	0.0001 to 999.9999	0.00001 to 999.99999	0.00001 to 99.99999	0.000001 to 99.999999	

Thread cutting inch input

Input unit system	B (0.0001inch)		C (0.00001inch)		B/C
Command address	F (inch/rev)	E (inch/rev)	F (inch/rev)	E (inch/rev)	K (n ∗ inch/rev) n: Number of pitches Same as F or E (signed)
Minimum command unit	1 (=0.000001) (1.=1.000000)	1 (=0.0000001) (1.=1.0000000)	1 (=0.0000001) (1.=1.0000000)	1 (=0.00000001) (1.=1.00000000)	
Command range	0.000001 to 99.999999	0.0000001 to 9.9999999	0.0000001 to 9.9999999	0.00000001 to 0.99999999	

(2) A positive value of K indicates incremental pitches.
Movement amount of one block (n pitches) = (F + K) + (F + 2K) + (F + 3K) + · · + (F + nK)

(3) A negative value of K indicates decremental pitches.
Movement amount of one block (n pitches) = (F – K) + (F – 2K) + (F – 3K) + · · + (F – nK)

(4) A program error will occur if the thread lead is not set correctly.

Error number	Meaning	Remedy
P93	**Illegal pitch value** • An invalid value is specified for F/E or K in a thread cutting command. • The last lead goes outside of the F/E command range.	Specify valid values for F/E and K. **(Reference 1)**

(Reference 1) Last lead = $\sqrt{(F^2 + 2KZ)}$
Number of pitches = (–F + last lead)/K
Z : Length of lead axis

(5) The other matters are the same as G33.
Refer to the section "6.6.1 Constant lead thread cutting; G33".

7. Feed Functions

7.1 Rapid traverse rate

Function and purpose

The rapid traverse rate can be set independently for each axis. The speed range that can be set is 1mm/min to 1,000,000mm/min when the input setting unit is 1μm. Note that the upper limit speed is limited by the machine specification.
Refer to the specifications manual of the machine for the rapid traverse rate settings.

Two paths are available during positioning: the interpolation type where the area from the start point to the end point is linearly interpolated or the non-interpolation type where movement proceeds at the maximum speed of each axis. The type is selected by parameter "#1086 G0Intp". The positioning time is the same in each case.

(Note) Rapid traverse override
Override can be applied by an external input signal for both manual and automatic rapid traverse. There are 2 types which are determined by the PLC specifications.
Type 1: Override in 4 steps: 1%, 25%, 50% and 100%
Type 2: Override in 1% steps from 0% to 100%.

7.2 Cutting feedrate

Function and purpose

The cutting feedrate is assigned with address F and 8 digits.
The F8 digits are assigned with a decimal point for a 5-digit integer and a 3-digit fraction. The cutting feedrate is valid for the G01, G02, G03, G33 and G34 commands.

Examples (asynchronous feed)

Feedrate	
G1 X100. Z100. F200 ;	200.0mm/min F200. or F200.000 gives the same rate.
F1 X100. Z100. F123.4 ;	123.4mm/min
F1 X100. Z100. F56.789 ;	56.789mm/min

Speed range that can be commanded (when input setting unit is 1μm or 10μm)

Command mode	F command range	Feed rate command range	Remarks
mm/min	0.001 ~ 1000000.000	0.001 ~ 1000000.000 mm/min	
inch/min	0.0001 ~ 39370.0787	0.0001 ~ 39370.0787inch/min	
°/min	0.001 ~ 1000000.000	0.001 ~ 1000000.000°/min	

(Note 1) A program error (P62) results when there is no F command in the first cutting command (G01, G02, G03, G33, or G34) after the power has been turned ON.

7.3 F1-digit feed

Function and purpose

By setting the F1-digit feed parameter, the feedrate which has been set to correspond to the 1-digit number following the F address serves as the command value.
When F0 is assigned, the rapid traverse rate is established and the speed is the same as for G00. (G modal does not change.)
When F1 to F5 is assigned, the feedrate set to correspond to the command serves as the command value.
The command greater than F6 is considered to be the normal cutting feedrate.
The F1-digit command is valid only in a G01, G02 or G03 modal.
The F1-digit command can also be used for fixed cycle.

Detailed description

Set the corresponding speed of F1 to F5 with the base specification parameters "#1185 spd_F1" to "#1189 spd_F5" respectively.
Operation alarm "104" will occur when the feedrate is 0.

(1) Operation method

(a) Make the F1-digit command valid. (Set the base specification parameter "#1079 F1digt" to 1.)

(b) Set F1 to F5. (Base specification parameter "1185 spd_F1" to "#1189 spd_F5")

(2) Special notes

(a) Use of both the F1-digit command and normal cutting feedrate command is possible when the F1-digit is valid.
(Example 1)

F0	Rapid traverse rate
F1 to F5	F1-digit
F6 or more	Normal cutting feedrate command

(b) F1 to F5 are invalid in the G00 mode and the rapid traverse rate is established instead.

(c) If F0 is used in the G02 or G03 mode, a program error (P121) will result.

(d) When F1. to F5. (with decimal point) are assigned, the 1mm/min to 5mm/min direct commands are established instead of the F1-digit command.

(e) When the commands are used with the millimeter or degree units, the feedrate set to correspond to F1 to F5 serves as the assigned speed mm (°)/min.

(f) When the commands are used with inch units, one-tenth of the feedrate set correspond to F1 to F5 serves at the assigned speed inch/min.

(g) During a F1-digit command, the F1-digit number and F1-digit command signal are output as the PLC signals.

(3) F1-digit and G commands

(a) 01 group G command in same block as F1-digit commands

	Executed feedrate	Modal display rate	G modal
G0F0 F0G0	Rapid traverse rate	0	G0
G0F1 F1G0	Rapid traverse rate	1	G0
G1F0 F0G1	Rapid traverse rate	0	G1
G1F1 F1G1	F1 contents	1	G1

(b) F1-digit and unmodal commands may be assigned in the same block. In this case, the unmodal command is executed and at the same time the F1-digit modal command is updated.

7.4 Synchronous/asynchronous feed; G94, G95

Function and purpose

Using the G95 command, it is possible to assign the feed amount per rotation with an F code. When this command is used, the rotary encoder must be attached to the spindle.

Command format

G94;
G95;

G94	Per-minute feed (mm/min) (asynchronous feed)
G95	Per-rotation feed (mm/rev) (synchronous feed)

The G95 command is a modal command and so it is valid until the G94 command (per-minute feed) is next assigned.

Detailed description

(1) The F code command range is as follows.
The movement amount per spindle rotation with synchronous feed (per-rotation feed) is assigned by the F code and the command range is as shown in the table below.

Metric input

Input command unit system	**B (0.001mm)**		**C (0.0001mm)**	
Command mode	Per-minute feed	Per-rotation feed	Per-minute feed	Per-rotation feed
Command address	F (mm/min)	F (mm/rev)	F (mm/min)	F (mm/rev)
Minimum command unit	1 (= 1.000), (1. = 1.000)	1 (= 0.0001), (1. = 1.0000)	1 (= 1.0000), (1. = 1.0000)	1 (= 0.00001), (1. = 1.00000)
Command range	0.001 ~1000000.000	0.0001 ~999.9999	0.0001 ~100000.0000	0.00001 ~99.99999

Inch input

Input command unit system	**B (0.0001inch)**		**C (0.00001inch)**	
Command mode	Per-minute feed	Per-rotation feed	Per-minute feed	Per-rotation feed
Command address	F (inch/min)	E (inch/rev)	F (inch/min)	E (inch/rev)
Minimum command unit	1 (= 0.01), (1. = 1.0000)	1 (= 0.000001), (1. = 1.000000)	1 (= 0.01), (1. = 1.00000)	1 (= 0.0000001), (1. = 1.0000000)
Command range	0.0001 ~ 39370.0787	0.000001 ~ 99.999999	0.00001 ~ 3937.00787	0.0000001 ~ 9.9999999

(2) The effective speed (actual movement speed of machine) under per-rotation feed conditions is given in the following formula (Formula 1).

FC = F × N × OVR .... (Formula 1)

Where FC = Effective rate (mm/min, inch/min)
F = Commanded speed (mm/rev, inch/rev)
N = Spindle rotation speed (r/min)
OVR = Cutting feed override

When a multiple number of axes have been commanded at the same time, the effective rate FC in formula 1 applies in the vector direction of the command.

Precautions

(1) The effective rate (mm/min or inch/min), which is produced by converting the commanded speed, the spindle rotation speed and the cutting feed override into the per-minute speed, appears as the FC on the monitor 1. screen of the setting and display unit.

(2) When the above effective rate exceeds the cutting feed clamp rate, it is clamped at that clamp rate.

(3) If the spindle rotation speed is zero when synchronous feed is executed, operation error "105" results.

(4) During machine lock high-speed processing, the rate will be 1,000,000 mm/min (or 39,370 inch/min, 1,000,000 °/min) regardless of the commanded speed and spindle rotation speed.

(5) Under dry run conditions, asynchronous speed applies and movement results at the externally set speed (mm/min or inch/min).

(6) Whether asynchronous feed (G94) or synchronous feed (G95) is to be established when the power is turned ON or when M02 or M30 is executed can be selected by setting parameter "#1074 I_Sync".

7.5 Feedrate designation and effects on control axes

Function and purpose

It has already been mentioned that a machine has a number of control axes. These control axes can be divided into linear axes which control linear movement and rotation axes which control rotary movement. The feedrate is designed to assign the displacement speed of these axes, and the effect exerted on the tool movement speed which poses problems during cutting differs according to when control is exercised over the linear axes or when it is exercised over the rotation axes.

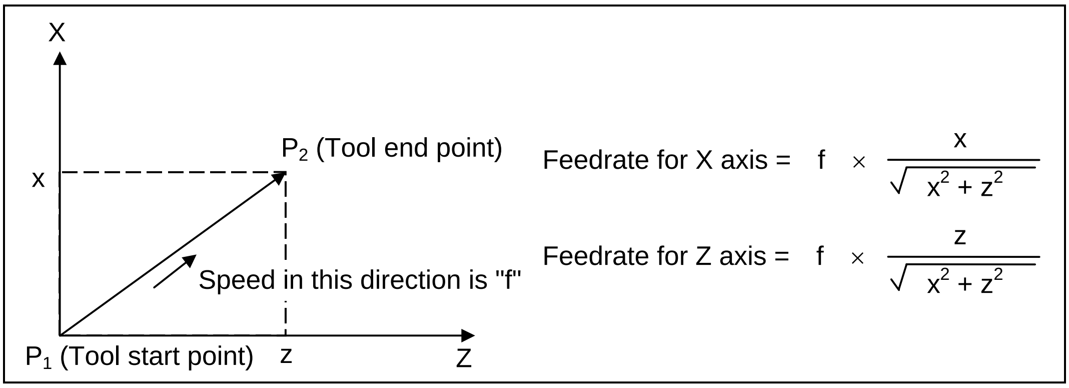
The displacement amount for each axis is assigned separately for each axis by a value corresponding to the respective axis. The feedrate is not assigned for each axis but assigned as a single value. Therefore, when two or more axes are to be controlled simultaneously, it is necessary to understand how this will work for each of the axes involved.

The assignment of the feedrate is described with the following related items.

When controlling linear axes

Even when only one machine axis is to be controlled or there are two or more axes to be controlled simultaneously, the feedrate which is assigned by the F code functions as a linear speed in the tool advance direction.

(Example) When the feedrate is designated as "f" and linear axes (X and Z) are to be controlled

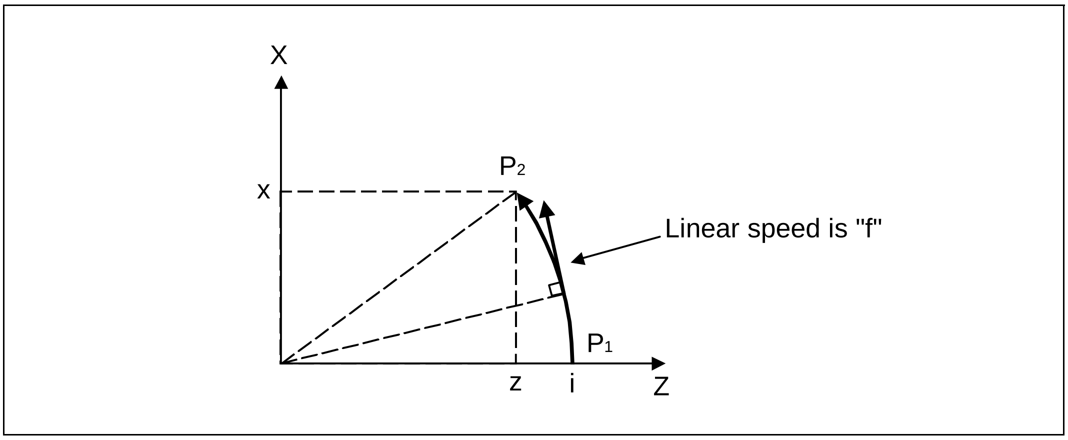


$$\text{Feedrate for X axis} = f \times \frac{x}{\sqrt{x^2 + z^2}}$$

$$\text{Feedrate for Z axis} = f \times \frac{z}{\sqrt{x^2 + z^2}}$$

When only linear axes are to be controlled, it is sufficient to designate the cutting feed in the program. The feedrate for each axis is such that the designated rate is broken down into the components corresponding to the movement amounts.

(Note) When the circular interpolation function is used and the tool is moved along the circumference of an arc by the linear control axis, the rate in the tool advance direction, or in other words the tangential direction, will be the feedrate designated in the program.

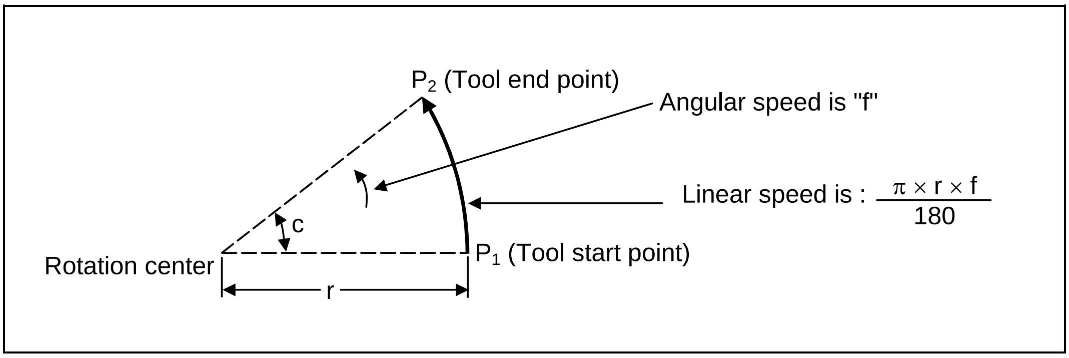


(Example) When the feedrate is designated as "f" and the linear axes (X and Z) are to be controlled using the circular interpolation function
In this case, the feedrate of the X and Z axes will change along with the tool movement. However, the combined speed will always be maintained at the constant value "f".

When controlling rotation axes

When rotation axes are to be controlled, the designated feedrate functions as the rotation speed of the rotation axes, in other words, as an angular speed.
Consequently, the cutting feed in the tool advance direction, or in other words the linear speed, varies according to the distance between the center of rotation and the tool. This distance must be borne in mind when designating the feedrate in the program.

(Example) When the feedrate is designated as "f" and rotation axis (C) is to be controlled ("f" units = °/min)



In this case, in order to make the cutting feed (linear speed) in the tool advance direction as "fc":

$$fc = f \times \frac{\pi \times r}{180}$$

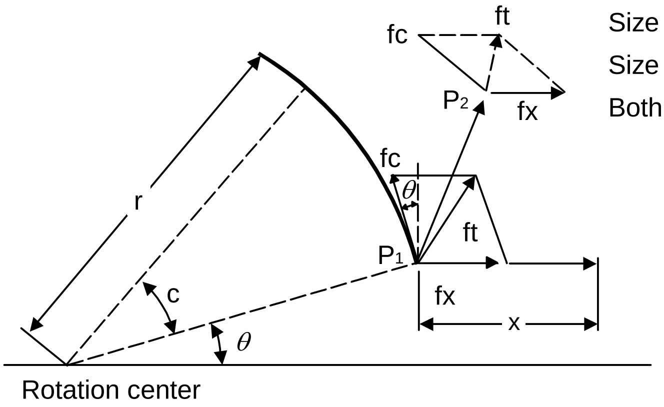
Therefore, the feedrate to be designated in the program must be:

$$f = fc \times \frac{180}{\pi \times r}$$

When linear and rotation axes are to be controlled at the same time

The NC unit proceeds in exactly the same way whether linear or rotation axes are to be controlled. When a rotation axis is to be controlled, the numerical value assigned by the coordinate words (C, H) is the angle and the numerical values assignees by the feedrate (F) are all handled as linear speeds. In other words, 1° of the rotation axis is treated as being equivalent to 1mm of the linear axis. Consequently, when both linear and rotation axes are to be controlled simultaneously, the components for each axis of the numerical values assigned by F will be the same as for section (1) above (applying when linear axes are to be controlled). However, although in this case both the size and direction of the speed components based on linear axis control do not vary, the direction of the speed components based on rotation axis control will change along with the tool movement (their size will not change). This means, as a result, that the combined tool advance direction feedrate with vary along with the tool movement.

(Example) When the feedrate is designated as "f" and linear (X) and rotation (C) axes are to be controlled simultaneously
If the X-axis incremental command value is "x" and the C-axis incremental command value is "c":



Size and direction are fixed for fx.
Size is fixed for fc but direction varies.
Both size and direction vary for ft.

X-axis feedrate (linear speed) "fx" and C-axis feedrate (angular speed) "ω" are expressed as:

$$fx = f \times \frac{x}{\sqrt{x^2 + c^2}} \quad \text{........ (1)} \qquad \omega = f \times \frac{c}{\sqrt{x^2 + c^2}} \quad \text{........ (2)}$$

Linear speed "fc" based on C-axis control is expressed as:

$$fc = \omega \times \frac{\pi \times r}{180} \quad \text{........ (3)}$$

If the speed in the tool advance direction at start point P_1 is "ft" and the component speeds in the X-axis and Y-axis directions are "ftx" and "fty" respectively. Then these are expressed as:

$$ftx = -r\sin\left(\frac{\pi}{180}\theta\right) \times \frac{\pi}{180}\omega + fx \quad \text{........ (4)}$$

$$fty = -r\cos\left(\frac{\pi}{180}\theta\right) \times \frac{\pi}{180}\omega \text{.................. (5)}$$

Where r is the distance between center of rotation and tool (in mm units), and
θ is the angle between the P_1 point and the X axis at the center of rotation (in units °).
The combined speed "ft" according to formulae (1), (2), (3), (4) and (5) is:

$$ft = \sqrt{ftx^2 + fty^2}$$

$$= f \times \frac{\sqrt{x^2 - x \times c \times r\sin\left(\frac{\pi}{180}\theta\right)\frac{\pi}{90} + \left(\frac{\pi \times r \times c}{180}\right)^2}}{x^2 + c^2}$$

.... (6)

Consequently, feedrate "f" designated by the program must be as follows:

$$f = ft \times \frac{x^2 + c^2}{\sqrt{x^2 - x \times c \times r\sin\left(\frac{\pi}{180}\theta\right)\frac{\pi}{90} + \left(\frac{\pi \times r \times c}{180}\right)^2}} \quad \text{.......... (7)}$$

"ft" in formula (6) is the speed at the P_1 point and the value of θ changes as the C axis rotates, which means that the value of "ft" will also change. Consequently, in order to keep the cutting feed "ft" as constant as possible, the angle of rotation which is designated in one block must be reduced to as low as possible and the extent of the change in the θ value must be minimized.

7.6 Thread cutting mode

Function and purpose

F7-digit or E8-digit commands for thread leads can be issued for the thread cutting mode (G33, G34, G76, G78 commands).
The thread lead command range is 0.0001 to 999.9999mm/rev (F7 digits) or 0.0001 to 999.99999 mm/rev (E8 digits) (with input unit of μm).

Thread cutting metric input

Input unit system	B (0.001mm)			C (0.0001mm)		
Command address	F (mm/rev)	E (mm/rev)	E (ridges/inch)	F (mm/rev)	E (mm/rev)	E (ridges/inch)
Minimum command unit	1 (= 0.0001), (1.=1.0000)	1 (= 0.00001), (1.=1.00000)	1 (= 1.00), (1.=1.00)	1 (= 0.00001), (1.=1.00000)	1(=0.000001), (1.=1.000000)	1 (= 1.000), (1.=1.000)
Command range	0.0001 ~ 999.9999	0.00001 ~ 999.99999	0.03 ~ 999.99	0.00001 ~ 99.99999	0.000001 ~ 99.999999	0.255 ~9999.999

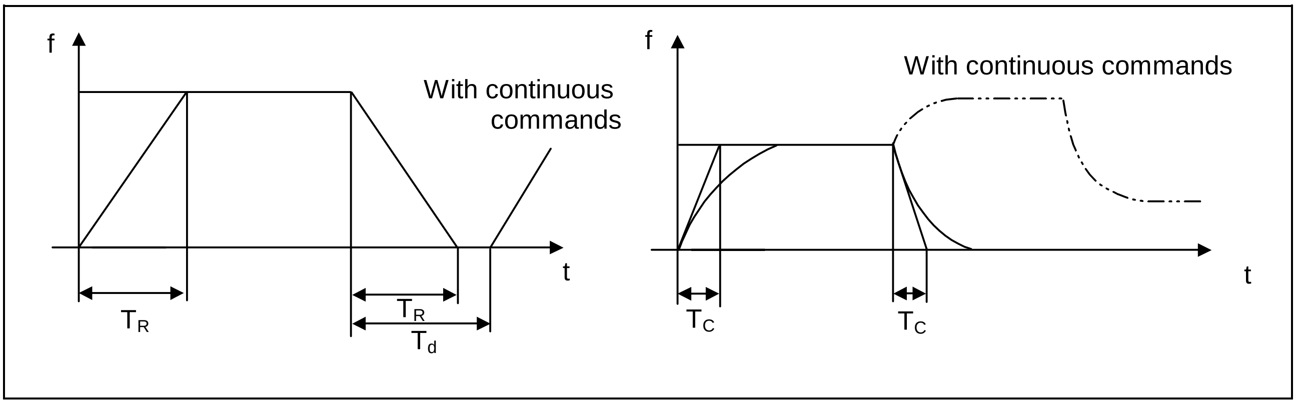
Thread cutting inch input

Input unit system	B (0.0001inch)			C (0.00001inch)		
Command address	F (inch/rev)	E (inch/rev)	E (ridges/inch)	F (inch/rev)	E (inch/rev)	E (ridges/inch)
Minimum command unit	1(=0.000001), (1.=1.000000)	1(=0.0000001), (1.=1.0000000)	1 (= 1.0000), (1.=1.0000)	1(=0.0000001), (1.=1.0000000)	1 (=0.00000001), (1.=1.00000000)	1(=1.00000), (1.=1.00000)
Command range	0.000001 ~ 99.999999	0.000010 ~ 9.9999999	0.0101 ~ 9999.9999	0.0000001 ~ 9.9999999	0.0000010 ~ 0.99999999	0.10001 ~999.99999

7.7 Automatic acceleration/deceleration

Function and purpose

The rapid traverse and manual feed acceleration/deceleration pattern is linear acceleration and linear deceleration.
Time constant T_R can be set independently for each axis using parameters in 1ms steps from 1 to 500ms.
The cutting feed (not manual feed) acceleration/deceleration pattern is exponential acceleration/ deceleration. Time constant Tc can be set independently for each axis using parameters in 1ms steps across a range from 1 to 500ms. (Normally, the same time constant is set for all axes.)



Rapid traverse acceleration/deceleration Pattern
(T_R = Rapid traverse time constant)
(T_d = Deceleration check time)

Cutting feed acceleration/deceleration pattern
(T_c = Cutting feed time constant)

With rapid traverse and manual feed, the following block is executed after the command pulse of the present block has become "0" and the tracking error of the acceleration/deceleration circuit has become "0". However, with cutting feed, the following block is executed as soon as the command pulse of the present block becomes "0" although an external signal (error detect) can detect that the tracking error of the acceleration/deceleration circuit has reached "0" and the following block can be executed. When the in-position check has been made valid (selected by parameter "#1193 inpos") during the deceleration check, it is first confirmed that the tracking error of the acceleration/deceleration circuit has reached "0", then it is checked that the position deviation is less than the parameter setting value "#2204 SV024", and finally the following block is executed. It depends on the machine as to whether the error detect function can be activated by a switch or M function and so reference should be made to the instructions issued by the machine maker.

7.8 Speed clamp

Function and purpose

This function exercises control over the actual cutting feedrate in which override has been applied to the cutting feedrate command so that the speed clamp value which has been preset independently for each axis is not exceeded.

(Note) Speed clamping is not applied to synchronous feed and thread cutting.

7.9 Exact stop check; G09

Function and purpose

In order for roundness to be prevented during corner cutting and for machine shock to be alleviated when the tool feedrate changes suddenly, there are times when it is desirable to start the commands in the following block once the in-position state after the machine has decelerated and stopped or the elapsing of the deceleration check time has been checked. The exact stop check function is designed to accomplish this purpose.

The parameter "#1193 inpos" among the base specifications parameters enables control to be exercised either by the deceleration check time or in-position state. The in-position state is valid when "#1193 inpos" is set to 1.

The in-position width is set into parameter "#2224 SV024" on the servo parameter screen by the machine maker.

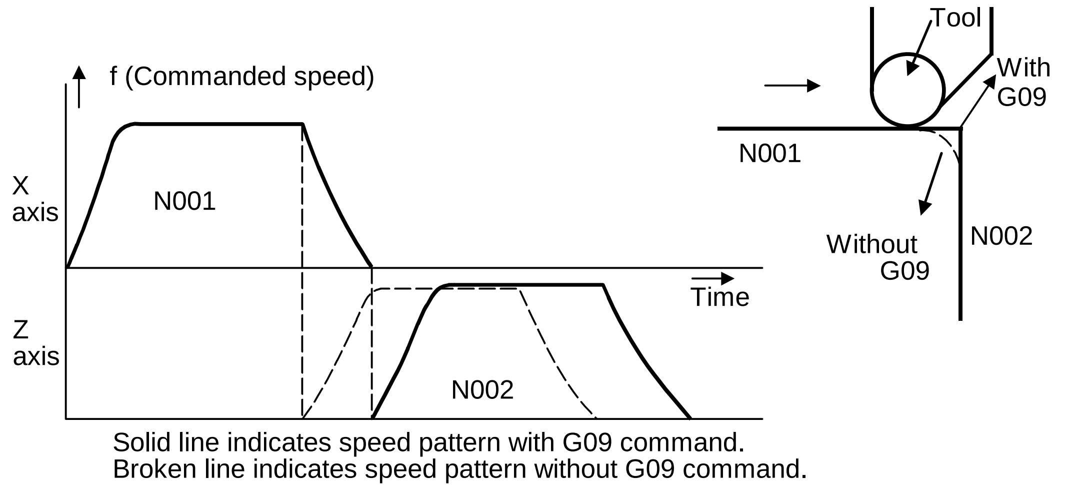
Command format

```
G09 G01 (G02, G03) ;
```

The exact stop check command G09 has an effect only with the cutting command (G01 ~ G03) in its particular block.

Example of program

N001 G09 G01 X100.000 F150 ;	The commands in the following block are started once the deceleration check time or in-position state has been checked after the machine has decelerated and stopped.
N002 Z100.000 ;	



Solid line indicates speed pattern with G09 command.
Broken line indicates speed pattern without G09 command.

Fig. 1 Exact stop check result

Detailed description

(1) With continuous cutting feed

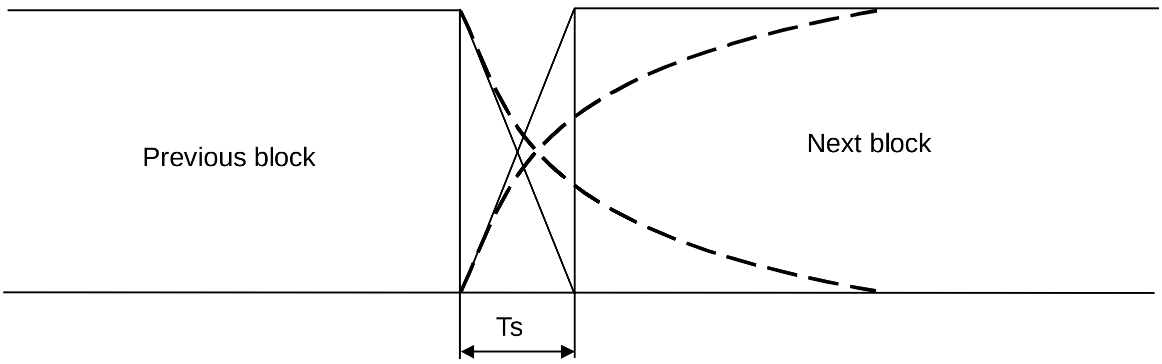


Fig. 2 Continuous cutting feed command

(2) With cutting feed in-position check

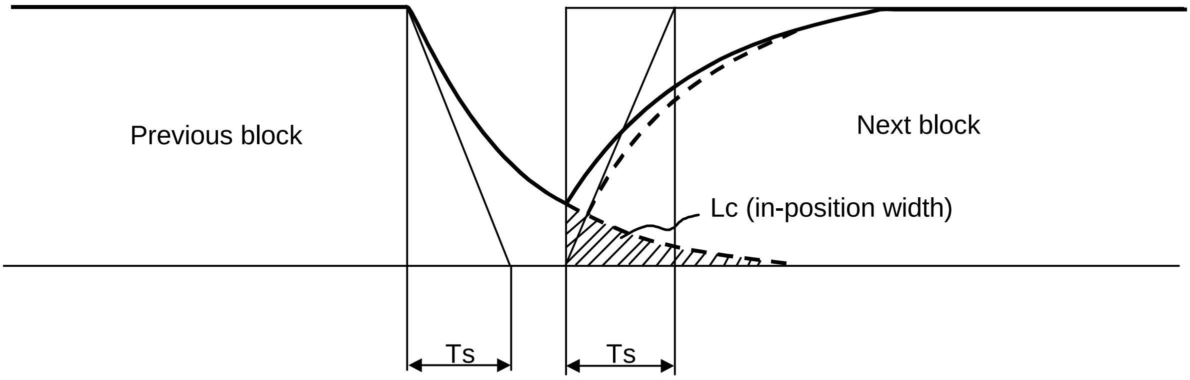
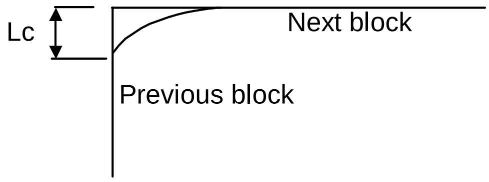


Fig. 3 Block joint with cutting feed in-position check

In Figs. 2 and 3:

Ts = Cutting feed acceleration/deceleration time constant
Lc = In-position width

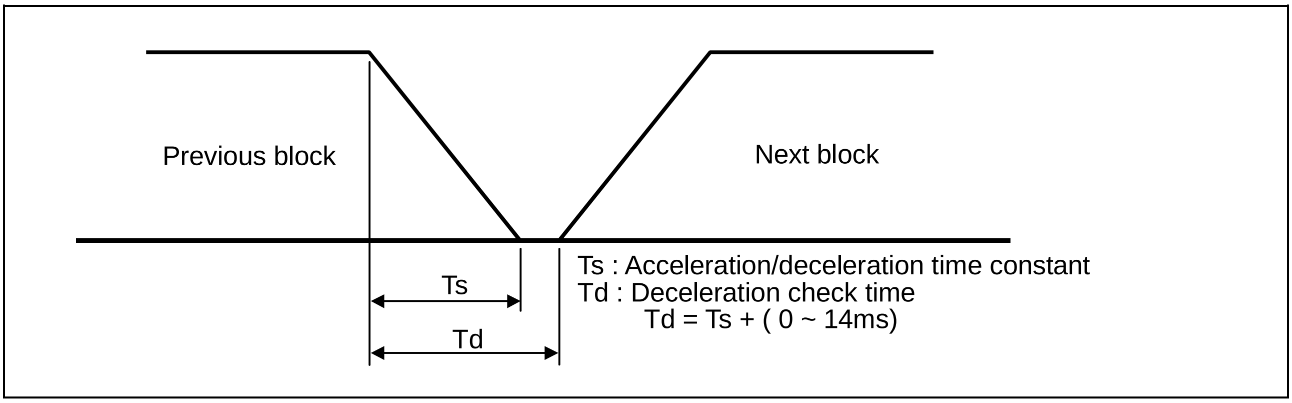
As shown in Fig. 3, the in-position width "Lc" can be set into the servo parameter "#2224 SV024" as the remaining distance (shaded area in Fig. 3) of the previous block when the next block is started.
The in-position width is designed to reduce the roundness at the workpiece corners to below the constant value.



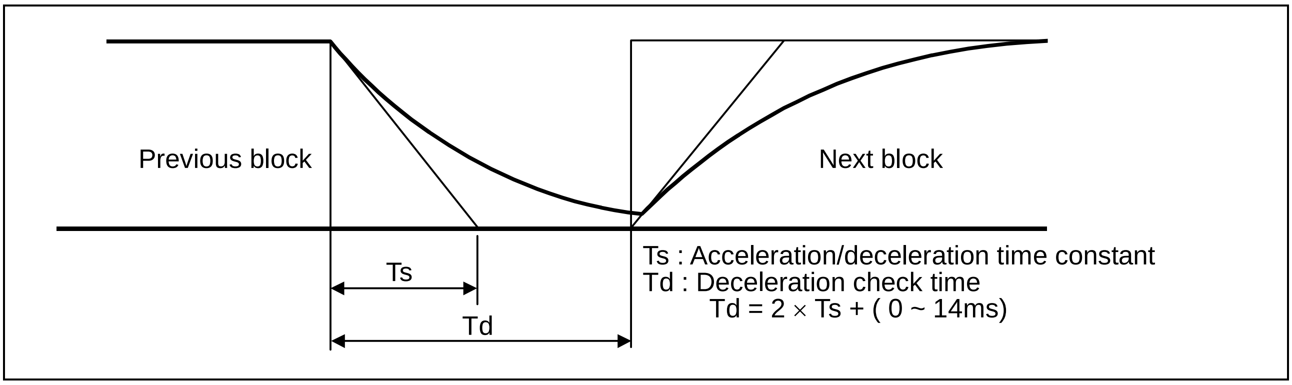
To eliminate corner roundness, set the servo parameter "#2224 SV024" to zero and perform an in-position check or assign the dwell command (G04) between blocks.

(3) **With deceleration check**

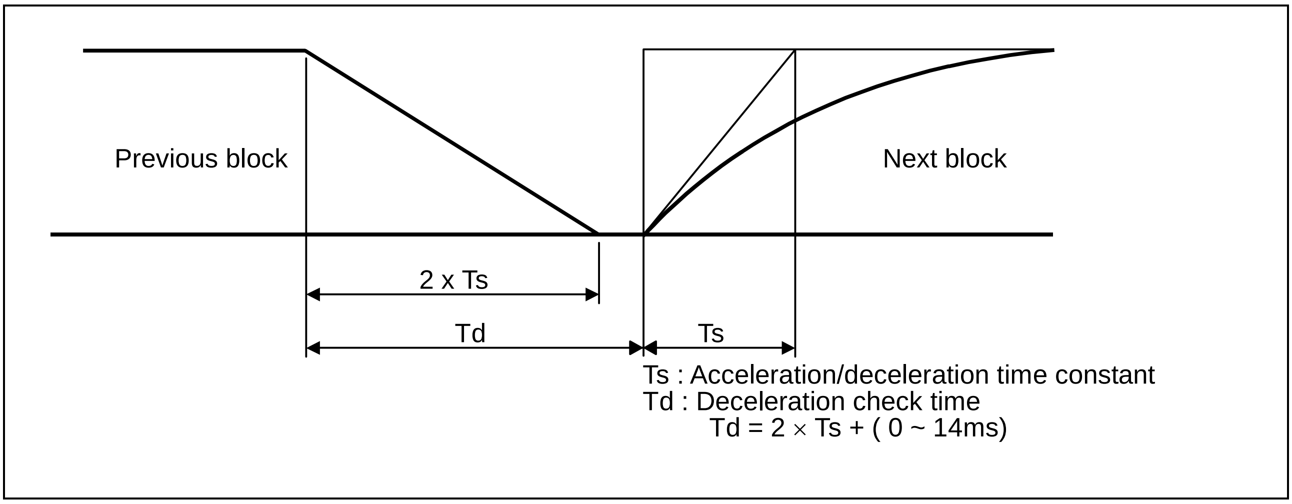
(a) **With linear acceleration/deceleration**


Previous block
Next block
Ts
Td
Ts : Acceleration/deceleration time constant
Td : Deceleration check time
Td = Ts + (0 ~ 14ms)

(b) **With exponential acceleration/deceleration**


Previous block
Next block
Ts
Td
Ts : Acceleration/deceleration time constant
Td : Deceleration check time
Td = 2 × Ts + (0 ~ 14ms)

(c) **With exponential acceleration/linear deceleration**


Previous block
Next block
2 x Ts
Td
Ts
Ts : Acceleration/deceleration time constant
Td : Deceleration check time
Td = 2 × Ts + (0 ~ 14ms)

The time required for the deceleration check during cutting feed is the longest among the cutting feed deceleration check times of each axis determined by the cutting feed acceleration/deceleration time constants and by the cutting feed acceleration/deceleration mode of the axes commanded simultaneously.

(Note 1) To execute exact stop check in a fixed cycle cutting block, insert command G09 into the fixed cycle subprogram.

7.10 Exact stop check mode ; G61

Function and purpose

Whereas the G09 exact stop check command checks the in-position status only for the block in which the command has been assigned, the G61 command functions as a modal. This means that deceleration will apply at the end points of each block to all the cutting commands (G01 to G03) subsequent to G61 and that the in-position status will be checked. G61 is released by automatic corner override (G62), tapping mode (G63), or cutting mode (G64).

Command format

```
G61 ;
```

In-position check is executed in the G61 block, and thereafter, the in-position check is executed at the end of the cutting command block is executed until the check mode is canceled.

7.11 Automatic corner override ; G62

Function and purpose

With this command, when cutting with tool radius compensation, an override is automatically applied to the feedrate to reduce the load during inside corner cutting or during inside cutting of automatic corner R.
Automatic corner override is valid until the nose R compensation cancel (G40), exact stop check mode (G61), tapping mode (G63), or cutting mode (G64) command is issued.

Command format

```
G62 ;
```

Machining inside corners

When cutting an inside corner as in Fig. 1, the machining allowance amount increases and a greater load is applied to the tool. To remedy this, override is applied automatically within the corner set range, the feedrate is reduced, the increase in the load is reduced and cutting is performed effectively.
However, this function is valid only when finished shapes are programmed.

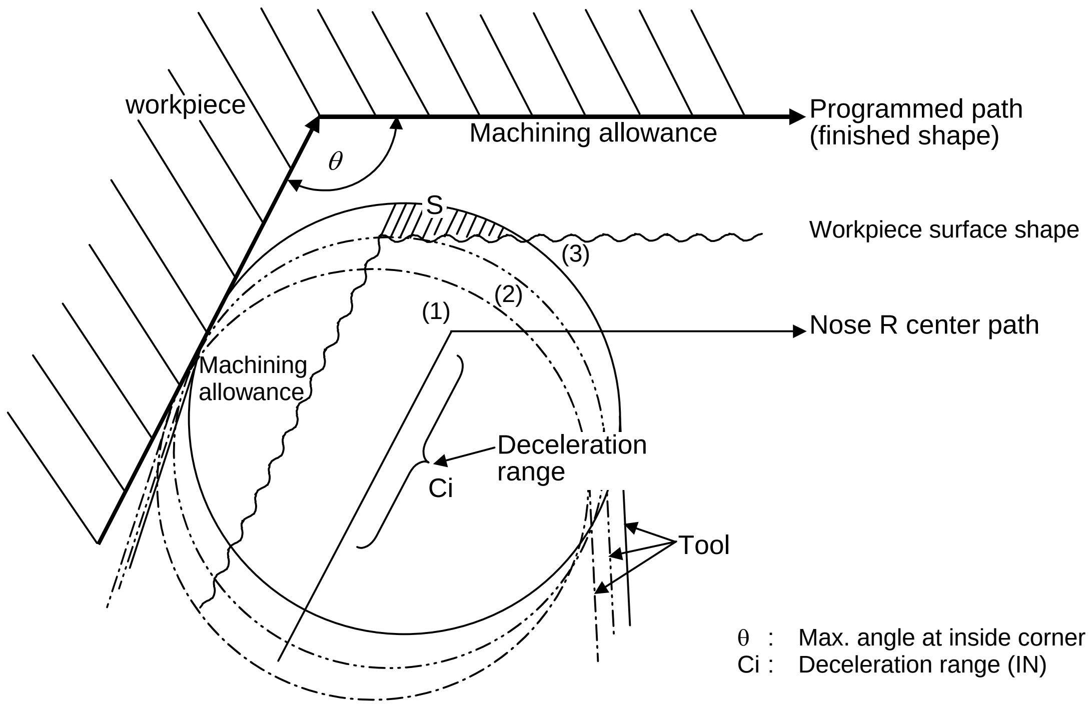


Fig. 1

(1) Operation

(a) When automatic corner override is not to be applied :

When the tool moves in the order of (1) → (2) → (3) in Fig. 1, the machining allowance at (3) increases by an amount equivalent to the area of shaded section S and so the tool load increases.

(b) When automatic corner override is to be applied :

When the inside corner angle θ in Fig. 1 is less than the angle set in the parameter, the override set into the parameter is automatically applied in the deceleration range Ci.

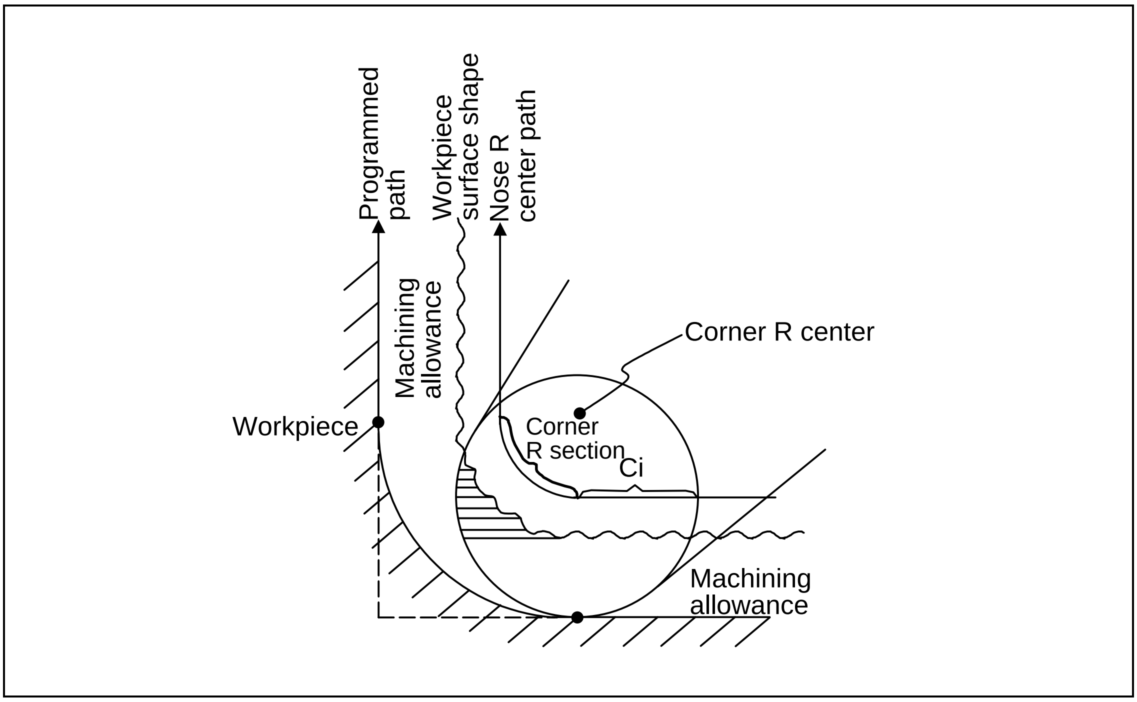
(2) Parameter setting

The following parameters are set into the machining parameters :

#	Parameter	Parameter setting
#8007	OVERRIDE	0 to 100%
#8008	MAX. ANGLE	0 to 180°
#8009	DSC. ZONE	0 to 99999.999mm or 0 to 3937.000 inches

Refer to the Instruction Manual for details on the setting method.

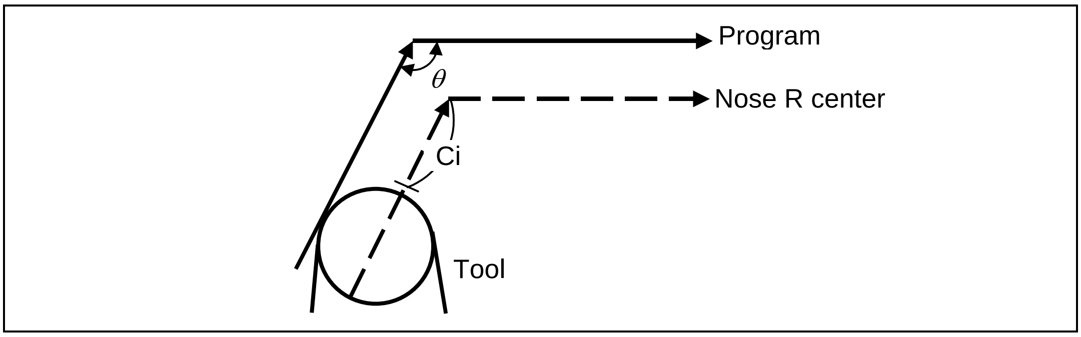
Automatic corner R



(1) The override set in the parameter is automatically applied at the deceleration range Ci and corner R section for inside offset with automatic corner R. (There is no angle check.)

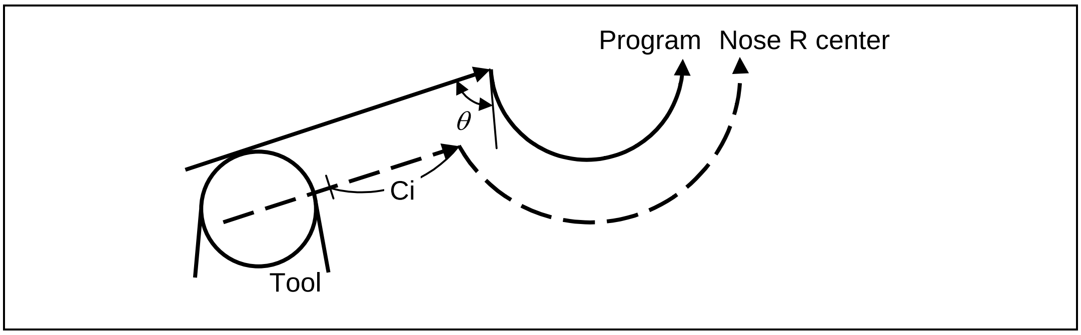
Application example

(1) Linear – linear corner



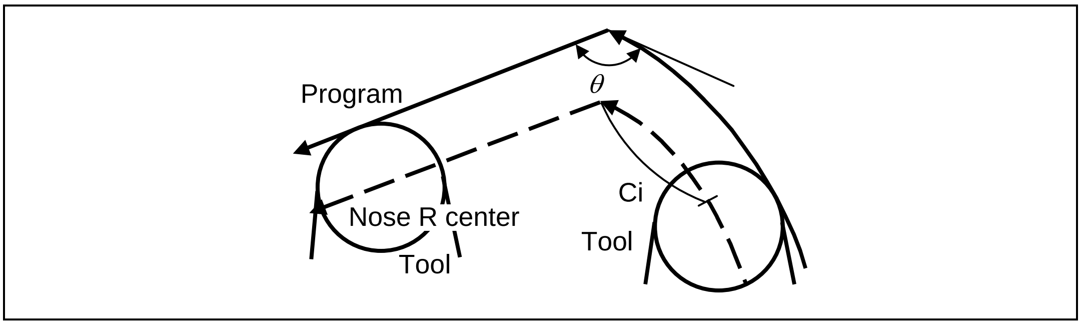
The override set in the parameter is applied at Ci.

(2) Linear – arc (outside offset) corner



The override set in the parameter is applied at Ci.

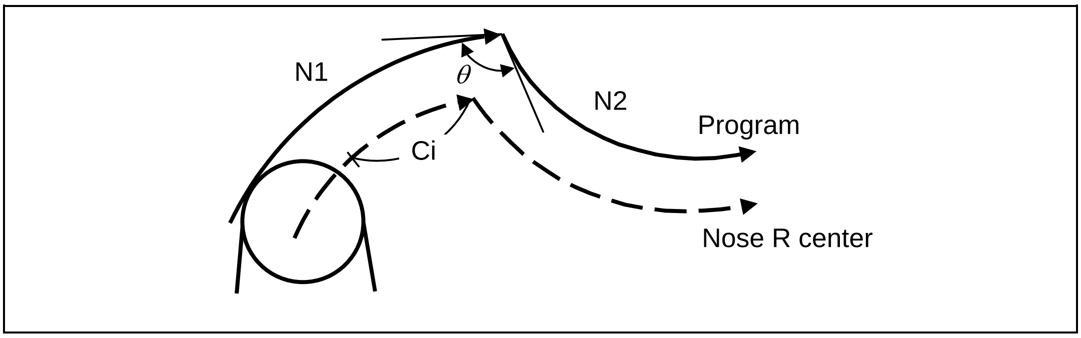
(3) Arc (inside offset) – linear corner



The override set in the parameter is applied at Ci.

(Note) The deceleration range Ci where the override is applied is the length of the arc with an arc command.

(4) Arc (inside offset) – arc (outside offset) corner



The override set in the parameter is applied at Ci.

Relation with other functions

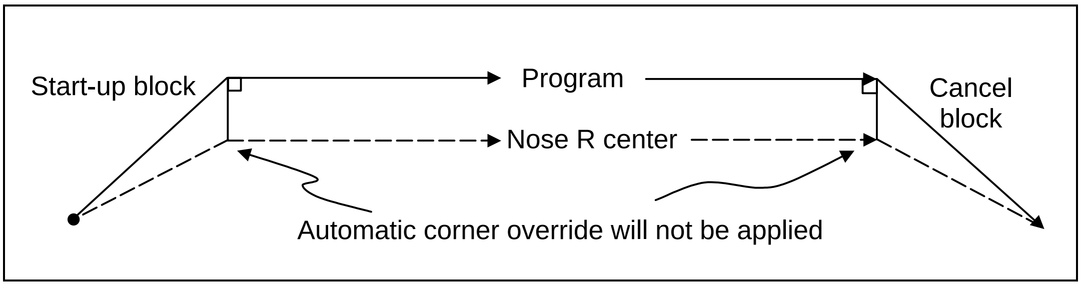
Function	Override at corner
Cutting feed override	Automatic corner override is applied after cutting feed override has been applied.
Override cancel	Automatic corner override is not canceled by override cancel.
Speed clamp	Valid after automatic corner override
Dry run	Automatic corner override is invalid.
Synchronous feed	Automatic corner override is applied to the synchronous feedrate.
Thread cutting	Automatic corner override is invalid.
G31 skip	Program error results with G31 command during nose R compensation.
Machine lock	Valid
Machine lock high speed	Automatic corner override is invalid.
G00	Invalid
G01	Valid
G02, G03	Valid

Precautions

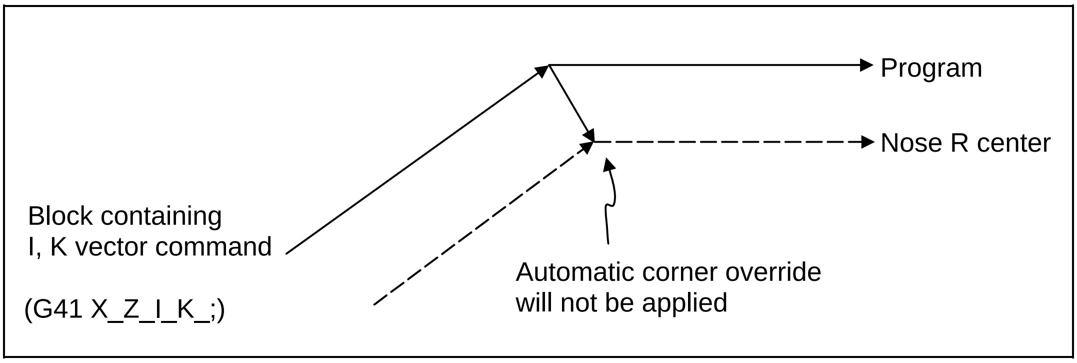
(1) Automatic corner override is valid only in the G01, G02, and G03 modes; it is not effective in the G00 mode. When switching from the G00 mode to the G01 (or G02 or G03) mode at a corner (or vice versa), automatic corner override will not be applied at that corner in the G00 block.

(2) Even if the automatic corner override mode is entered, the automatic corner override will not be applied until the nose R compensation mode is entered.

(3) Automatic corner override will not be applied on a corner where the nose R compensation is started or canceled.



(4) Automatic corner override will not be applied on a corner where the nose R compensation I, K vector command is issued.



(5) Automatic corner override will not be applied when intersection calculation cannot be executed. Intersection calculation cannot be executed in the following case.

(a) When the movement command block does not continue for four or more times.

(6) The deceleration range with an arc command is the length of the arc.

(7) The inside corner angle, as set by parameter, is the angle on the programmed path.

(8) Automatic corner override will not be applied when the maximum angle in the parameter is set to 0 or 180.

(9) Automatic corner override will not be applied when the override in the parameter is set to 0 or 100.

7.12 Tapping mode ; G63

Function and purpose

The G63 command allows the control mode best suited for tapping to be entered, as indicated below :

1. Cutting override is fixed at 100%.
2. Deceleration commands at joints between blocks are invalid.
3. Feed hold is invalid.
4. Single block is invalid.
5. In-tapping mode signal is output.

G63 is released by the exact stop check mode (G61), automatic corner override (G62), or cutting mode (G64) command.

Command format

```
G63 ;
```

7.13 Cutting mode ; G64

Function and purpose

The G64 command allows the cutting mode in which smooth cutting surfaces are obtained to be established. Unlike the exact stop check mode (G61), the next block is executed continuously with the machine not decelerating and stopping between cutting feed blocks in this mode.

G64 is released by the exact stop check mode (G61), automatic corner override (G62), or tapping mode (G63) command.

This cutting mode is established in the initialized status.

Command format

```
G64 ;
```

8. Dwell

The G04 command can delay the start of the next block. The dwell remaining time can be canceled by adding the multistep skip function.

8.1 Per-second dwell ; G04

Function and purpose

The machine movement is temporarily stopped by the program command to make the waiting time state. Therefore, the start of the next block can be delayed. The waiting time state can be canceled by inputting the skip signal.

Command format

```
G04 X/U__ ; or G04 P__ ;
X/U, P   Dwell time
```

The input command unit for the dwell time depends on the parameter.
In addition to the address P and X, the address U (actually, the address corresponding to the X-axis designated with the #1014 incax) can be used. Note that this is invalid when the #1076 AbsInc is set to 0.

Detailed description

(1) When designating the dwell time with X/U, the decimal point command is valid.

(2) The dwell time command range is as follows.
0.001 ~ 99999.999 (s)

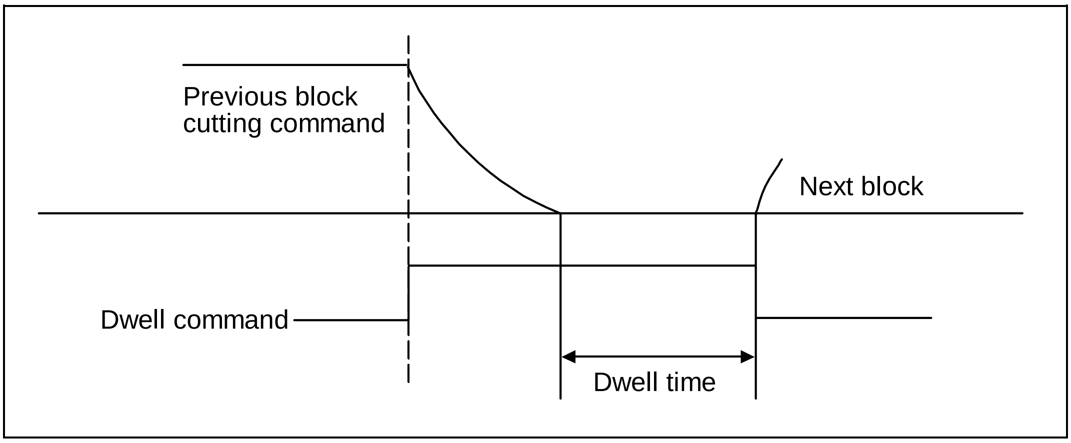
(3) The dwell time setting unit applied when there is no decimal point can be made 1s by setting 1 in the parameter #1078 Decpt2. This is effect only for X/U and P for which the decimal command is valid.

(4) When a cutting command is in the previous block, the dwell command starts calculating the dwell time after the machine has decelerated and stopped. When it is commanded in the same block as an M, S, T or B command, the calculation starts simultaneously.

(5) The dwell is valid during the interlock.

(6) The dwell is valid even for the machine lock.

(7) The dwell can be canceled by setting the parameter #1173 dwlskp beforehand. If the set skip signal is input during the dwell time, the remaining time is discarded, and the following block will be executed.



Example of program

Command	Dwell time (s)	
	#1078 Decpt2 = 0	#1078 Decpt2 = 1
G04 X500 ;	0.5	500
G04 X5000 ;	5	5000
G04 X5. ;	5	5
G04 X#100 ;	1000	1000
G04 U500 ;	0.5	500
G04 U5000 ;	5	5000
G04 U5. ;	5	5
G04 U#100 ;	100	1000
G04 P5000 ;	5	5000
G04 P12.345 ;	12.345	12.345
G04 P#100 ;	1000	1000

(Note 1) The above examples are the results under the following conditions.
- Input setting unit 0.001mm or 0.0001inch
- #100 = 1000 ;

(Note 2) If the input setting unit is 0.0001inch, the X before G04 will be multiplied by 10. For example for "X5. G04 ;", the dwell time will be 50 seconds.

Precautions and restrictions

(1) When using this function, command X/U after G04 in order to make sure that the dwell is based on X/U.

9. Miscellaneous Functions

9.1 Miscellaneous functions (M8-digits BCD)

Function and purpose

The miscellaneous (M) functions are also known as M functions, and they include such numerically controlled machine functions as spindle forward and reverse rotation, operation stop and coolant ON/OFF. These functions are designated by an 8-digit number (0 to 99999999) following the address M with this controller, and up to 4 groups can be commanded in a single block.

(Example) G00 Xx Mm1 Mm2 Mm3 Mm4 ;

When five or more commands are issued, only the last four will be valid.
The output signal is an 8-digit BCD code and start signal.
The eight commands of M00, M01, M02, M30, M96, M97, M98 and M99 are used as auxiliary commands for specific objectives and so they cannot be used as general auxiliary commands. This therefore leaves 92 miscellaneous functions which are usable as such commands. Reference should be made to the instructions issued by the machine maker for the actual correspondence between the functions and numerical values.
When the M00, M01, M02, and M30 functions are used, the next block is not read into the pre-read buffer due to pre-read inhibiting.
When an M function is specified together with a movement command in the same block, there are two possible sequences in which the commands are executed, as follows. The machine specifications determine which sequence applies.

(1) The M function is executed after the movement command.

(2) The M function is executed at the same time as the movement command.
Which of these sequences actually applies depends on the machine specifications.

Processing and completion sequences are required in each case for all M commands except M96, M97, M98 and M99. The 8 M functions used for specific purposes will now be described.

Program stop : M00

When the NC has read this function, it stops reading the next block. Whether such machine functions as the spindle rotation and coolant supply are stopped or not differs according to the machine in question.
Re-start is enabled by pressing the automatic start button on the machine operation board.
Whether resetting can be initiated by M00 depends on the machine specifications.

Optional stop : M01

If the M01 command is read when the optional stop switch on the machine operation board is ON, reading of the next block will stop and the same effect as with the M00 function will apply.

(Example)

≀ N10 G00 X1000 ; N11 M01 ; N12 G01 X2000 Z3000 F600 ; ≀	Optional stop switch command is ignored. Stops at N11 when switch is ON Next command (N12) is executed without stopping at N11 when switch is OFF

Program end : M02 or M30

This command is normally used in the final block for completing the machining, and so it is primarily used for indexing the machining program. Whether indexing the machining program or not depends on the machine specifications. Depending on the machine specifications, the system is reset by the M02 or M30 command upon completion of indexing the machining program and any other commands issued in the same block.
(Although the contents of the command position display counter are not cleared by this reset action, the modal commands and compensation amounts are canceled.)
The next operation stops when the indexing the machining program is completed (the in-automatic operation lamp goes off). To restart the unit, the automatic start button must be pressed or similar steps must be taken.

(Note 1) Independent signals are also output respectively for the M00, M01, M02 and M30 commands and these outputs are each reset by pressing the reset key.

(Note 2) M02 or M30 can be assigned by manual data input (MDI). At this time, commands can be issued simultaneously with other commands.

Macro interrupt : M96, M97

M96 and M97 are M codes for user macro interrupt control.
The M code for user macro interrupt control is processed internally, and is not output externally.
To use M96 and M97 as a miscellaneous code, change the setting to another M code with the parameter (#1109 subs_M and #1110 M96_M, #1111 M97_M).

Subprogram call/completion : M98, M99

These commands are used as the return instructions from branch destination subprograms and branches to subprograms.
M98 and M99 are processed internally and so M code signals and strobe signals are not output.

Internal processing with M00/M01/M02/M30 commands

Internal processing suspends pre-reading when the M00, M01, M02 or M30 command has been read. Indexing operation other than M02/M03 and the initialization of modals by resetting differ according the machine specifications.

9.2 2nd miscellaneous functions (A8-digits, B8-digits or C8-digits)

Function and purpose

These serve to assign the indexing table positioning and other such functions. In this controller, they are assigned by an 8-digit number from 0 to 99999999 following address A, B or C. The machine maker determines which codes correspond to which positions.
When the A, B and C functions are commanded in the same block as movement commands, there are 2 sequences in which the commands are executed, as below. The machine specifications determine which sequence applies.

(1) The A, B or C function is executed after the movement command.

(2) The A, B or C function is executed simultaneously with the movement command.

Processing and completion sequences are required for all 2nd miscellaneous functions.
The table below given the various address combinations. It is not possible to use an address which is the same for the axis name of an additional axis and 2nd miscellaneous function.

Additional axis name / 2nd miscellaneous function	A	B	C
A	×	○	○
B	○	×	○
C	○	○	×

(Note) When "A" has been assigned as the 2nd miscellaneous function address, the following commands cannot be used.

(1) Geometric commands

(2) Deep hole drilling cycle (2) command

10. Spindle Functions

10.1 Spindle function (S2-digits BCD) ..... During standard PLC specifications

Function and purpose

The spindle functions are also known simply as S functions and they assign the spindle rotation speed. In this controller, they are assigned with a 2-digit number following the S code ranging from 0 to 99, and 100 commands can be designated. In actual fact, however, it depends on the machine specifications as to how many of these 100 functions are used and which numbers correspond to which functions, and thus reference should be made to the instruction issued by the machine manufacturer. When a number exceeding 2 digits is assigned, the last 2 digits will be valid.
When S functions are commanded in the same block as movement commands, there are 2 sequences in which the commands are executed, as below. The machine specifications determine which sequence applies.

(1) The S function is executed after the movement command.

(2) The S function is executed simultaneously with the movement command.

Processing and completion sequences are required for all S commands from S00 to S99.

10.2 Spindle function (S6-digits Analog)

Function and purpose

When the S6-digits function is added, commands with a 6-dight number following the S code can be designated. Other commands conform to the S2-digits function. Always select S command binary output when using this function.
In this function, the appropriate gear signal, voltage corresponding to the commanded spindle rotation speed, and start signal are output by the numeric command of the six digits following the S code.
Processing and completion sequences are required for all S commands.
The analog signal specifications are given below.

(1) Output voltage................. 0 to 10V

(2) Resolution.........................1/4096 (2^{-12})

(3) Load conditions…………. 10kΩ

(4) Output impedance………. 220Ω

If the parameters for up to 4 gear stages are set in advance, the gear stage corresponding to the S command will be selected and the gear signal will be output. The analog voltage is calculated in accordance with the input gear signal.

(1) Parameters corresponding to individual gears……….. Limit rotation speed, maximum rotation speed, shift rotation speed and tapping rotation speed
(2) Parameters corresponding to all gears……………… Orientation rotation speed, minimum rotation speed

10.3 Spindle functions (S8-digits)

Function and purpose

These functions are assigned with an 8-digit (0 ~ 99999999) number following the address S, and one group can be assigned in one block.

The output signal is a 32-bit binary data with sign and start signal. Processing and completion sequences are required for all S commands.

10.4 Multiple spindle control I

10.4.1 Multiple spindle control

Function and purpose

Spindle rotation command for up to 7 spindles is provided.
Although the S∗∗∗∗∗ command is normally used to designate the spindle rotation speed, the Sn=∗∗∗∗∗ command is also used for multiple spindle control.
S commands can be issued from the machining program of any part systems.
Number of usable spindles differ the machine model, confirm the specifications of the model used.

Command format

Sn=∗∗∗∗∗ ;	S6-digit binary data.
n	Designate the spindle number with one numeric character.
∗∗∗∗∗	Rotation speed or constant surface speed command value.

Detailed description

(1) Each spindle command is delimited by the details of n.

(Example)

S1 = 3500 ; 1st spindle 3500(r/min) command
S2 = 1500 : 2nd spindle 1500(r/min) command
S3 = 2000 ; 3rd spindle 2000(r/min) command
S4 = 2500 : 4th spindle 2500(r/min) command
S5 = 2000 ; 5th spindle 2000(r/min) command
S6 = 3000 : 6th spindle 3000(r/min) command
S7 = 3500 ; 7th spindle 3500(r/min) command

(2) Multiple spindles can be commanded in one block.

(3) If two or more commands are issued to the same spindle in a block, the command issued last will be valid.

(Example) S1 = 3500 S1 = 3600 S1 = 3700 ; S1 = 3700 will be valid.

(4) The S∗∗∗∗∗ command and Sn=∗∗∗∗∗ command can be used together.
The spindle targeted for the S∗∗∗∗∗ command is normally the 1st spindle, however, the S∗∗∗∗∗ command can be used for 2nd or following spindle according to the spindle selection command.

(5) The commands for each spindle can be commanded from the machining program of any part systems.
The spindles will rotate with the speed commanded last.
If the S commands are issued from two or more part systems, the command from the part system of largest No. will be valid.

(6) As for C6 T-type and L-type, C64 T-type, and C64T T-type, the multiple spindles control can not be used in a part system. A program error (P33) will occur when the Sn=∗∗∗∗∗ command is issued. Refer to "10.4.2 Spindle selection command" for details.

10.4.2 Spindle selection command

Function and purpose

This function controls which spindle’s rotation the cutting follows, in addition, designates the spindle to be selected when "S******" command is issued.

Command format

G43.1;	**Selected spindle (nth spindle) control mode ON (Selected with parameter)**
G44.1;	**2nd spindle control mode ON**

Detailed description

(1) G43.1 and G44.1 are modal G codes.

(2) The spindle control mode entered when the power is turned ON or reset depends on the parameter setting.
Designate the spindle No. to be selected in G43.1 modal with the parameter (basic specifications parameter "#1199 Sselect").
This parameter is provided for every part system to set as follows.

#	Items		Details	Setting range (unit)
1199 (PR)	Sselect	Select initial spindle control	Select the initial condition of spindle control when power is turned ON or reset.	0: Selected spindle control mode (G43.1) 1: 2nd spindle control mode (G44.1)
21049	SPname		Designate the spindle No. selected for the G43.1 modal in each part system.	0: 1st spindle 4: 4th spindle 1: 1st spindle 5: 5th spindle 2: 2nd spindle 6: 6th spindle 3: 3rd spindle 7: 7th spindle

Reset the NC after changing "#1199 Sselect " and "#21049 SPname" parameters. It is no use to turn the power OFF once and ON again.

(3) As for C6 L-type, T-type, C64 T-type and C64T T-type, there are following restrictions;
· A program error (P34) will occur if G44.1 command is issued.
· No data can be set to "#1199 Sselect". "0" is set when the NC power is turned ON.
· Only one spindle than is selected with "#21049 SPname" can be commanded as "S*****" in each part system.
· A program error (P33) will occur if the "S0=*****" command is issued.

(4) If the S command is issued in the same as the spindle selection commands (G43.1, and G44.1), which spindle the S command is valid for depends on the order that G43.1, G44.1, and S command are issued.
When S command precedes the G codes, it follows the G43.1 / G44.1 mode before S command is issued.
When G codes precede, it follows the G43.1 / G44.1 mode issued in the same block.

(5) G43.1 and G44.1 commands can be issued from every part system.

Relation with other functions

(1) The following functions change after the spindle selection command.

(a) Per rotation command (synchronous feed)
Even if F is commanded in the G95 mode, the per rotation feedrate for the selected spindle (nth spindle) will be applied during G43.1 mode and for the 2nd spindle during G44.1 mode.

(b) S commands (S∗∗∗∗∗, Sn=∗∗∗∗∗), constant surface speed control, thread cutting

Function	G43.1 mode	G44.1 mode
S command during G97/G96 constant surface speed control Upper limit / Lower limit of spindle rotation speed command during constant surface speed control (G92 S_ Q) Thread cutting	Command control for the selected spindle (nth spindle). (Note 1)	Command control for the 2nd spindle.

(Note 1) The spindle selected during G43.1 mode depends on the parameter "#21049 SPname".

(2) The Sn=∗∗∗∗∗ command can be used to command the other spindle even if it is commanded during G43.1 or G44.1 mode.
Note that the rotation speed designation will be applied for such command even if the G96 mode is ON.

(Example) When "SPname" = 0;

	Rotation speed	
G43.1;	1st spindle	2nd spindle
G97 S1000; :	1000(r/min)	0(r/min)
S2 = 2000; :		2000(r/min)
G96 S100; :	100(m/min)	
S2 = 2500; :		2500(r/min)
G44.1 S200; :	(Note 2)	200(m/min)
S1 = 3000; :	3000(r/min)	
G97 S4000; :		4000(r/min)

(Note 2) The constant surface speed control will be switched to the 2nd spindle by G44.1 command. Therefore, the 1st spindle retains its rotation speed as that of "G44.1 S200;" command.
The 1st spindle rotation speed will be 3000 (r/min) when "S1=3000;" command is issued.

10.5 Constant surface speed control; G96, G97

Function and purpose

These commands automatically control the spindle rotation speed in line with the changes in the radius coordinate values as cutting proceeds in the diametrical direction, and they serve to keep the cutting point speed constant during the cutting.

Command format

G96 Ss Pp; Constant surface speed ON	
Ss	Surface speed (1 to 999999 m/min)
Pp	Designation of constant surface speed control axis

G97; Constant surface speed cancel

Detailed description

(1) The constant surface speed control axis is set by parameter (#1181 G96_ax).
0 : Fixed at 1st axis (P command invalid)
1 : 1st axis
2 : 2nd axis
3 : 3rd axis

(2) When the above-mentioned parameter is not zero, the constant surface speed control axis can be designated by address P.
(Example) When G96_ax = 1

Program	Constant surface speed control axis
G96 S100 ;	1st axis
G96 S100 P3 ;	3rd axis

(3) Example of selection program and operation

```
G90 G96 G01 X50. Z100. S200 ;   } The spindle rotation speed is controlled so that
        ≀                       } the surface speed is 200m/min.
G97 G01 X50. Z100. F300 S500 ;  } The spindle rotation speed is controlled to 500
        ≀                       } r/min.
M02 ;                             The modal returns to the initial value.
```

(4) Constant surface speed control can be commanded on the selected spindle (nth spindle) / the 2nd spindle.
Select which spindle (the selected spindle or 2nd one) the commands are made to by the spindle selection G codes (G43.1 and G44.1).
Select which spindle (the selected spindle or 2nd one) is valid as the initial state with the parameter (base specifications parameter "#1199 Sselect").

(5) Select whether calculating the surface speed at rapid traverse command is performed constantly or only at the block end poing.

10.6 Spindle clamp speed setting; G92

Function and purpose

The maximum clamp rotation speed of the spindle can be assigned by address S following G92 and the minimum clamp rotation speed by address Q.

Command format

G92 Ss Qq ;

Ss	Maximum clamp rotation speed
Qq	Minimum clamp rotation speed

Detailed description

(1) Besides this command, parameters can be used to set the rotation speed range up to 4 stages in 1 r/min units to accommodate gear selection between the spindle and spindle motor. The lowest upper limit and highest lower limit are valid among the rotation speed ranges based on the parameters and based on "G92 Ss Qq ;".

(2) Set in the parameters "#1146 Sclamp" and "#1227 aux11/bit5" whether to carry out rotation speed clamp only in the constant surface speed mode or even when the constant surface speed is canceled.

(Note) G92S command and rotation speed clamp operation

		Sclamp = 0		**Sclamp = 1**	
		aux11/bit5 = 0	**aux11/bit5 = 1**	**aux11/bit5 = 0**	**aux11/bit5 = 1**
Command	**In G96**	Rotation speed clamp command		Rotation speed clamp command	Rotation speed clamp command
	In G97	Spindle rotation speed command		Rotation speed clamp command	Rotation speed clamp command
Operation	**In G96**	Rotation speed clamp execution		Rotation speed clamp execution	Rotation speed clamp execution
	In G97	No rotation speed clamp		Rotation speed clamp execution	No rotation speed clamp

(3) Spindle clamp speed command can be commanded on the selected spindle (nth spindle) / the 2nd spindle.
Select which spindle (the selected spindle or 2nd one) the commands are made to by the spindle selection G codes (G43.1 and G44.1).
Select which spindle (the selected spindle or 2nd one) is valid as the initial state with the parameter (base specifications parameter "#1199 Sselect").

10.7 Spindle synchronous control I; G114.1

Function and purpose

In a machine having two or more spindles, this function controls the rotation speed and phase of one spindle (basic spindle) in synchronization with the rotation of the other spindle (synchronous spindle).
The function is used "when the rotation speed of the two spindles must be matched, for example, if a workpiece grasped by the 1st spindle is to be grasped by a 2nd spindle", or "if the spindle rotation speed has to be changed when one workpiece is grasped by both the 1st and 2nd spindles".
With the spindle synchronous control function I, designation of spindles and controls start / stop of synchronization are commanded using G codes in the machining program.

Command format

(1) Spindle synchronous control ON (G114.1)

This command designates the basic spindle and synchronous spindle, and synchronizes the two designated spindles. By commanding the synchronous spindle phase shift amount, the phases of the basic spindle and synchronous spindle can be aligned.

G114.1 H_ D_ R_ A_ ;

H_	Basic spindle selection
D_	Synchronous spindle selection
R_	Spindle synchronization phase shift amount
A_	Spindle synchronization acceleration/deceleration time constant

(2) Spindle synchronous control cancel (G113)

This command cancels the synchronous state of the two spindles rotating in synchronization with the spindle synchronous command.

G113 ;

Address	Meaning of address	Command range (unit)	Remarks
H	Basic spindle selection Select the No. of the spindle to be used as the basic spindle from the two spindles.	1 to 7 1: 1st spindle 2: 2nd spindle : 7: 7th spindle	• A program error (P35) will occur if a value exceeding the command range or spindle No. without specifications is commanded. • A program error (P33) will occur if there is no command. • A program error (P610) will occur if a spindle not serially connected is commanded.

Add-ress	Meaning of address	Command range (unit)	Remarks
D	Synchronous spindle selection Select the No. of the spindle to be synchronized with the basic spindle from the two spindles.	1 to 7 or –1 to –7 1: 1st spindle 2: 2nd spindle : 7: 7th spindle	• A program error (P35) will occur if a value exceeding the command range or spindle No. without specifications is commanded. • A program error (P33) will occur if there is no command. • A program error (P33) will occur if the same spindle as that commanded for the basic spindle selection is designated. • The rotation direction of the synchronous spindle in respect to the basic spindle is commanded with the D sign. • A program error (P610) will occur if a spindle not serially connected is commanded.
R	Synchronous spindle phase shift amount Command the shift amount from the Z-phase point (one rotation signal) of the synchronous spindle.	0 to 359.999 (°) or 0 to 35999 (° × 10^{-3})	• A program error (P35) will occur if a value exceeding the command range is commanded. • The commanded shift amount is effective in the clockwise direction of the basic spindle. • The commanded shift amount's minimum resolution is as follows: For semi-closed (Only gear ratio 1:1) 360/4096 (°) For full closed (360/4096) ∗ K (°) K: Spindle and encoder gear ratio • If there is no R command, the phases will not be aligned.
A	Spindle synchronization acceleration/deceleration time constant Command the acceleration/deceleration time constant for when the spindle synchronous command rotation speed changes. (Command this to accelerate or decelerate at a speed slower than the time constant set in the parameters.)	0.001 to 9.999 (s) or 1 to 9999 (ms)	• A program error (P35) will occur if a value exceeding the command range is commanded. • If the commanded value is smaller than the acceleration/deceleration time constant set with the parameters, the value set in the parameters will be applied.

Rotation and rotation direction

(1) The rotation speed and rotation direction of the basic spindle and synchronous spindle during spindle synchronous control are the rotation speed and rotation direction commanded for the basic spindle. Note that the rotation direction of the synchronous spindle can be reversed from the basic spindle through the program.

(2) The basic spindle's rotation speed and rotation direction can be changed during spindle synchronous control.

(3) The synchronous spindle's rotation command is also valid during spindle synchronous control. When spindle synchronous control is commanded, if neither a forward run command nor reverse run command is commanded for the synchronous spindle, the synchronization standby state will be entered without starting the synchronous spindle's rotation. If the forward run command or reverse run command is input in this state, the synchronous spindle will start rotation. The synchronous spindle's rotation direction will follow the direction commanded in the program.

If spindle stop is commanded for the synchronous spindle during spindle synchronization control (when both the forward run and reverse run commands are turned OFF), the synchronous spindle rotation will stop.

(4) The rotation speed command (S command) and constant surface speed control are invalid for the synchronous spindle during spindle synchronous control. Note that the modal is updated, so these will be validated when the spindle synchronization is canceled.

(5) The constant surface speed can be controlled by issuing a command to the basic spindle even during spindle synchronous control.

Rotation synchronization

(1) When rotation synchronization control (command with no R address) is commanded with the G114.1 command, the synchronous spindle rotating at a random rotation speed will accelerate or decelerate to the rotation speed commanded beforehand for the basic spindle, and will enter the rotation synchronization state.

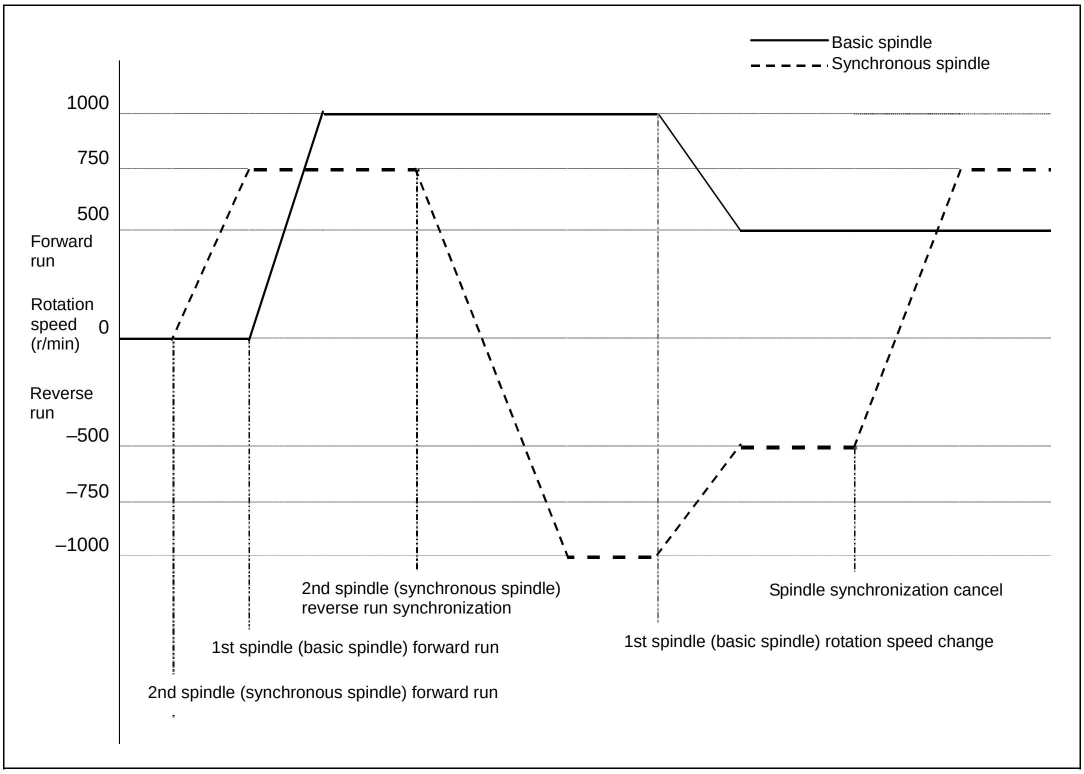
(2) If the basic spindle's commanded rotation speed is changed during the rotation synchronization state, acceleration/deceleration will be carried out while maintaining the synchronization state following the spindle acceleration/deceleration time constants set in the parameters, and the commanded rotation speed will be achieved.

(3) In the rotation synchronization state, the basic spindle can be controlled to the constant surface speed even when two spindles are grasping one workpiece.

(4) Operation will take place in the following manner.

```
M23 S2=750 ;        ... Forward rotate 2nd spindle (synchronous spindle) at 750
:                       r/min (speed command)
M03 S1=1000 ;       ... Forward rotate 1st spindle (basic spindle) at 1000 r/min
:                       (speed command)
G114.1 H1 D-2 ;     ... Synchronize 2nd spindle (synchronous spindle) to 1st
:                       spindle (basic spindle) with reverse run
S1=500 ;            ... Change 1st spindle (basic spindle) rotation speed to 500
:                       r/min
G113 ;              ... Cancel spindle synchronization
```

<Operation>



Phase synchronization

(1) When phase synchronization (command with R address) is commanded with the G114.1 command, the synchronous spindle rotating at a random rotation speed will accelerate or decelerate to the rotation speed commanded beforehand for the basic spindle, and will enter the rotation synchronization state.
Then, the phase is aligned so that the rotation phase commanded with the R address is reached, and the phase synchronization state is entered.

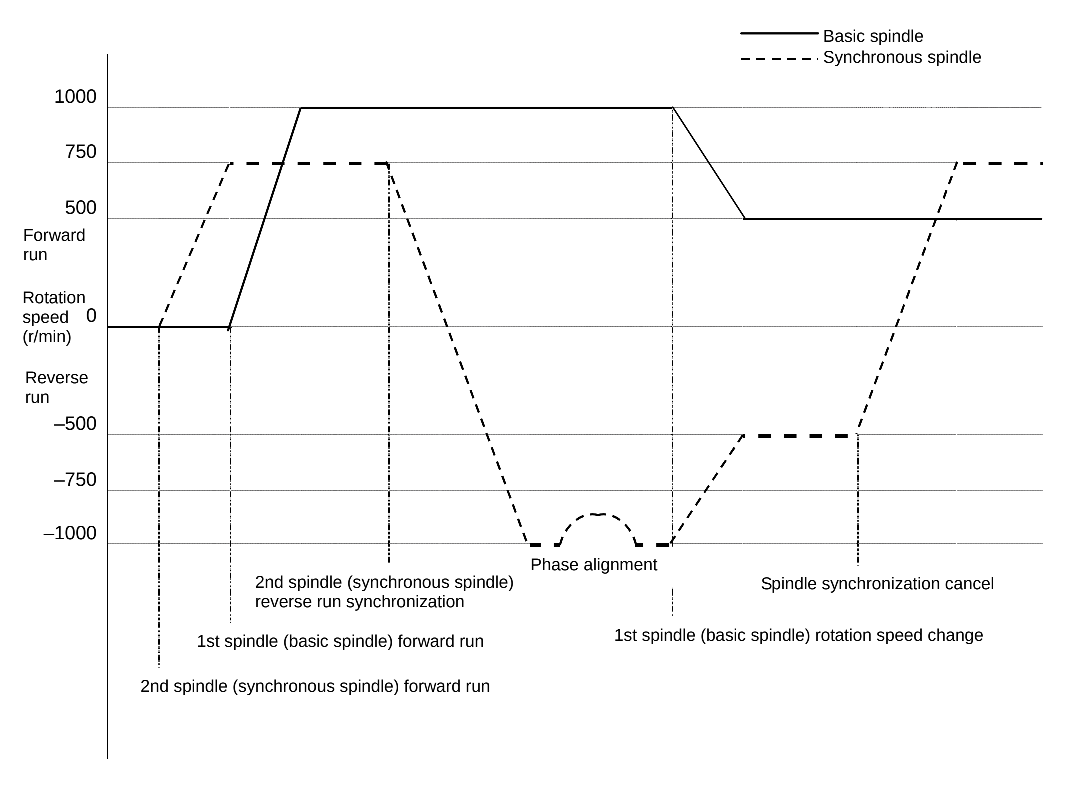
(2) If the basic spindle's commanded rotation speed is changed during the phase synchronization state, acceleration/deceleration will be carried out while maintaining the synchronization state following the spindle acceleration/deceleration time constants set in the parameters, and the commanded rotation speed will be achieved.

(3) In the phase synchronization state, the basic spindle can be controlled to the constant surface speed even when two spindles are grasping one workpiece.

(4) Operation will take place in the following manner.

```
M23 S2=750 ;           ...  Forward rotate 2nd spindle (synchronous spindle) at 750
:                           r/min (speed command)
M03 S1=1000 ;          ...  Forward rotate 1st spindle (basic spindle) at 1000 r/min
:                           (speed command)
G114.1 H1 D-2 Rxx ;    ...  Synchronize 2nd spindle (synchronous spindle) to 1st
:                           spindle (basic spindle) with reverse run
:                           Shift phase of synchronous spindle by R command value
S1=500 ;               ...  Change 1st spindle (basic spindle) rotation speed to 500
:                           r/min
G113 ;                 ...  Cancel spindle synchronization
```

<Operation>



Cautions on programming

(1) To enter the rotation synchronization mode while the basic spindle and synchronous spindle are chucking the same workpiece, turn the basic spindle and synchronous spindle rotation commands ON before turning the spindle synchronous control mode ON.

```
$1 (1st part system)                      $2 (2nd part system)
:                                         :
M6 ;          1st spindle chuck close     :
:                                         M25 S2=0 ;      2nd spindle stops at S=0
:                                         :
!2 ;  ----------------------------------  !1 ;            Waiting between part
                                                          systems
M5 S1=0 ;     1st spindle stops at S=0    M15 ;           2nd spindle chuck close
:                                         M24 ;           2nd spindle rotation
                                                          command ON
M3 ;          1st spindle rotation        :
              command ON
!2 ;  ----------------------------------  !1 ;            Waiting between part
                                                          systems
:                                         G114.1 H1 D-2 ; Rotation synchronization
:                                         :                            mode ON
S1=1500 ;     Synchronous rotation at     :
              S=1500
:                                         :
S1=0 ;        Both spindles stop
G113 ;        Synchronization mode OFF
```

(2) To chuck the same workpiece with the basic spindle and synchronous spindle in the phase synchronization mode, align the phases before chucking.

```
$1                                        $2
:                                         :
M6 ;          1st spindle chuck close     :
:                                         :
M3 S1=1500 ;  1st spindle rotation        :
              command ON
:                                         G114.1 H1 D-2 R0 ; Phase synchronization
:                                         :                            mode ON
:                                         M24 ;           2nd spindle rotation
                                                          command ON
:                                         :
:                                         M15 ;           2nd spindle chuck close
                                                          (Note 1)
:                                         :
```

(Note 1) Close the chuck after confirming that the spindle phase synchronization complete signal (X42A) has turned ON (phase alignment complete).

⚠ CAUTION

⚠ Do not make the synchronous spindle rotation command OFF with one workpiece chucked by the basic spindle and synchronous spindle during the spindle synchronous control mode.
Failure to observe this may cause the synchronous spindle stop, and hazardous situation.

Precautions and restrictions

(1) To carry out the spindle synchronization, it is required to command spindle rotation for both basic spindle and synchronous spindle. Note that the rotating direction of the synchronous spindle follows the rotating direction of the basic spindle and rotating direction designation by "D" address.

(2) The spindle rotating with spindle synchronous control will stop when emergency stop is applied.

(3) The rotation speed clamp during spindle synchronization control will follow the smaller clamp value set for the basic spindle or synchronous spindle.

(4) Orientation of the basic spindle and synchronous spindle is not possible during the spindle synchronous control mode. To carry out orientation, cancel the spindle synchronous control mode first.

(5) The rotation speed command (S command) is invalid for the synchronous spindle during the spindle synchronous control mode. Note that the modal will be updated, so this will be validated when spindle synchronous control is canceled.

(6) The constant surface speed control is invalid for the synchronous spindle during the spindle synchronization control mode. Note that the modal will be updated, so this will be validated when spindle synchronization is canceled.

(7) The rotation speed command (S command) and constant surface speed control for the synchronous spindle will be validated when spindle synchronous control is canceled. Thus, the synchronous spindle may carry out different operations when this control is canceled.

(8) An attention should be made that if the phase synchronization command is executed with the phase error not obtained by the phase shift calculation request signal, the phase shift amount will not be obtained correctly.

(9) The spindle rotation speed command (S command) and the constant surface speed control for the synchronous spindle will become valid when the spindle synchronous control is canceled. Thus, special attention should be made because the synchronous spindle may do different action than before when the spindle synchronous control is canceld.

(10) If the phase synchronization command (command with R address) is issued while the phase shift calculation request signal is ON, an operation error (1106) will occur.

(11) If the phase shift calculation request signal is ON and the basic spindle or synchronous spindle is rotation while rotation synchronization is commanded, an operation error (1106) will occur.

(12) If the phase synchronization command R0 (<Ex.> G114.2 H1 D-2 R0) is commanded while the phase offset request signal is ON, the basic spindle and synchronous spindle phases will be aligned to the phase error of the basic spindle and synchronous spindle saved in the NC memory.

(13) If a value other than the phase synchronization command R0 (<Ex.> G114.1 H1 D-2 R000) is commanded while the phase offset request signal is ON, the phase error obtained by adding the value commanded with the R address command to the phase difference of the basic spindle and synchronous spindle saved in the NC memory will be used to align the basic spindle and synchronous spindle.

(14) The phase offset request signal will be ignored when the phase shift calculation request signal is ON.

(15) The phase error of the basic spindle and synchronous spindle saved in the NC is valid only when the phase shift calculation signal is ON and for the combination of the basic spindle selection (H_) and synchronous spindle (D_) commanded with the rotation synchronization command (no R address).
For example, if the basic spindle and synchronous spindle phase error is saved as "G114.1 H1 D-2 ;", the saved phase error will be valid only when the phase offset request signal is ON and "G114.1 H1 D_2 R∗∗∗ ;" is commanded. If "G114.1 H2 D-1 R∗∗∗ ;" is commanded in this case, the phase shift amount will not be calculated correctly.

(16) The phase error of the basic spindle and synchronous spindle saved in the NC is retained until the spindle synchronization phase shift calculation, in other words, until the rotation synchronous control command completes with the phase shift calculation request signal is ON.

(17) Synchronous tapping can not be used during spindle synchronous mode.

(18) When the spindle synchronous control commands are being issued with the PLC I/F method (#1300 ext36/bit7 OFF), a program error (P610) will occur if the spindle synchronous control is commanded with G114.1/G113.

10.8 Spindle synchronization control II

Function and purpose

In a machine having two or more spindles, this function controls the rotation speed and phase of one spindle (synchronous spindle) in synchronization with the rotation of the other spindle (basic spindle).
The function is used if a workpiece grasped by the basic spindle is to be grasped by a synchronous spindle, or if the spindle rotation speed has to be changed when one workpiece is grasped by both spindles.
With the spindle synchronous control II, selection of the spindles and synchronization start, etc., are all designated from the PLC.

Basic spindle and synchronous spindle selection

Select the basic spindle and synchronous spindle for synchronous control from the PLC.

Device No.	Signal name	Abbrev.	Explanation
R157	Basic spindle selection	–	Select a serially connected spindle to be controlled as the basic spindle. (0: 1st spindle), 1: 1st spindle, 2: 2nd spindle, … , 7: 7th spindle **(Note 1)** Spindle synchronization control will not take place if a spindle not connected in serial is selected. **(Note 2)** If "0" is designated, the 1st spindle will be controlled as the basic spindle.
R158	Synchronous spindle selection	–	Select a serially connected spindle to be controlled as the synchronous spindle. (0: 2nd spindle), 1: 1st spindle, 2: 2nd spindle, … , 7: 7th spindle **(Note 3)** Spindle synchronous control will not take place if a spindle not connected in serial is selected or if the same spindle as the basic spindle is selected. **(Note 4)** If "0" is designated, the 2nd spindle will be controlled as the synchronous spindle.

Starting spindle synchronization

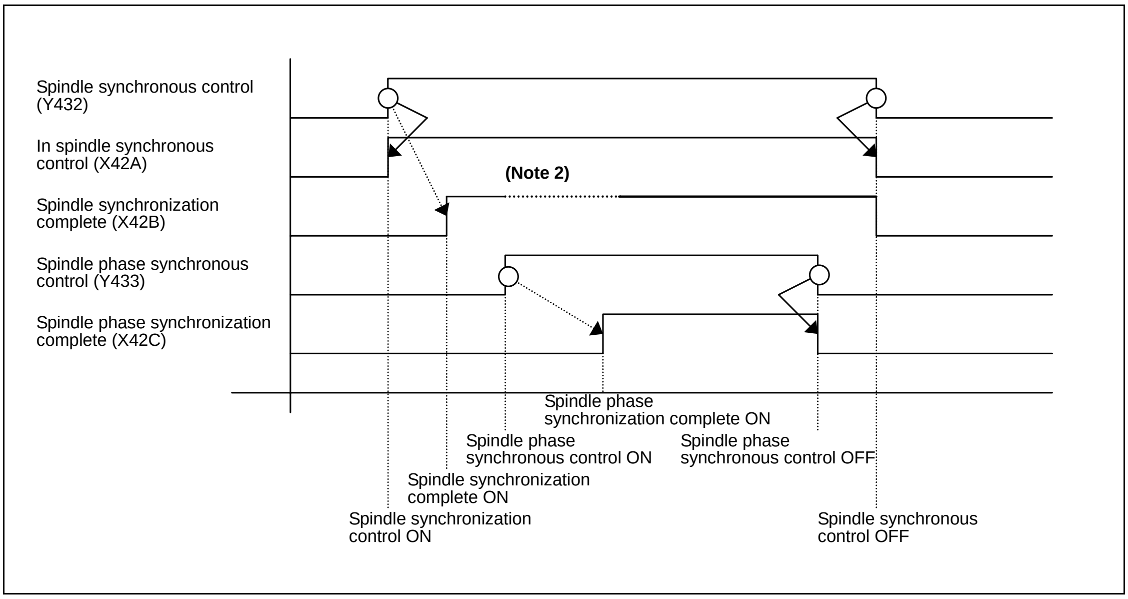
The spindle synchronous control mode is entered by inputting the spindle synchronous control signal (SPSYC). The synchronous spindle will be controlled in synchronization with the rotation speed commanded for the basic spindle during the spindle synchronous control mode.
When the difference of the basic spindle and synchronous spindle rotation speeds reaches the spindle synchronization rotation speed reach level setting value (#3050 sprlv), the spindle rotation speed synchronization complete signal (FSPRV) will be output.
The synchronous spindle's rotation direction is designated with the spindle synchronization rotation direction designation as the same as the basic spindle or the reverse direction.

Device No.	Signal name	Abbrev.	Explanation
Y432	Spindle synchronous control	SPSYC	The spindle synchronous control mode is entered when this signal turns ON.
X42A	In spindle synchronous control	SPSYN1	This notifies that the mode is the spindle synchronous control.
X42B	Spindle rotation speed synchronization complete	FSPRV	This turns ON when the difference of the basic spindle and synchronous spindle rotation speeds reaches the spindle rotation speed reach level setting value during the spindle synchronous control mode. This signal turns OFF when the spindle synchronous control mode is canceled, or when an error exceeding the spindle rotation speed reach level setting value occurs during the spindle synchronous control mode.
Y434	Spindle synchronization rotation direction designation	SPSDR	Designate the basic spindle and synchronous spindle rotation directions for spindle synchronous control. 0: The synchronous spindle rotates in the same direction as the basic spindle. 1: The synchronous spindle rotates in the reverse direction of the basic spindle.

Spindle phase alignment

Spindle phase synchronization starts when the spindle phase synchronous control signal (SPPHS) is input during the spindle synchronization control mode. The spindle phase synchronization complete signal is output when the spindle synchronization phase reach level setting value (#3051 spplv) is reached.
The synchronous spindle's phase shift amount can also be designated from the PLC.

Device No.	Signal name	Abbrev.	Explanation
Y433	Spindle phase synchronous control	SPPHS	Spindle phase synchronization starts when this signal is turned ON during the spindle synchronous control mode. **(Note 1)** If this signal is turned ON in a mode other than the spindle synchronous control mode, it will be ignored.
X42C	Spindle phase synchronization complete	FSPPH	This signal is output when the spindle synchronization phase reach level is reached after starting spindle phase synchronization.
R159	Phase shift amount setting	–	Designate the synchronous spindle's phase shift amount. Unit: 360°/4096

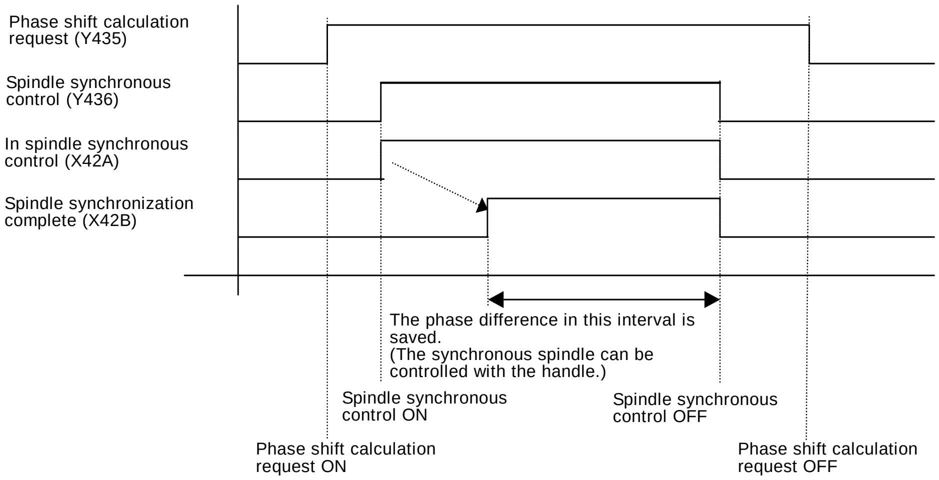

Spindle synchronous control (Y432)
In spindle synchronous control (X42A)
(Note 2)
Spindle synchronization complete (X42B)
Spindle phase synchronous control (Y433)
Spindle phase synchronization complete (X42C)
Spindle phase synchronization complete ON
Spindle phase synchronous control ON
Spindle phase synchronous control OFF
Spindle synchronization complete ON
Spindle synchronization control ON
Spindle synchronous control OFF

(Note 2) Turns OFF temporarily to change the rotation speed during phase synchronization.

Calculating the spindle synchronization phase shift amount and requesting phase offset

The spindle phase shift amount calculation function obtains and saves the phase difference of the basic spindle and synchronous spindle by turning the PLC signal ON during spindle synchronization. When calculating the spindle phase shift, the synchronous spindle can be rotated with the handle, so the relation of the phases between the spindles can also be adjusted visually.
If the spindle phase synchronization control signal is input while the phase offset request signal (SSPHF) is ON, the phases will be aligned using the position shifted by the saved phase shift amount as a reference.
This makes aligning of the phases easier when grasping the material that the shape of one end differ from another end.

Device No.	Signal name	Abbrev.	Explanation
Y435	Phase shift calculation request	SSPHM	If spindle synchronization is carried out while this signal is ON, the phase difference of the basic spindle and synchronous spindle will be obtained and saved.
Y436	Phase offset request	SSPHF	If spindle phase synchronization is carried out while this signal is ON, the phases will be aligned using the position shifted by the saved phase shift amount as a basic position.
R55	Phase difference output	–	The delay of the synchronous spindle in respect to the basic spindle is output. Unit: 360°/4096 **(Note 1)** If either the basic spindle or synchronous spindle has not passed through the Z phase, etc., and the phase cannot be calculated, –1 will be output. **(Note 2)** This data is output only while calculating the phase shift or during spindle phase synchronization.
R59	Phase offset data	–	The phase difference saved with phase shift calculation is output. Unit: 360°/4096 **(Note 3)** This data is output only during spindle synchronous control.

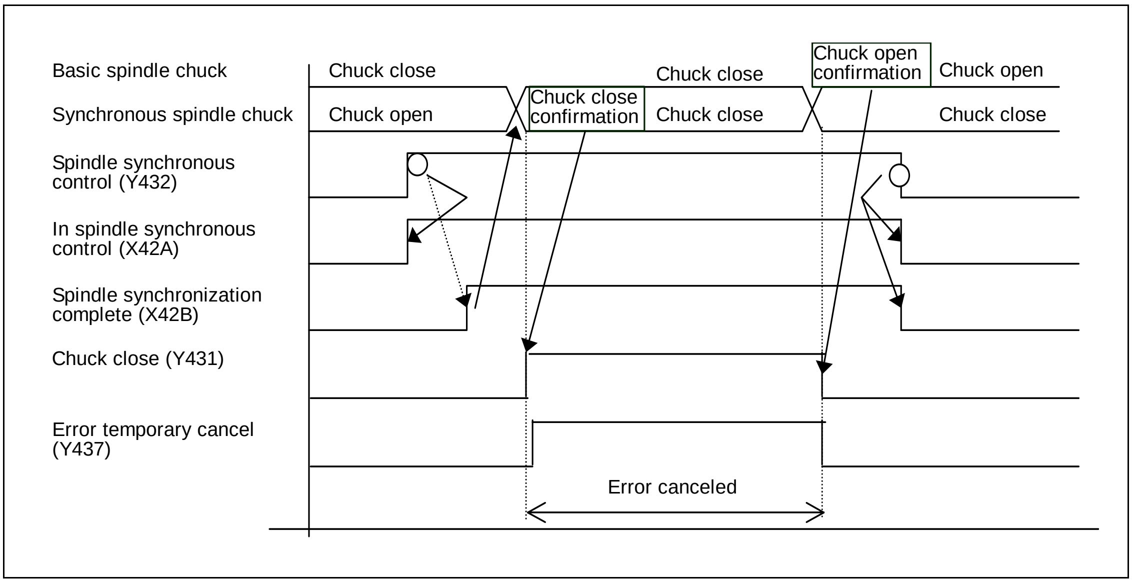

Phase shift calculation request (Y435)
Spindle synchronous control (Y436)
In spindle synchronous control (X42A)
Spindle synchronization complete (X42B)
The phase difference in this interval is saved.
(The synchronous spindle can be controlled with the handle.)
Spindle synchronous control ON
Spindle synchronous control OFF
Phase shift calculation request ON
Phase shift calculation request OFF

(Note 4) The phases cannot be aligned while calculating the phase shift.
(Note 5) The synchronous spindle cannot be rotated with the handle when the manual operation mode is set to the handle mode.

Chuck close signal

The synchronous spindle side carries out droop compensation while the chuck is opened, and aligns itself with the basic spindle. However, when the chuck is closed, the droop compensation is added, and the synchronization error with the base increases. Droop compensation is prevented with the chuck close signal and the position where the chuck is grasped is maintained with position compensation.

Device No.	Signal name	Abbrev.	Explanation
Y431	Chuck close	SPCMPC	This turns ON when the chuck of both spindles are closed. This signal is ON while the basic spindle and the synchronous spindle grasp the same workpiece.
X42D	Chuck close confirmation	SPCMP	This turns ON when the chuck close signal is received during the spindle synchronous control mode.


Basic spindle chuck
Synchronous spindle chuck
Spindle synchronous control (Y432)
In spindle synchronous control (X42A)
Spindle synchronization complete (X42B)
Chuck close (Y431)
Error temporary cancel (Y437)
Chuck close
Chuck open
Chuck close confirmation
Chuck close
Chuck close
Chuck open confirmation
Chuck open
Chuck close
Error canceled

(Note 1) Use the error temporary cancel only when there is still an error between the spindle and synchronization with the chuck close signal.

Error temporary cancel function

When spindle synchronization is carried out while grasping the workpiece with the basic spindle and rotating, if the chuck is closed to grasp the workpiece with the synchronous spindle, the speed will fluctuate due to external factors and an error will occur. If spindle synchronization is continued without compensating this error, the workpiece will twist.
This torsion can be prevented by temporarily canceling this error.

Device No.	Signal name	Abbrev.	Explanation
Y437	Error temporary cancel	SPDRP0	The error is canceled when this signal is ON.

(Note 1) Even if the chuck close signal (Y431) is OFF, the error will be canceled while this signal (Y437) is ON.

(Note 2) Turn this signal ON after the both chucks of basic spindle side and synchronous spindle side are closed to grasp the workpiece.
Turn this signal OFF if even one chuck is opened.

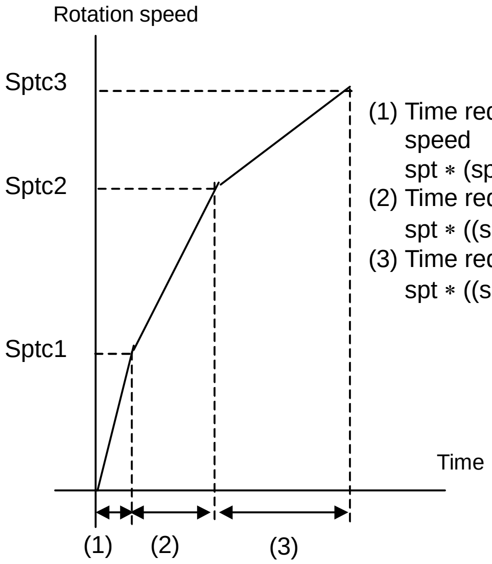
Phase error monitor

The phase error can be monitored during spindle phase synchronization.

Device No.	Signal name	Abbrev.	Explanation
R56	Phase error monitor	–	The phase error during spindle phase synchronous control is output as a pulse unit.
R57	Phase error monitor (lower limit value)	–	The lower limit value of the phase error during spindle phase synchronous control is output as a pulse unit.
R59	Phase error monitor (upper limit value)	–	The upper limit value of the phase error during spindle phase synchronous control is output as a pulse unit.

Multi-speed acceleration/deceleration

Up to eight steps of acceleration/deceleration time constants for spindle synchronization can be selected according to the spindle rotation speed.



(1) Time required from stopped state to sptc1 setting rotation speed
spt ∗ (sptc1/maximum rotation speed)
(2) Time required from sptc1 to sptc2 setting rotation speed
spt ∗ ((sptc2–sptc1)/maximum rotation speed) ∗ spdiv1
(3) Time required from sptc2 to sptc3 setting rotation speed
spt ∗ ((sptc3–sptc2)/maximum rotation speed) ∗ spdiv2

Precautions and restrictions

(1) When carrying out spindle synchronization, a rotation command must be issued to both the basic spindle and synchronous spindle. The synchronous spindle's rotation direction will follow the basic spindle rotation direction and spindle synchronization rotation direction designation regardless of whether a forward or reverse run command is issued.

(2) The spindle synchronization control mode will be entered even if the spindle synchronization control signal is turned ON while the spindle rotation speed command is ON. However, synchronous control will not actually take place. Synchronous control will start after the rotation speed is commanded to the basic spindle, and then the spindle synchronization complete signal will be output.

(3) The spindle rotating with spindle synchronization control will stop when emergency stop is applied.

(4) An operation error will occur if the spindle synchronization control signal is turned ON while the basic spindle and synchronous spindle designations are illegal.

(5) The rotation speed clamp during spindle synchronization control will follow the smaller clamp value set for the basic spindle or synchronous spindle.

(6) Orientation of the basic spindle and synchronous spindle is not possible during the spindle synchronization. To carry out orientation, turn the spindle synchronization control signal OFF first.

(7) The rotation speed command is invalid for the synchronous spindle during the spindle synchronization. Note that the modal is rewritten, thus, the commanded rotation speed will be validated after spindle synchronization is canceled.

(8) The constant surface speed control is invalid for the synchronous spindle during the spindle synchronization. However, note that the modal is rewritten and it will be valid after spindle synchronization is canceled.

(9) If the phase offset request signal is turned ON before the phase shift is calculated and then spindle phase synchronization is executed, the shift amount will not be calculated and incorrect operation results.

(10) The spindle rotation speed command (S command) and the constant surface speed control for the synchronous spindle will become valid when the spindle synchronous control is canceled. Thus, special attention should be made because the synchronous spindle may do different action than before when the spindle synchronous control is canceled.

(11) The spindle Z-phase encoder position parameter (sppst) is invalid (ignored) when phase offset is carried out.
This parameter will be valid when the phase offset request signal is OFF.

(12) If spindle phase synchronization is started while the phase shift calculation request signal is ON, the error "M01 OPERATION ERROR 1106" will occur.

(13) Turn the phase shift calculation request signal ON when the basic spindle and synchronous spindle are both stopped. If the phase shift calculation request signal is ON while either of the spindles is rotating, the error "M01 OPERATION ERROR 1106" will occur.

(14) The phase offset request signal is ignored when the phase shift calculation request signal (Y435) is ON.

(15) "M01 OPERATION ERROR 1106" will occur when a spindle No. out of specifications is designated in the R registers to set the basic spindle and the synchronous spindle, or when the spindle synchronous control signal (Y432) is turned ON with R resister value illegal.

(16) The phase shift amount saved in the NC is held until the next phase shift is calculated. (This value is saved even when the power is turned OFF.)

(17) Synchronous tapping can not be used during spindle synchronous mode.

11. Tool Functions

11.1 Tool functions (T8-digits BCD)

Function and purpose

Tool functions are also known as T functions, and are used to designate the tool Nos. and tool compensation Nos. The designations are made by the 8 digits (0 to 99999999) following the address T. These commands are used with the higher-order six or seven digits indicating the tool No., and the lower-order one or two digits indicating the compensation No.
Which is to be used is determined by setting in the parameter "#1098 TLno.". The usable T commands differ according to each machine, so refer to the instruction manual issued by the machine maker. One set of T commands can be issued in one block.

Command format

```
T   *******   *   ;
       |      └──────Tool compensation number
       └─────────────Tool number

T   ******   **   ;
       |      └──────Tool compensation number
       └─────────────Tool number
```

Reference should be made to the instructions issued by the machine maker for the correspondence between the actual tools and the tool numbers commanded in the program.
BCD codes and start signals are output.
When the T functions are commanded in the same block as movement commands, there are 2 sequences in which the commands are executed, as below. The machine specifications determine which sequence applies.

(a) The T function is executed after the movement command.

(b) The T function is executed simultaneously with the movement command.

Processing and completion sequences are required for all T commands.

12. Tool Offset Functions

12.1 Tool offset

Function and purpose

Tool offset is performed by the T functions which are commanded with the 3-, 4- or 8-digit number following address T. There are two types of tool offset: tool length offset and tool nose wear offset. There are two ways to issue the commands: the tool length offset and tool nose wear offset are designated by the last 1 or 2 digits of the T command or the tool nose wear offset is assigned by the last 1 or 2 digits of the T command and the tool length offset by the tool number. Parameter "#1098 TLno." is used to switch between them. Parameter "#1097 T1digt" is also used to select the last 1 or 2 digits for the offset.
One group of T command can be assigned in a block.

Command format

(1) When designating the tool length and tool nose wear offset number using the last 1 or 2 digits of the T command.

```
T ******* * ;
                    Tool length offset + tool nose wear offset
                    Tool number

T ****** ** ;
                    Tool length offset + tool nose wear offset
                    Tool number
```

(2) When differentiating between the tool length offset number and tool nose wear offset number

```
T ******* * ;
                    Tool nose wear offset
                    Tool number + tool length offset

T ****** ** ;
                    Tool nose wear offset
                    Tool number + tool length offset
```

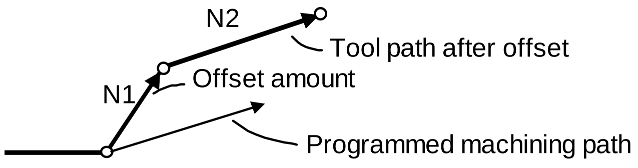
The lower two digits of the tool No. are the tool length offset No.

12.1.1 Tool offset start

Detailed description

There are two ways to execute tool offset and these can be selected by parameter: executing offset when the T command is executed and executing offset in the block with a movement command without performing offset when the T command is executed.

(1) Offset with T command execution

 N2 Tool path after offset Offset amount N1 Programmed machining path	N1 T0101 ; N2 X100. Z200. ;

Tool length offset and tool nose wear offset are conducted simultaneously.

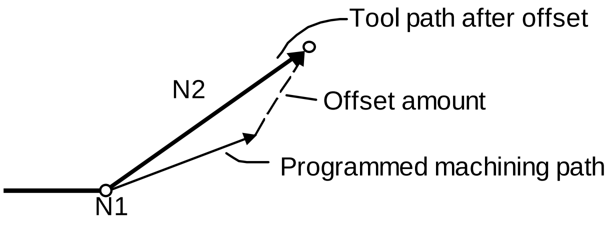
(Note 1) The movement applying to offset with the T command execution is rapid traverse in a G00 modal and cutting feed with other modals.

(Note 2) When performing offset with T command execution, the path is offset as a linear movement in a circular modal.

(Note 3) When performing offset with T command execution, offset will not function until the arrival of any G command except those listed below when the T command has been assigned in the same block as the G commands listed below.

G04 : Dwell
G10 : Program tool offset input/program parameter input
G11 : Program parameter input mode cancel
G65 : User macro simple call
G92 : Coordinate system setting

(2) Offset with movement command

 Tool path after offset N2 Offset amount Programmed machining path N1	N1 T0101 ; N2 X100. Z200. ;

Tool length offset and tool nose wear offset are conducted simultaneously.

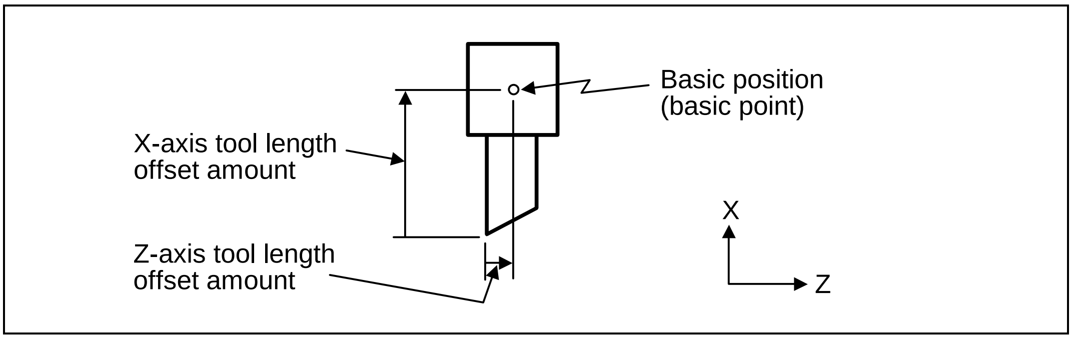
(Note 1) When performing offset with a movement command, offset is applied if the offset amount is lower than the parameter "#1084 RadErr" when offset is performed for the first time with a circular command. If the amount is higher, the program error (P70) results. (This also applies when the arc command and T command are in the same block for offsetting with T command execution.)

12.2 Tool length offset

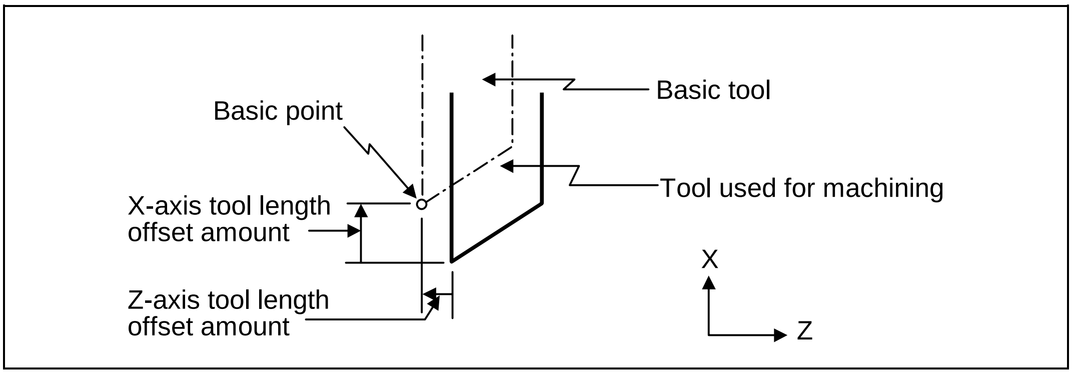
Tool length offset amount setting

This function offsets the tool length with respect to the programmed basic position. This position may generally be set to either the center position of the turret or the tool nose position of the basic tool.

(1) Center position of turret

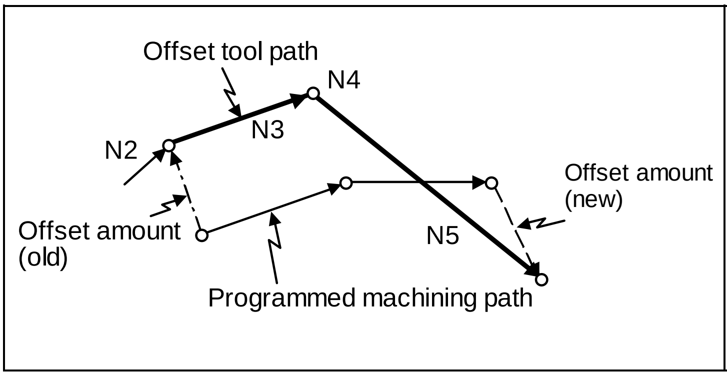


(2) Tool nose position of basic tool



Tool length offset number change

When tool numbers are changed, the tool length offset corresponding to the new tool numbers are added to the movement amounts in the machining program.



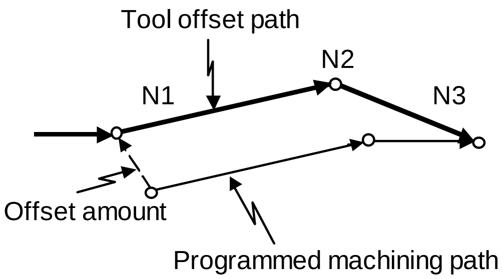
```
N1 T0100 ;
N2 G1 X10.0 Z10.0 F100 ;
N3 G1 X13.0 Z15.0 F20.0 ;
N4 T0200 ;
N5 G1 X13.0 Z20.0 F25.0 ;
```

In this example, the tool length is offset with the tool number and offset is performed in the block with the movement command.

Tool length offset cancel

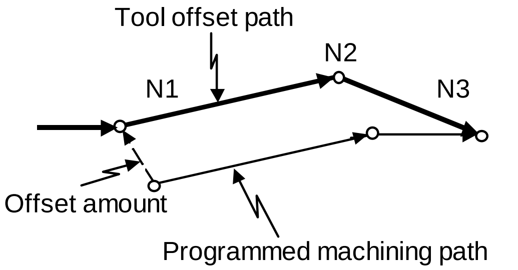
(1) When an offset number of 0 has been assigned

Offset is canceled when 0 has been assigned as the tool length offset number by the T command.

 Tool offset path N2 N1 N3 Offset amount Programmed machining path	N1 X10.0 Z10.0 F10 ; N2 T0000 ; N3 G1 X10.0 Z20.0 ; In this case, offset is performed by the block with the movement command.

(2) When the assigned offset amount is 0

Offset is canceled when the offset amount in the tool length offset number assigned by the T command is 0.

 Tool offset path N2 N1 N3 Offset amount Programmed machining path	N1 G1 X10.0 Z10.0 F10 ; N2 T0100 ; N3 G1 X10.0 Z20.0 ; In this case, offset is performed by the block with the movement command.

(Note 1) When G28, G29 or G30 is commanded, the offset is temporarily canceled. Therefore, the machine moves to the position where the offset was canceled and the offset amount is stored in the memory. This means that with the next movement command the machine will move to the offset position.

(Note 2) When G28, G29 or G30 and the offset cancel are commanded in the same block, the machine is moved to the position where the offset was canceled, however the offset amount remains stored in the memory. This means that the display coordinate may be displayed including the offset amount. Issue these command in the separate block so that the offset amount should not be stored in the memory.

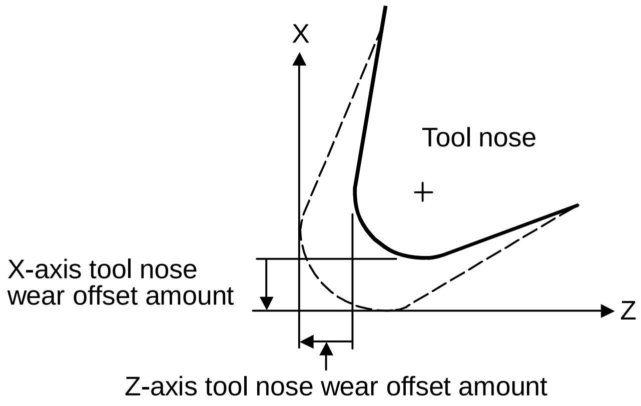
(Note 3) Even if the offset amount of the offset number currently selected by MDI is changed during automatic operation, the changed offset amount will not be valid unless a T command with the same number is executed again.

(Note 4) The tool length offset and tool nose wear offset amounts are cleared by resetting and by emergency stop. They can be retained according to the parameter "#1099 Treset" setting .

12.3 Tool nose wear offset

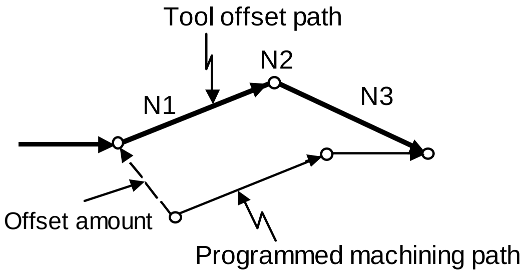
Tool nose wear offset amount setting

The wear sustained by the tool being used can be offset.


X
Tool nose
X-axis tool nose wear offset amount
Z
Z-axis tool nose wear offset amount

Tool nose wear offset cancel

Tool nose wear offset is canceled when 0 has been assigned as the offset number.



```
N1 G1 X10.0 Z10.0 F10 ;
N2 T0100 ;
N3 G1 X10.0 Z20.0 ;
```

In this case, offset is performed in the block with the movement command.

(Note 1) When G28, G29 or G30 is commanded, the offset is temporarily canceled. Therefore, the machine moves to the position where the offset was canceled and the offset amount is stored in the memory. This means that with the next movement command the machine will move to the offset position.

(Note 2) When G28, G29 or G30 and the offset cancel are commanded in the same block, the machine is moved to the position where the offset was canceled, however the offset amount remains stored in the memory. This means that the display coordinate may be displayed including the offset amount. Issue these command in the separate block so that the offset amount should not be stored in the memory.

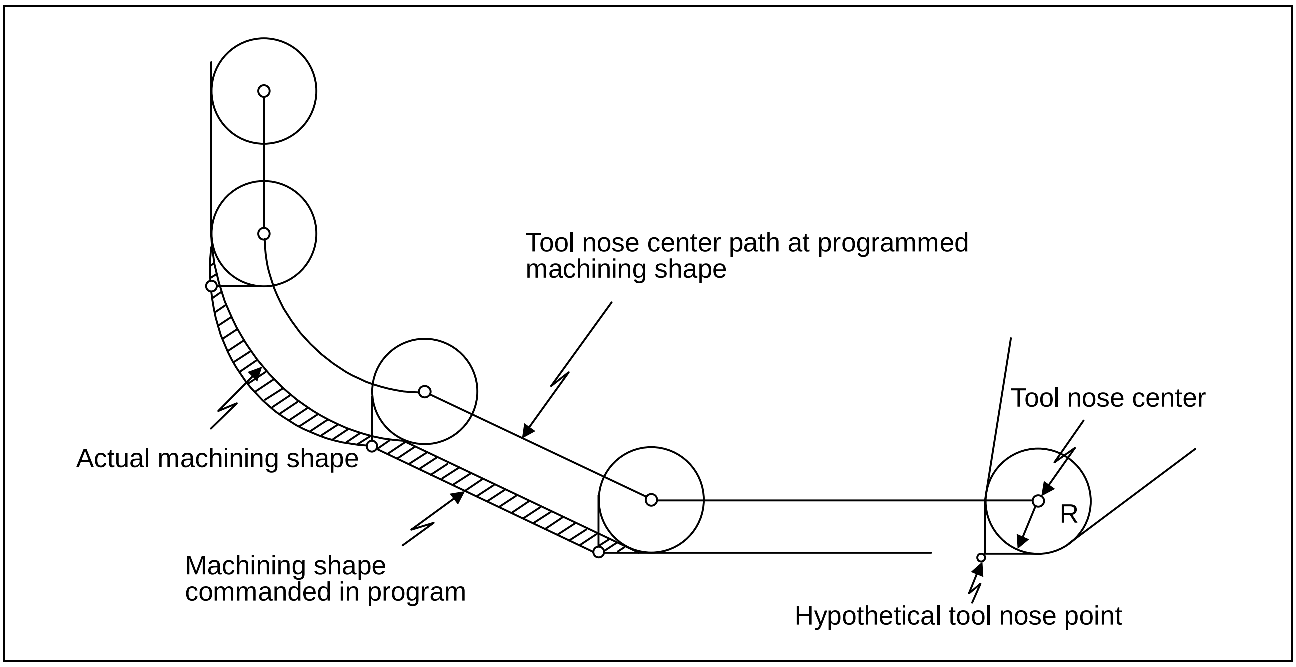
(Note 3) Even if the offset amount of the offset number currently selected by MDI is changed during automatic operation, the changed offset amount will not be valid unless a T command with the same number is executed again.

(Note 4) The tool length offset and tool nose wear offset amounts are cleared by resetting and by emergency stop. They can be retained by parameter "#1099 Treset".

12.4 Tool nose radius compensation; G40, G41, G42, G46

Function and purpose

The tool nose is generally rounded and so a hypothetical tool nose point is treated as the tool nose for programming purposes. When this is done, an error caused by the tool nose rounding arises during taper cutting or circular cutting between the actually programmed shape and the cutting shape. Tool nose radius compensation is a function for automatically calculating and offsetting this error by setting the tool nose radius value.
The command codes enable the offset direction to be fixed or automatically identified.

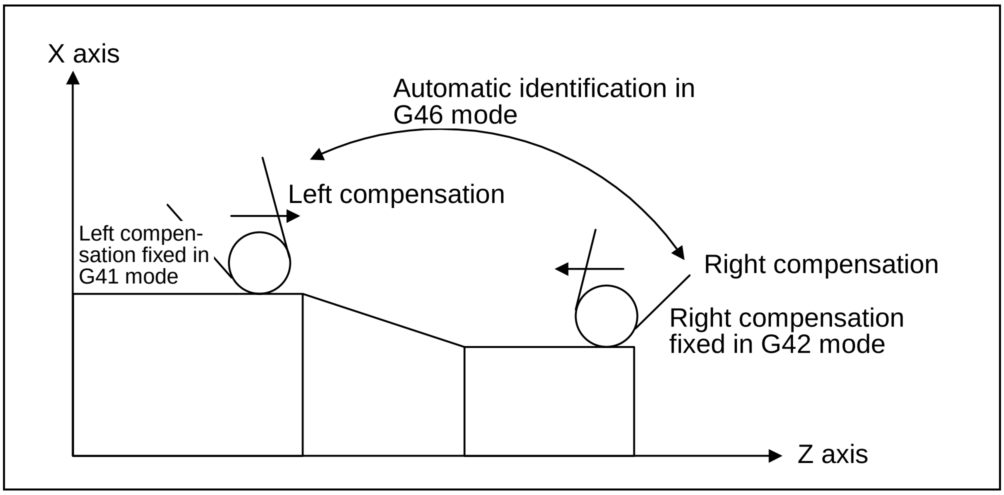

Tool nose center path at programmed machining shape
Tool nose center
R
Actual machining shape
Machining shape commanded in program
Hypothetical tool nose point

Functions and command formats

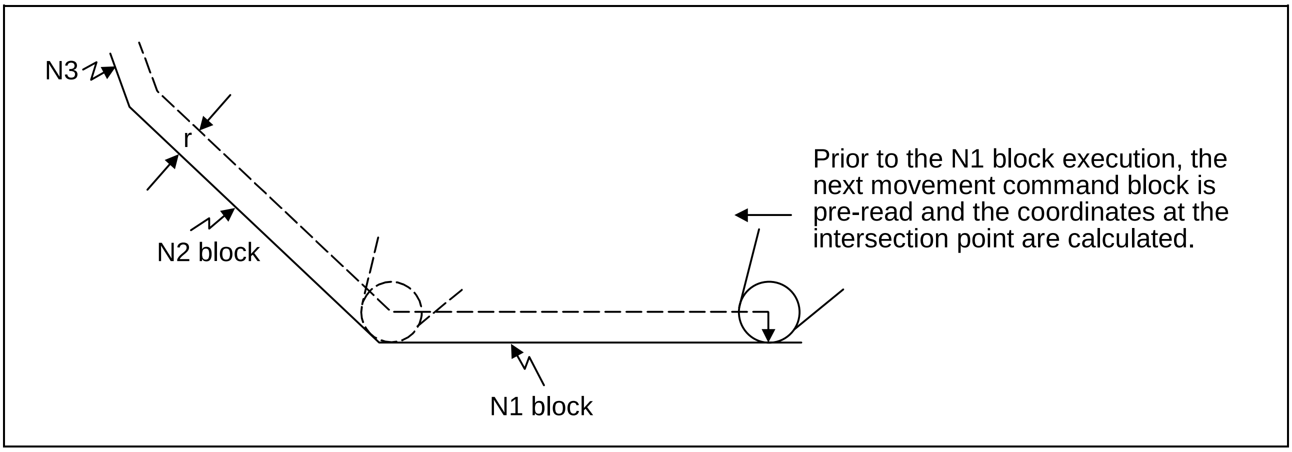
Code	Function	Command format
G40	Tool nose radius compensation mode cancel	G40 (Xx/Uu Zz/Ww Ii Kk) ;
G41	Tool nose radius compensation left mode ON	G41 (Xx/Uu Zz/Ww) ;
G42	Tool nose radius compensation right mode ON	G42 (Xx/Uu Zz/Ww) ;
G46	Tool nose radius compensation automatic direction identification mode ON	G46 (Xx/Uu Zz/Ww) ;

(Note 1) By means of the preset hypothetical tool nose point and movement commands in the machining program, the G46 tool nose radius compensation function automatically identifies the compensation direction and provides tool nose radius compensation.

(Note 2) G40 serves to cancel the tool nose radius compensation mode.


X axis
Automatic identification in G46 mode
Left compensation
Left compen-sation fixed in G41 mode
Right compensation
Right compensation fixed in G42 mode
Z axis

(Note 3) Tool nose radius compensation pre-reads the data in the following two movement command blocks (up to 5 blocks when there are no movement commands) and controls the tool nose radius center path by the intersection point calculation method so that it is offset from the programmed path by an amount equivalent to the nose radius.


N3
r
N2 block
N1 block
Prior to the N1 block execution, the next movement command block is pre-read and the coordinates at the intersection point are calculated.

(Note 4) In the above figure, "r" is the tool nose radius compensation amount (nose radius).

(Note 5) The tool nose radius compensation amount corresponds to the tool length number and it is preset along with the tool nose point.

(Note 6) If there are 4 or more blocks without movement amounts among 5 continuous blocks, overcutting or undercutting will result.
Blocks in which optional block skip is valid are ignored.

(Note 7) Tool nose radius compensation is also valid for fixed cycles (G77 ~ G79) and for rough cutting cycles (G70, G71, G72, G73).
However, in the rough cutting cycles, the finished shape with the tool nose radius compensation applied will be cut with the compensation canceled and, upon completion of the cutting, operation will automatically return to the compensation mode.

(Note 8) With thread cutting commands, compensation is temporarily canceled 1 block before.

(Note 9) A tool nose radius compensation (G41 or G42) command can be assigned during tool nose radius compensation (G46). Compensation does not need to be canceled with G40 at this time.

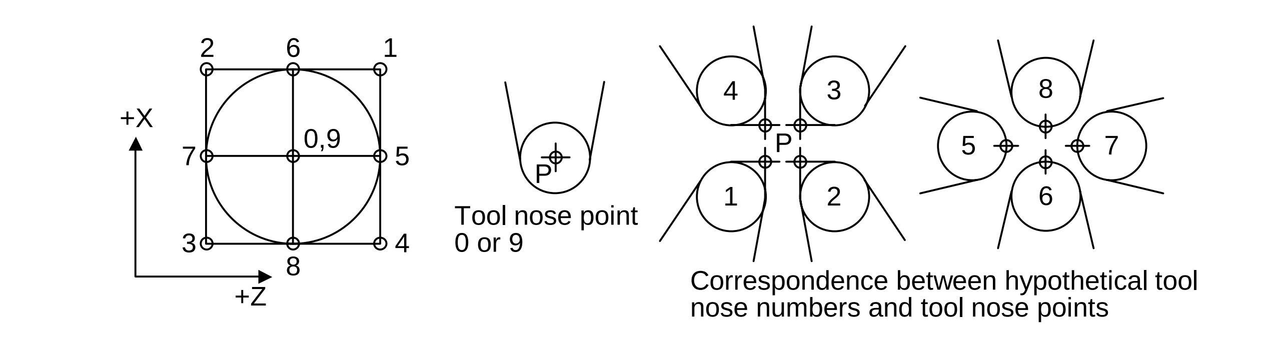
(Note 10) The compensation plane, movement axes and next advance direction vector follow the plane selection command designated by G17, G18 or G19.

G17 : X-Y plane X, Y, I, J
G18 : Z-X plane Z, X, K, I
G19 : Y-Z plane Y, Z, J, K

12.4.1 Tool nose point and compensation directions

Tool nose point

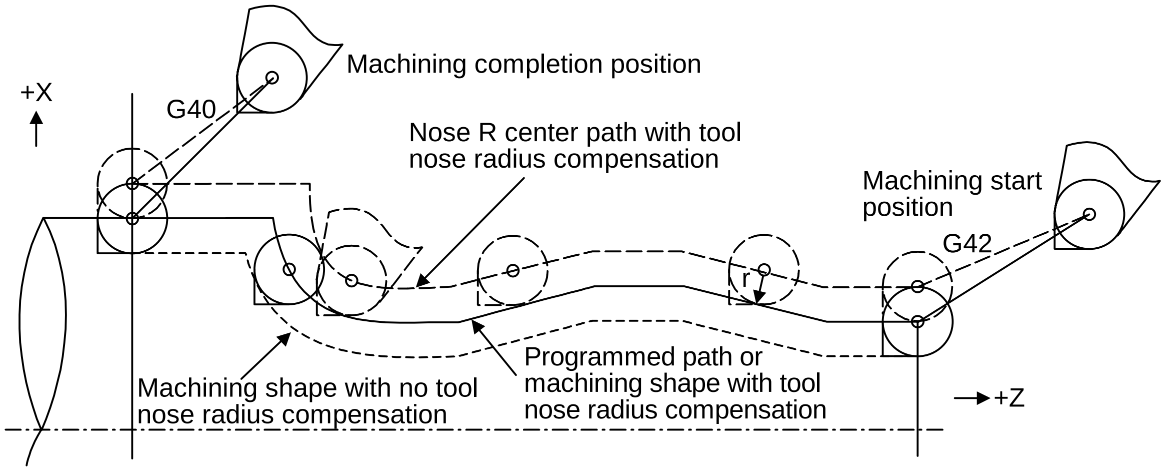
Since the tool nose is generally rounded, the programmed tool nose position is aligned with point P shown in the examples of the figures below.
With tool nose radius compensation, one point among those in the figures below indicating the position relationship is selected for each tool length number and preset.
(Selection from points 1 to 8 in the G46 mode and 0 to 9 in the G41/G42 mode.)



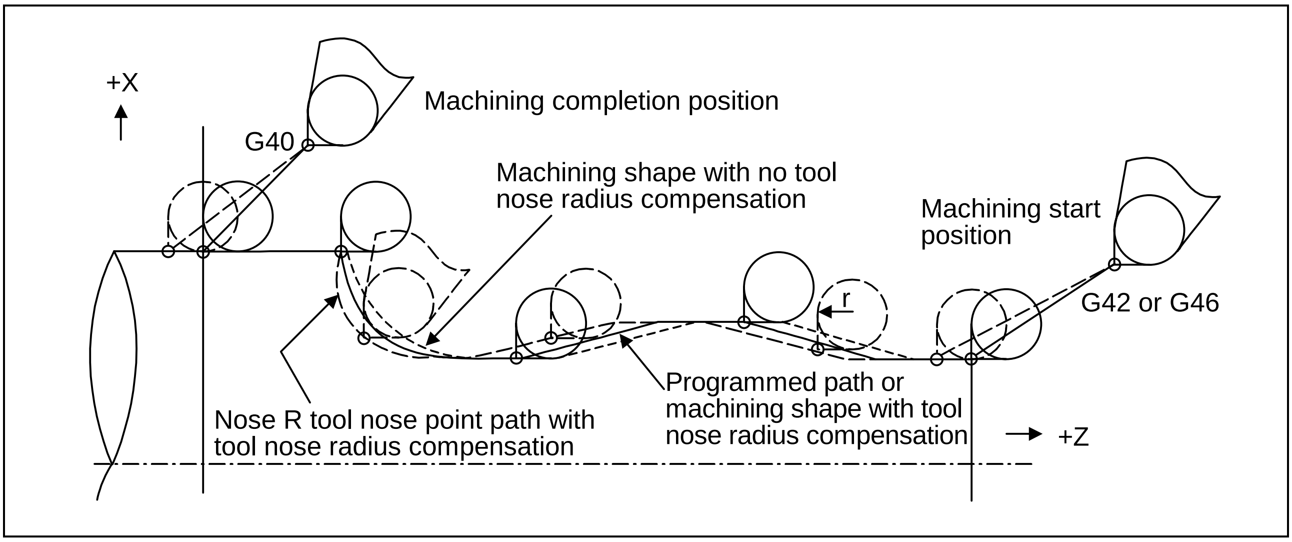
Correspondence between hypothetical tool nose numbers and tool nose points

Tool nose point and compensation operation

(1) When the nose R center has been aligned with the machining start position


Machining completion position
+X
G40
Nose R center path with tool nose radius compensation
Machining start position
G42
r
Machining shape with no tool nose radius compensation
Programmed path or machining shape with tool nose radius compensation
+Z

(2) When the tool nose point has been aligned with the machining start position


+X
G40
Machining completion position
Machining shape with no tool nose radius compensation
Machining start position
r
G42 or G46
Programmed path or machining shape with tool nose radius compensation
Nose R tool nose point path with tool nose radius compensation
+Z

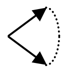
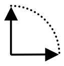
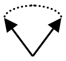
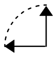
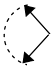
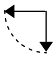
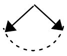
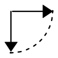
Compensation directions

(1) The compensation direction of the G41/G42 commands is determined by the G41/G42 codes. The direction in a G46 command is automatically determined in accordance with the following table from the relationship between the tool nose points and the commanded movement vectors.

(2) When tool nose radius compensation has been started and the initial movement vector (including G0) corresponds to an "×" mark in the table, the compensation direction cannot be specified and so it is determined by the next movement vector. When the direction cannot be determined even after reading 5 blocks ahead, program error (P156) results.

(3) When an attempt is made to reverse the compensation direction during tool nose radius compensation, program error (P157) results except when the reversal is done in the G00 block. Even if the directions differ before and after the G28, G30 or G53 block, an error will not result since compensation is temporarily canceled. Using a parameter (#8106 G46 reverse axis error evade), the tool can also be moved unchanged in the same compensation direction.

(4) When the compensation direction during tool nose radius compensation coincides with an "×" in the table below, the direction complied with the previous compensation direction. Determining the compensation direction by the movement vectors and tool nose point in command G46

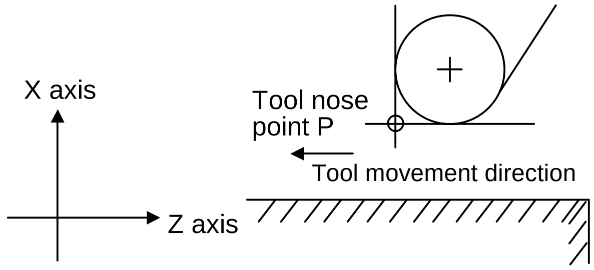
Compensation direction of tool nose / Direction of tool nose advance		Tool nose points								Compensation direction of tool nose / Direction of tool nose advance	
		1	2	3	4	5	6	7	8		
Move-ment vector (tool nose points 1 to 4)		Right	Right	Left	Left	×	Right	×	Left	→	Move-ment vector (tool nose points 5 to 8)
	↗	×	Right	×	Left	Left	Right	Right	Left		
		Left	Right	Right	Left	Left	×	Right	×	↑	
	↖	Left	×	Right	×	Left	Left	Right	Right		
		Left	Left	Right	Right	×	Left	×	Right	←	
	↙	×	Left	×	Right	Right	Left	Left	Right		
		Right	Left	Left	Right	Right	×	Left	×	↓	
	↘	Left	×	Left	×	Right	Right	Left	Left		

(Note 1) An "×" mark in the tables indicates that the compensation direction is not determined from the movement vector (tool nose points).

(Note 2) The "↗" mark denotes a movement vector in the 45° direction. (The other movement vectors are based on this.)

(Note 3) The " " mark denotes a movement vector with a range larger than 45° and smaller than 135°. (The other movement vectors are based on this.)

(Example) With tool nose point 3, movement vector in the Z axis (–) direction
(with "←" movement vector in the figure below)

 X axis Tool nose point P Tool movement direction Z axis	As shown in the figure on the left, the workpiece is on the X axis (–) side from the tool nose position and tool movement direction. Consequently, the right side compensation of the workpiece in the direction of the tool's advance serves as the compensation direction.

12.4.2 Tool nose radius compensation operations

Tool nose radius compensation cancel mode

The tool nose radius compensation cancel mode is established by any of the following conditions.

(1) After the power has been turned ON

(2) After the reset button on the setting and display unit has been pressed

(3) After the M02 or M30 command with reset function has been executed

(4) After the compensation cancel command (G40) has been executed

(5) After tool number 0 has been selected (T00 has been executed)

The offset vectors are zero in the compensation cancel mode, and the tool nose point path coincides with the program path.
Programs including tool nose radius compensation must be terminated in the compensation cancel mode.

Tool nose radius compensation start (start-up)

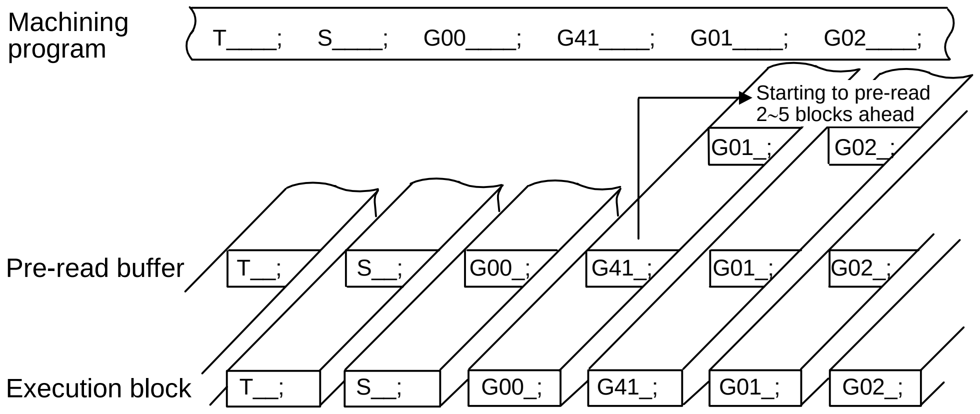
Tool nose radius compensation starts when all the following conditions are met in the compensation cancel mode.

(1) A movement command is issued after the G41, G42 or G46 command has been issued.

(2) The movement command of positioning (G00) or linear interpolation (G01) is issued.

At the start of compensation, the operation is executed after at least 2 to 5 blocks have been read continuously for intersection point calculation regardless of single block operation (Two flocks are pre-read if movement commands are present; up to 5 blocks are pre-read if such commands are not present.)
During compensation mode, up to 5 blocks are pre-read and the compensation is arithmetically processed.

Control mode transition diagram



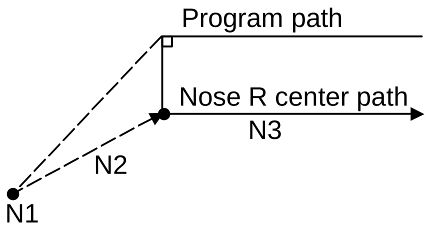
There are two ways of starting the compensation operation: type A and type B.
The type can be selected with bit2 of parameter "#1229 set 01 ".
This type is used in common with the compensation cancel type.
In the following explanatory figure, "S" denotes the single block stop point.

Start operation for tool nose radius compensation

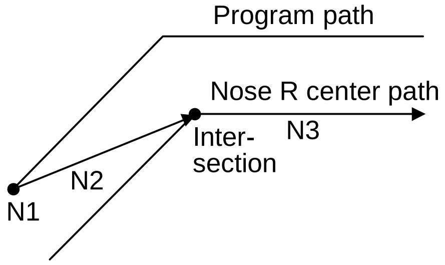
With a G41, G42 or G46 command alone, the tool does not moves as much as the specified amount of tool nose radius compensation. It does not start tool nose radius compensation with a G00 command. It starts tool nose radius compensation normally with a G01, G02 or G03 command.
Note that even if there is an axis command, the tool nose radius compensation will not be applied unless there is movement.

(1) When an independent G41/G42/G46 command is issued at an inside corner

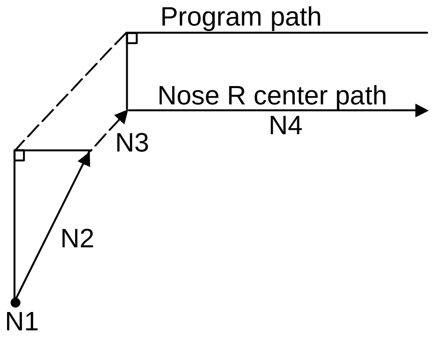
```
      ≀
N1   G42 ;
N2   G00   X_Z_ ;
N3   G01   X_Z_F_ ;
      ≀
```



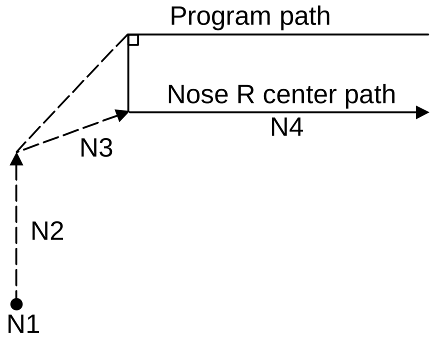
```
      ≀
N1   G42 ;
N2   G01   X_Z_F_ ;
N3   G01   X_Z_ ;
      ≀
```



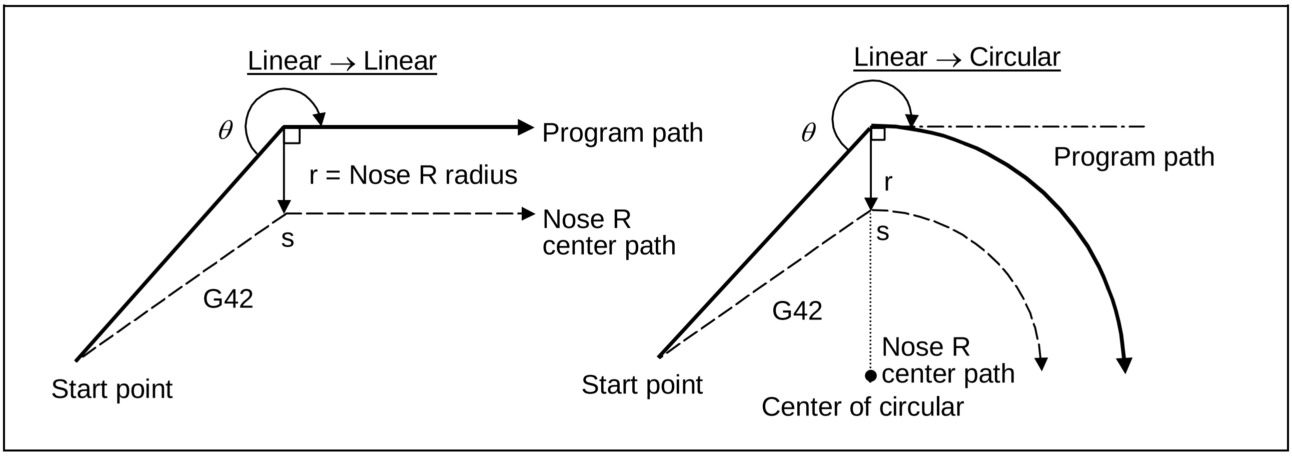
```
      ≀
N1   G42 ;
N2   G01   X_Z_F_ ;
N3   G00   X_Z_ ;
N4   G01   X_Z_ ;
      ≀
```



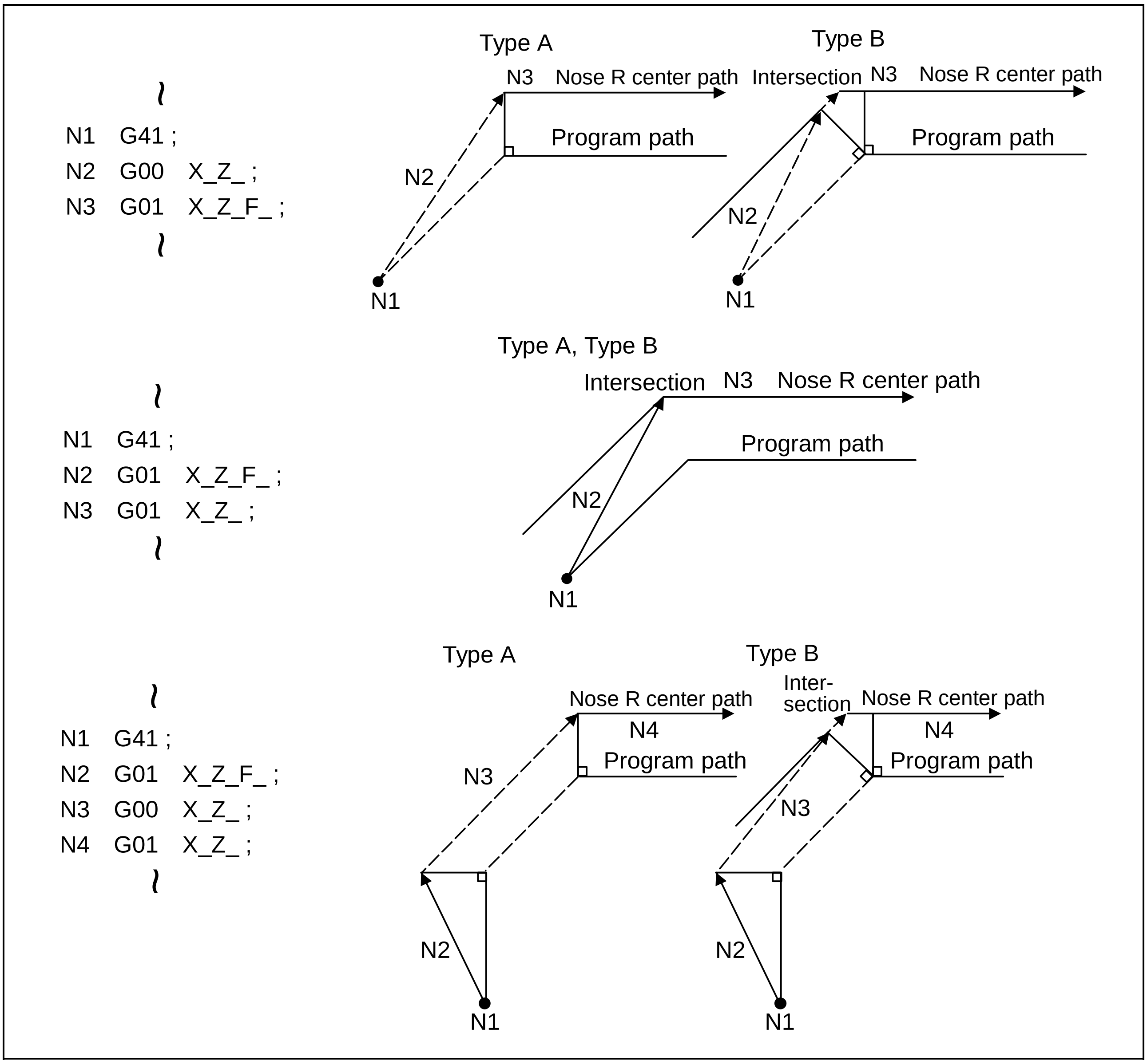
```
      ≀
N1   G42 ;
N2   G00   X_Z_ ;
N3   G00   X_Z_ ;
N4   G01   X_Z_F_ ;
      ≀
```



(2) When a G41/G42/G46 command is issued at an inside corner, in the same block as a movement command



(3) When an independent G41/G42/G46 command is issued at an outside corner (obtuse angle)

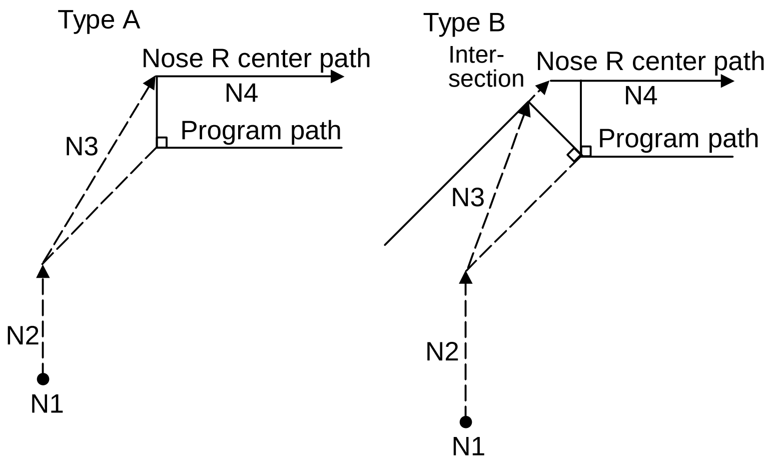


```
   ≀
N1  G41 ;
N2  G00  X_Z_ ;
N3  G01  X_Z_F_ ;
   ≀
```

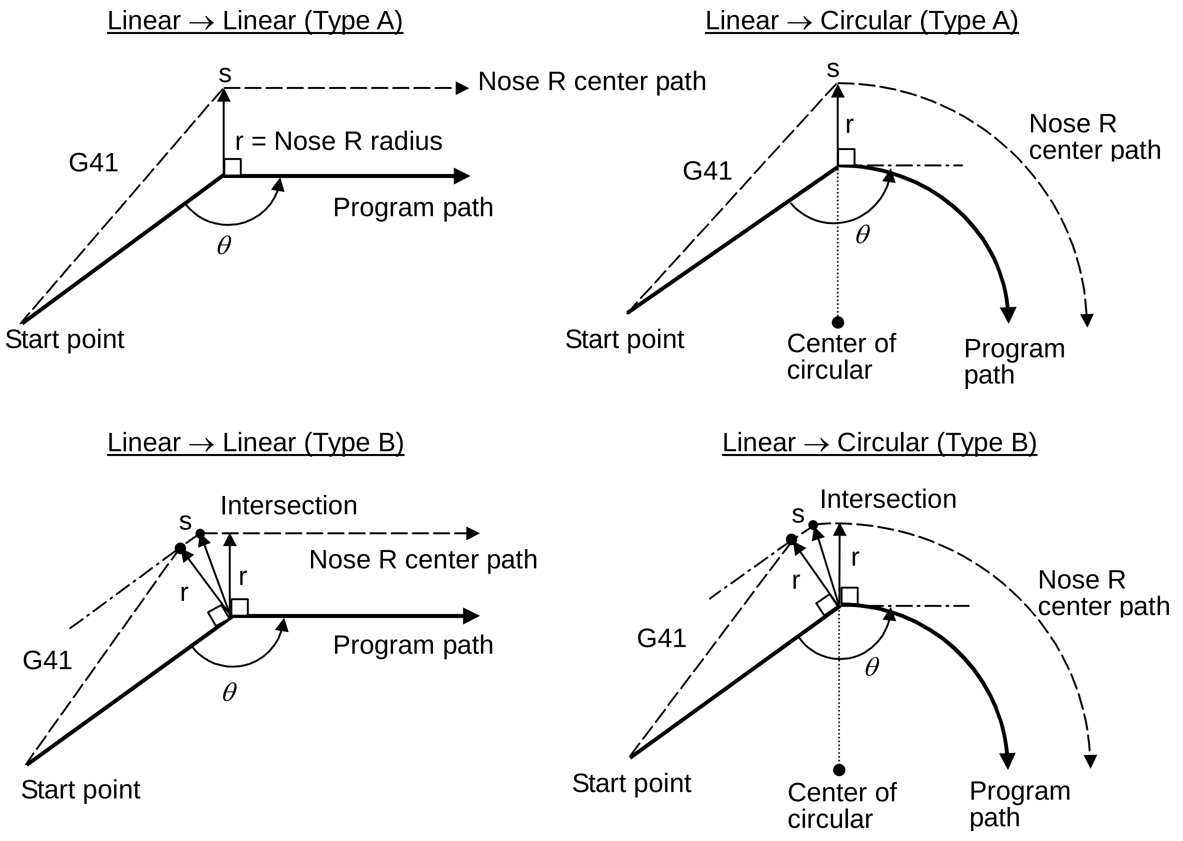
```
   ≀
N1  G41 ;
N2  G01  X_Z_F_ ;
N3  G01  X_Z_ ;
   ≀
```

```
   ≀
N1  G41 ;
N2  G01  X_Z_F_ ;
N3  G00  X_Z_ ;
N4  G01  X_Z_ ;
   ≀
```

```
        ≀
N1   G41 ;
N2   G00   X_Z_ ;
N3   G00   X_Z_ ;
N4   G01   X_Z_F_ ;
        ≀
```



(4) When a G41/G42/G46 command is issued at an outside corner (obtuse angle), in the same block as a movement command [90° ≤ θ < 180°]


Linear → Linear (Type A)

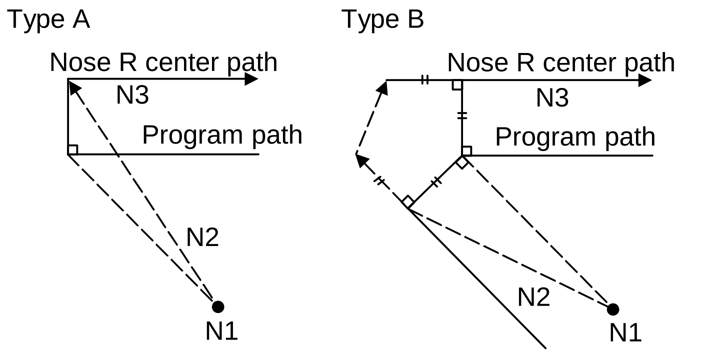
Linear → Circular (Type A)

Linear → Linear (Type B)

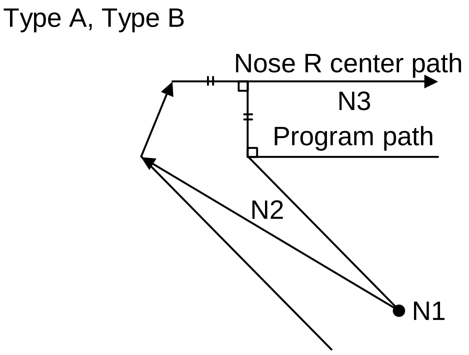
Linear → Circular (Type B)

(5) When an independent G41/G42/G46 command is issued at an outside corner (acute angle)

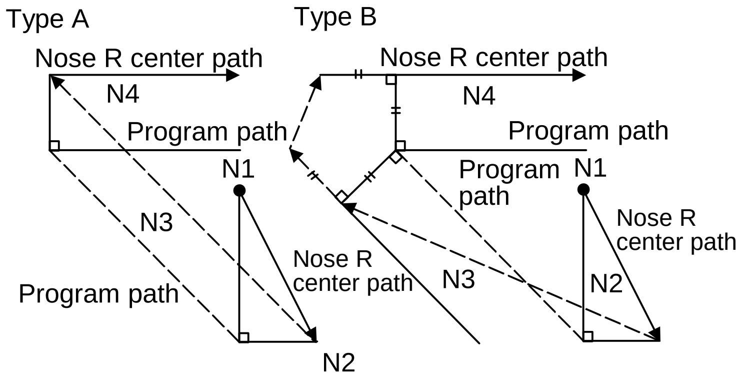
```
      ≀
N1   G41 ;
N2   G00   X_Z_ ;
N3   G01   X_Z_F_ ;
      ≀
```



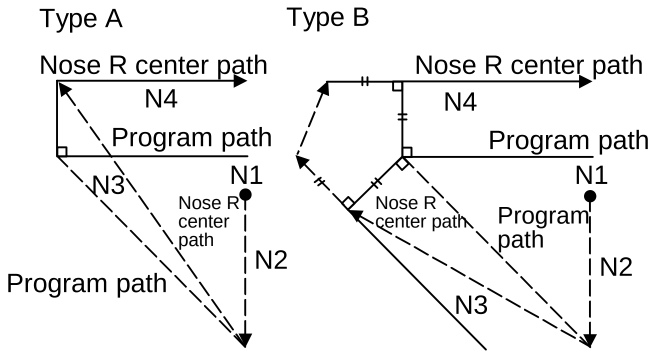
```
      ≀
N1   G41 ;
N2   G01   X_Z_F_ ;
N3   G01   X_Z_ ;
      ≀
```



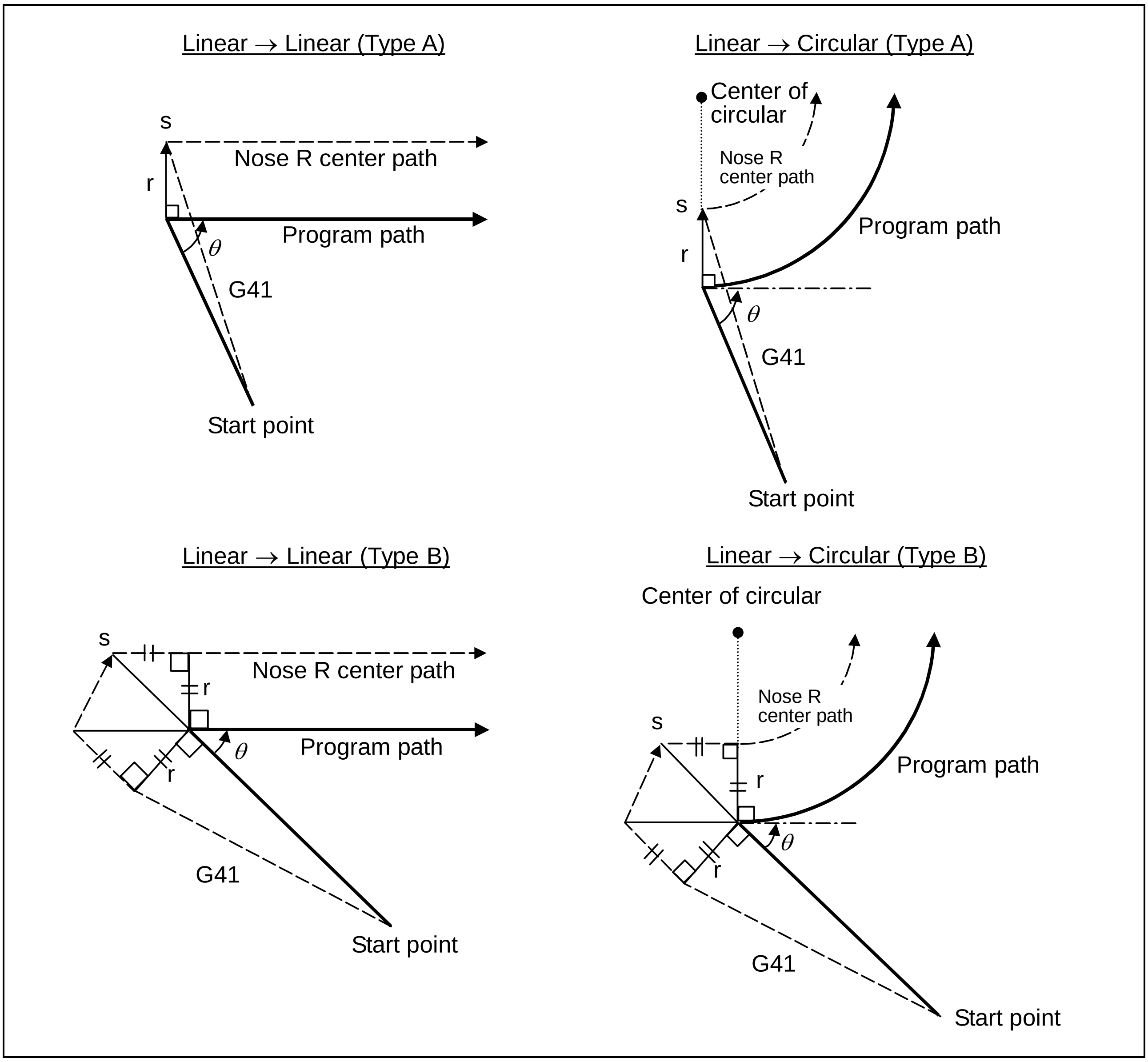
```
      ≀
N1   G41 ;
N2   G01   X_Z_F_ ;
N3   G00   X_Z_ ;
N4   G01   X_Z_ ;
      ≀
```



```
      ≀
N1   G41 ;
N2   G00   X_Z_ ;
N3   G00   X_Z_ ;
N4   G01   X_Z_ F_ ;
      ≀
```



(6) When a G41/G42/G46 command is issued at an outside corner (acute angle), in the same block as a movement command [θ < 90°]

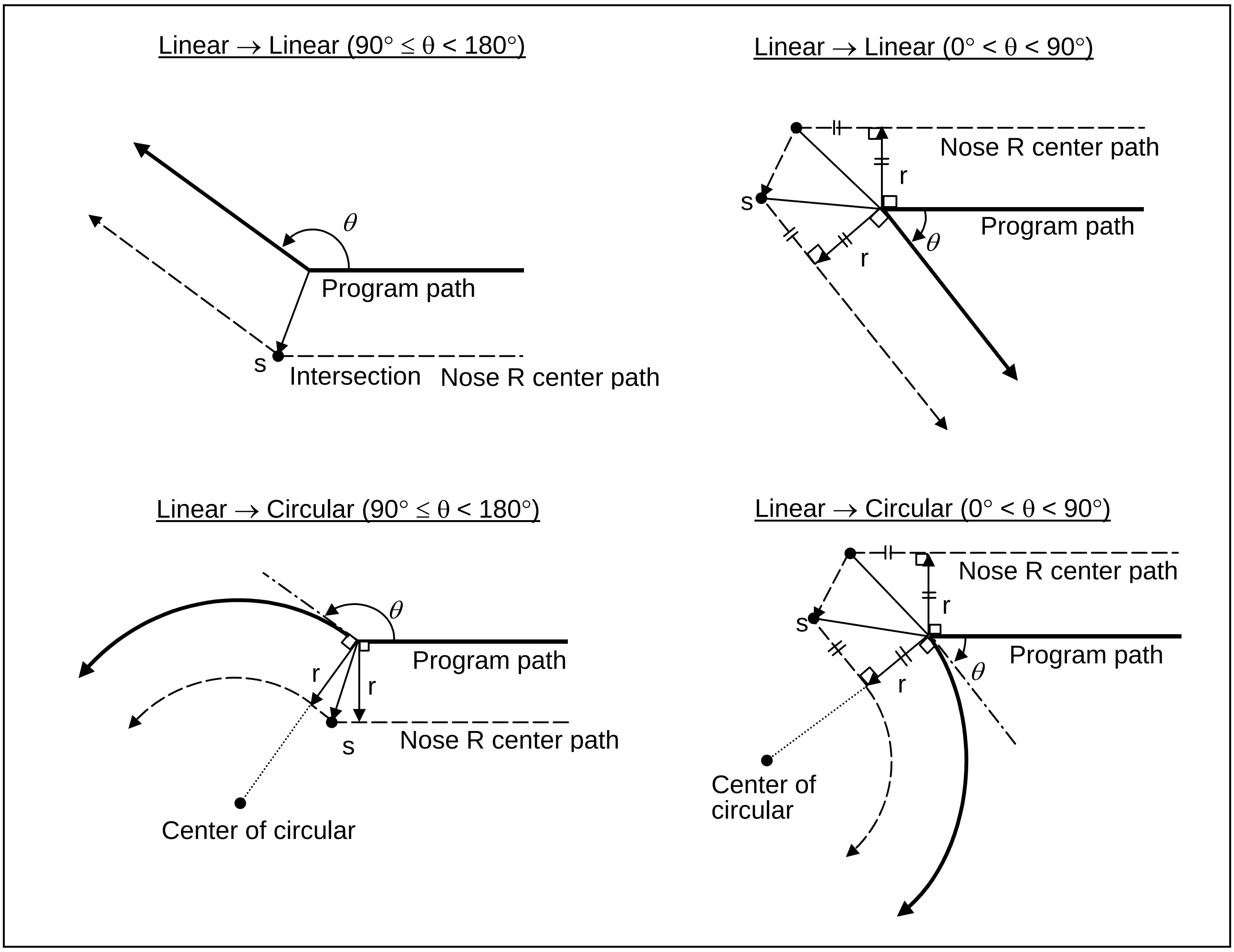


(Note 1) Where is no axis movement command in the same block as G41 or G42, compensation is performed perpendicularly to the next block direction.

Operations in compensation mode

The tool center path is obtained and compensated from the linear and arc designations for the program path (G00, G01, G02, G03).
Compensation is valid both for positioning and for interpolation commands such as circular and linear interpolation.
Even if the same compensation command (G41, G42, G46) is issued in a tool nose radius compensation (G41, G42, G46) mode, the command will be ignored.
When 4 or more blocks not accompanying movement are commanded continuously in the compensation mode, overcutting or undercutting will result.
When the M00 command has been issued during tool nose radius compensation, pre-reading is prohibited.

(1) Machining an outside corner

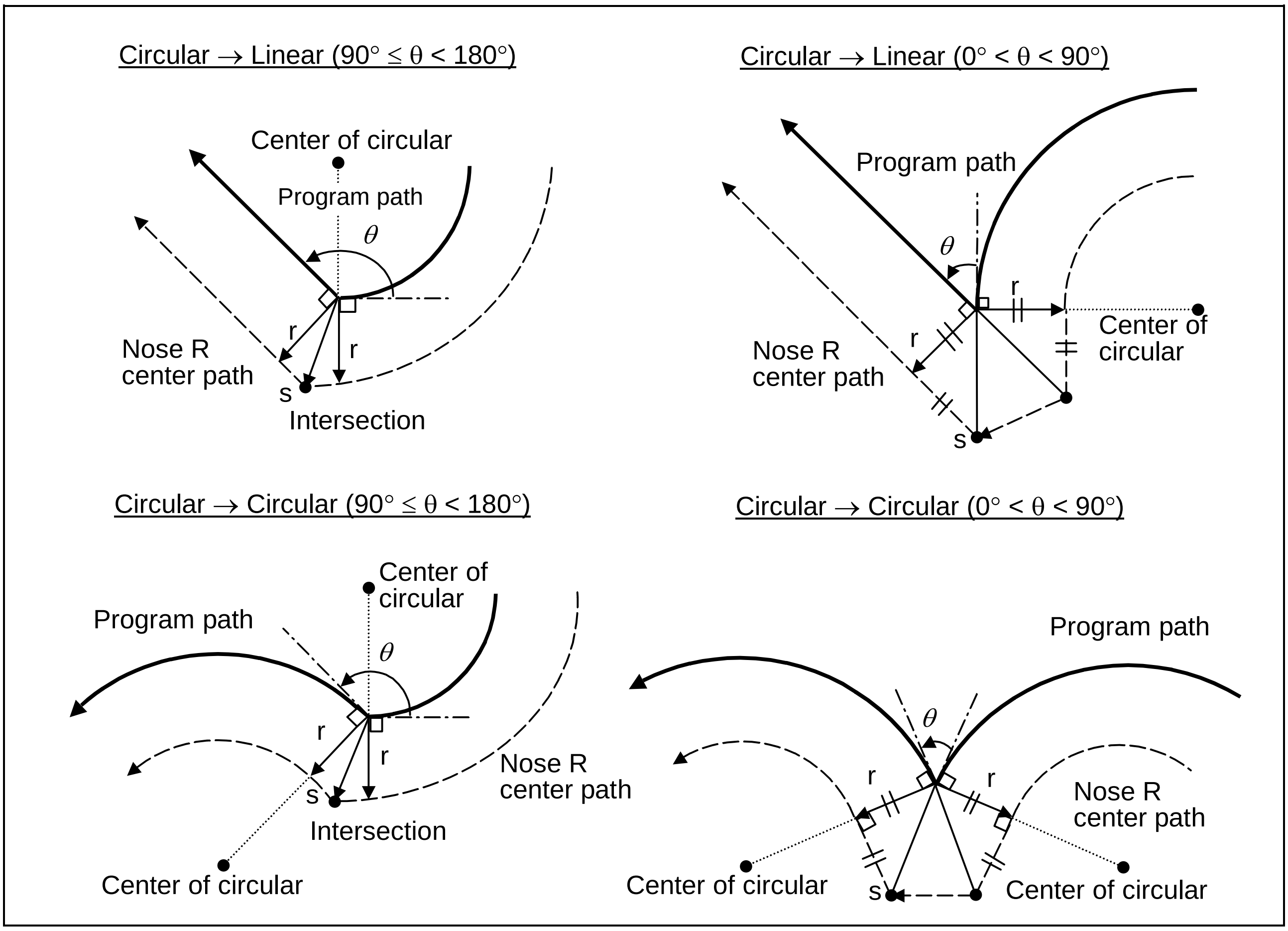


Linear → Linear (90° ≤ θ < 180°)

Linear → Linear (0° < θ < 90°)

Linear → Circular (90° ≤ θ < 180°)

Linear → Circular (0° < θ < 90°)



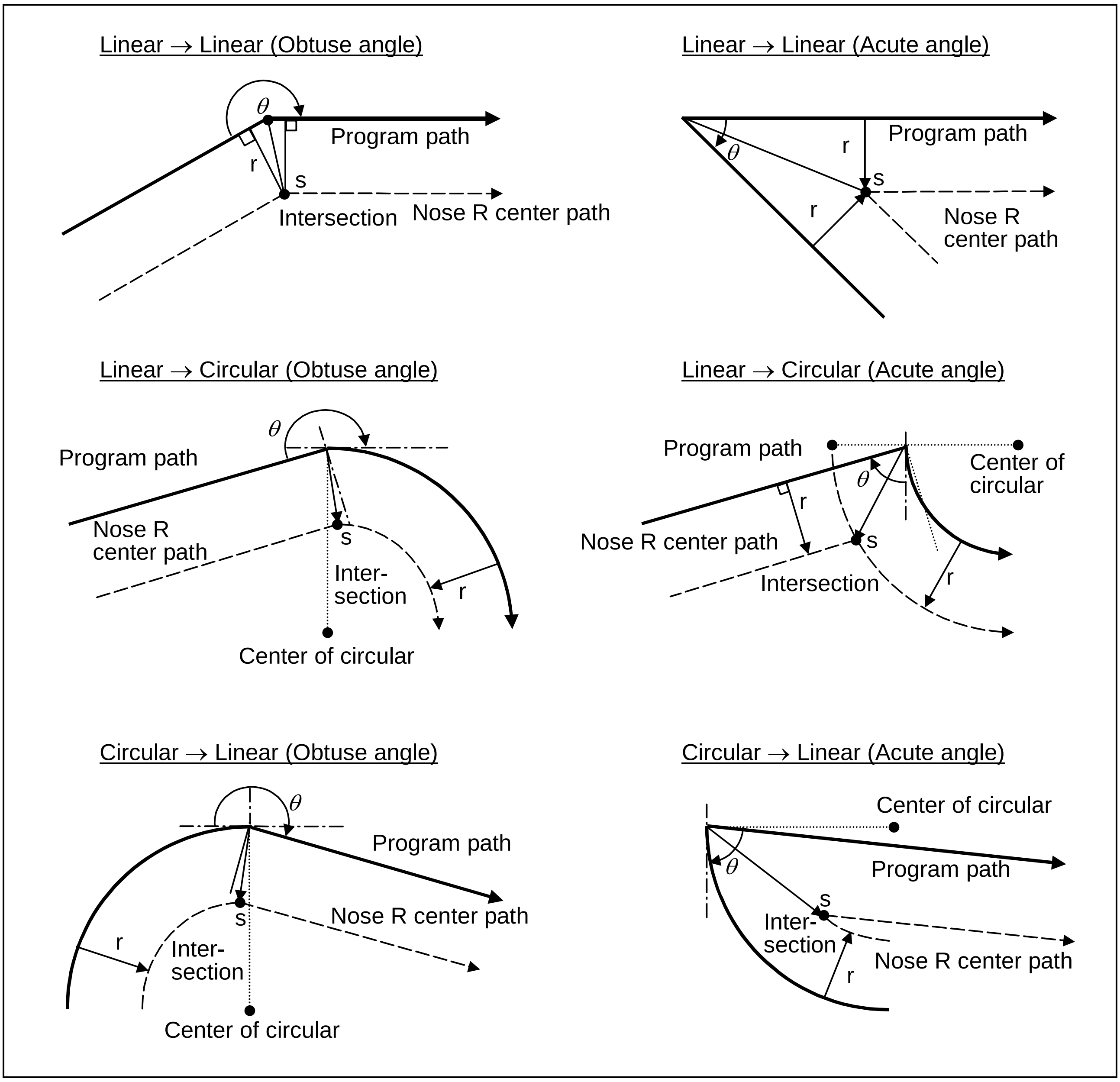
Circular → Linear (90° ≤ θ < 180°)

Circular → Linear (0° < θ < 90°)

Circular → Circular (90° ≤ θ < 180°)

Circular → Circular (0° < θ < 90°)

(2) Machining an inner wall



Linear → Linear (Obtuse angle)

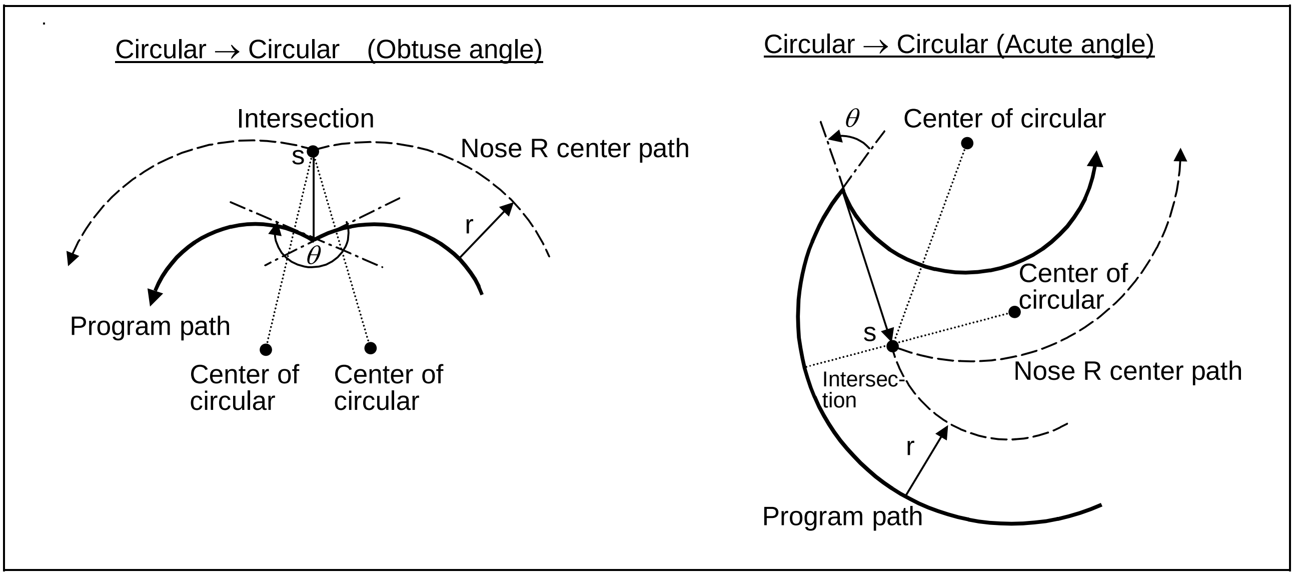
Linear → Linear (Acute angle)

Linear → Circular (Obtuse angle)

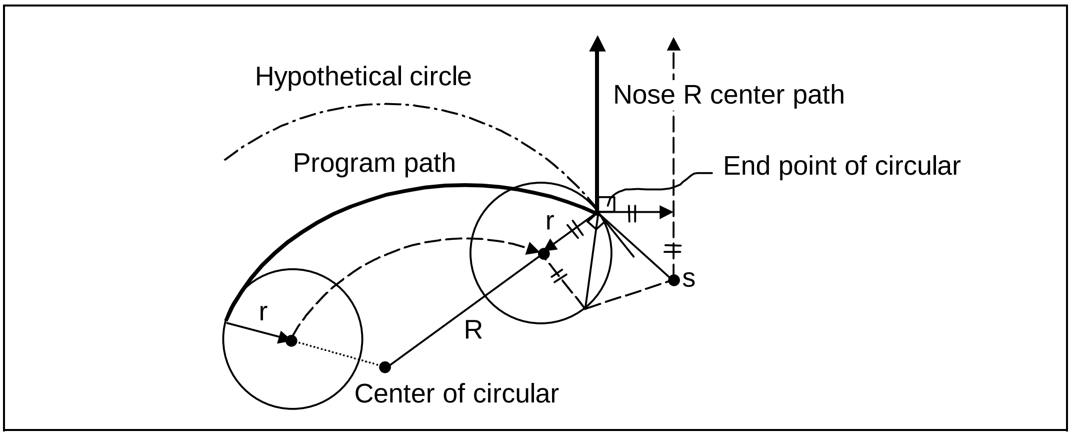
Linear → Circular (Acute angle)

Circular → Linear (Obtuse angle)

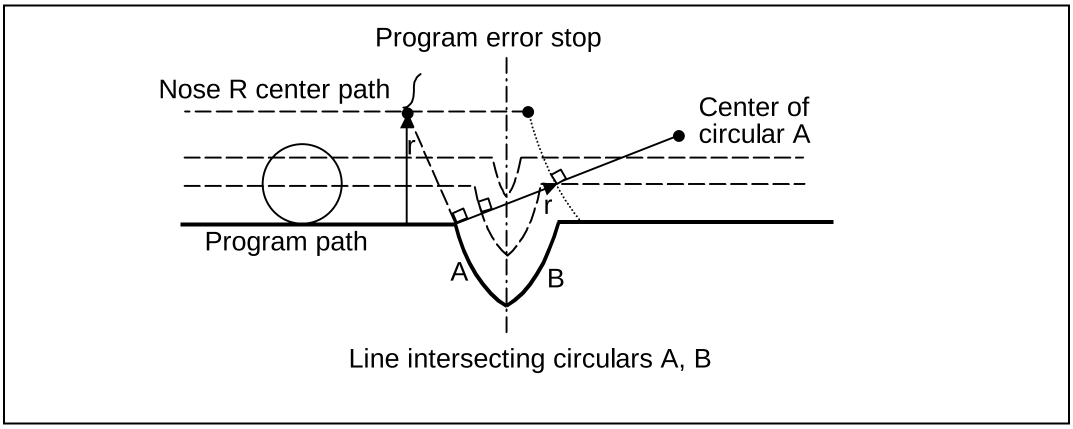
Circular → Linear (Acute angle)



(3) When the arc end point is not on the arc
If the error applying after compensation is within the parameter (#1084 RadErr), the area from the arc start point to the end point is interpolated as a spiral arc.



(4) When the inner intersection point does not exist
In an instance such as that shown in the figure below, the intersection point of circulars A and B may cease to exist due to the offset amount. In such cases, program error (P152) appears and the tool stops at the end point of the previous block.



Tool nose radius compensation cancel

If either of the following conditions is met in the tool nose radius compensation mode, the compensation will be canceled. However, the movement command must be a command which is not a circular command.
If the compensation is canceled by a circular command, program error (P151) results.

(1) The G40 command has been executed.

(2) The T00 tool number has been executed.

The cancel mode is established once the compensation cancel command has been read, 5-block pre-reading is suspended and 1-block pre-reading is applies instead.

Tool nose radius compensation cancel operation

Issuing a tool nose radius compensation cancel command results in the following.

(1) If the command before G40 is G00 after the tool nose radius compensation is completed, the tool nose radius compensation is temporarily stopped, and the tool nose radius compensation is canceled in that state by an independent G40 command.

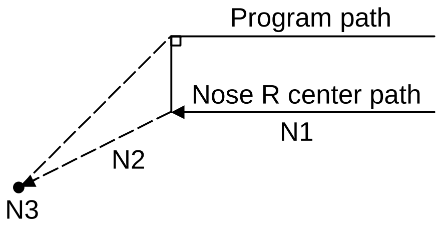
(2) If there is an interpolation command before G40 after the tool nose radius compensation is completed, the tool nose radius compensation is not canceled by the independent G40 command, so the nose R center can stop in a vertical position. Instead, the tool nose radius compensation is canceled by the first axis movement command after G40. The nose radius compensation will not be canceled by the axis command if there is no axis movement. If there is no axis movement command after G40, and the program finishes by M02, etc., the tool nose radius compensation will remain valid. Resetting will cancel the tool nose radius compensation, but the operation will not be canceled.

(3) When an independent T00 command is issued in a block, a tool nose radius cancel mode will result in that block, and the axis will move to the tool nose radius cancel position.

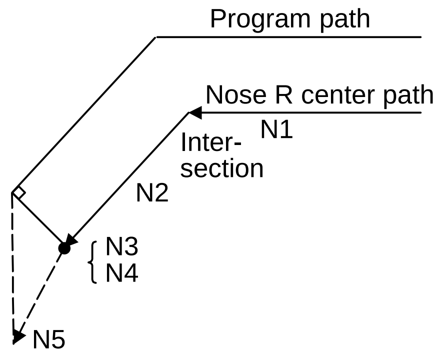
(4) Relation of an inside corner/outside corner and cancel

(a)-1 When an independent G40 command is issued at an inside corner

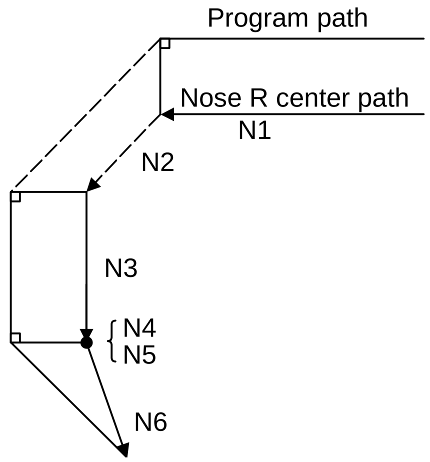
```
        ≀
N1   G01   X_Z_F_ ;
N2   G00   X_Z_ ;
N3   G40 ;
        ≀
```



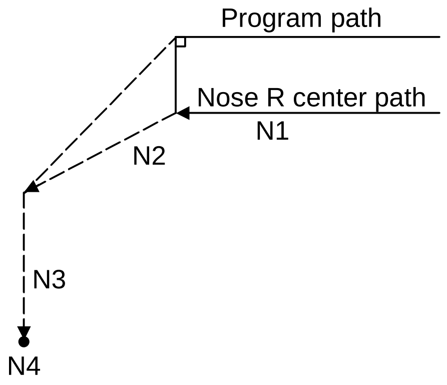
```
        ≀
N1   G01   X_Z_F_ ;
N2   G01   X_Z_ ;
N3   G40 ;
N4   M05 ;
N5   G00   X_Z_ ;
        ≀
```



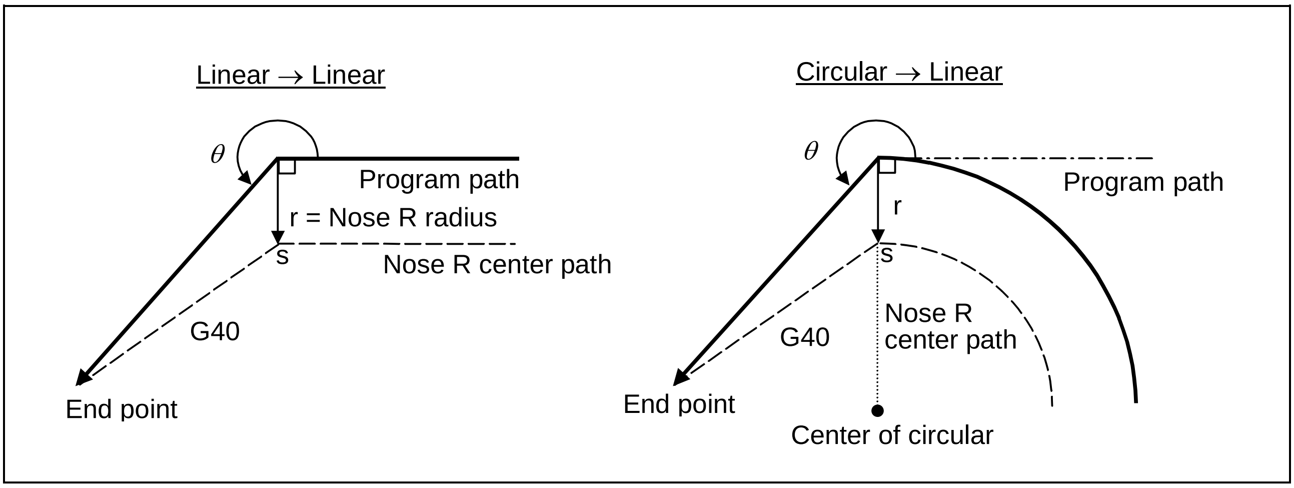
```
        ≀
N1   G01   X_Z_F_ ;
N2   G00   X_Z_ ;
N3   G01   X_Z_ ;
N4   G40 ;
N5   M05 ;
N6   G01   X_Z_ ;
        ≀
```



```
        ≀
N1   G01   X_Z_F_ ;
N2   G00   X_Z_ ;
N3   G00   X_Z_ ;
N4   G40 ;
        ≀
```



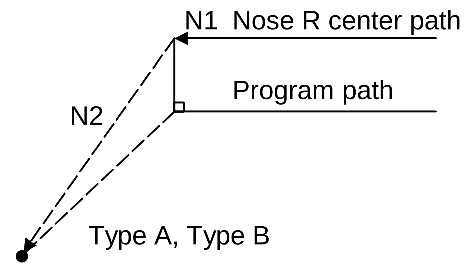
(a)-2 When a G40 command is issued at an inside corner, in the same block as a movement command



(b)-1 When an independent G40 command is issued at an outside corner (obtuse angle)

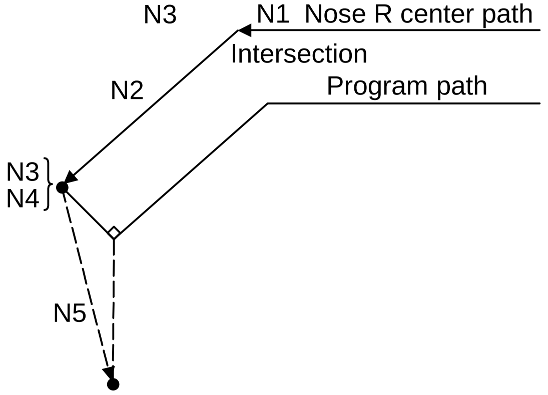
```
      ≀
N1   G01   X_Z_F_ ;
N2   G00   X_Z_ ;
N3   G40 ;
      ≀
```

Type A, Type B

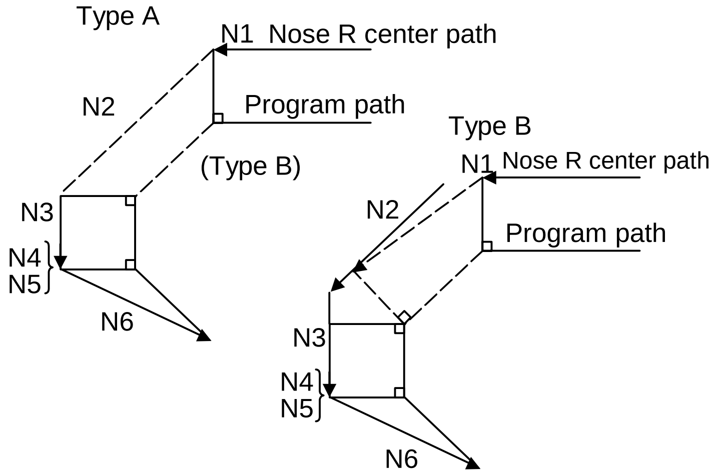


```
      ≀
N1   G01   X_Z_F_ ;
N2   G01   X_Z_ ;
N3   G40 ;
N4   M05 ;
N5   G00   X_Z_ ;
      ≀
```

Type A, Type B

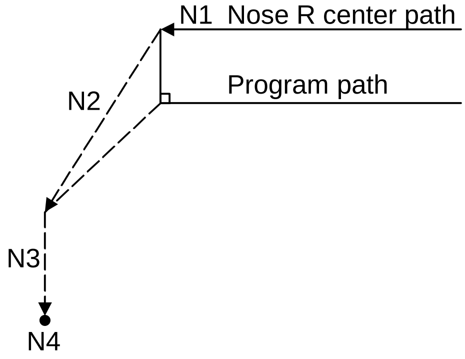


```
      ≀
N1   G01   X_Z_F_ ;
N2   G00   X_Z_ ;
N3   G01   X_Z_ ;
N4   G40 ;
N5   M05 ;
N6   G01   X_Z_ ;
      ≀
```

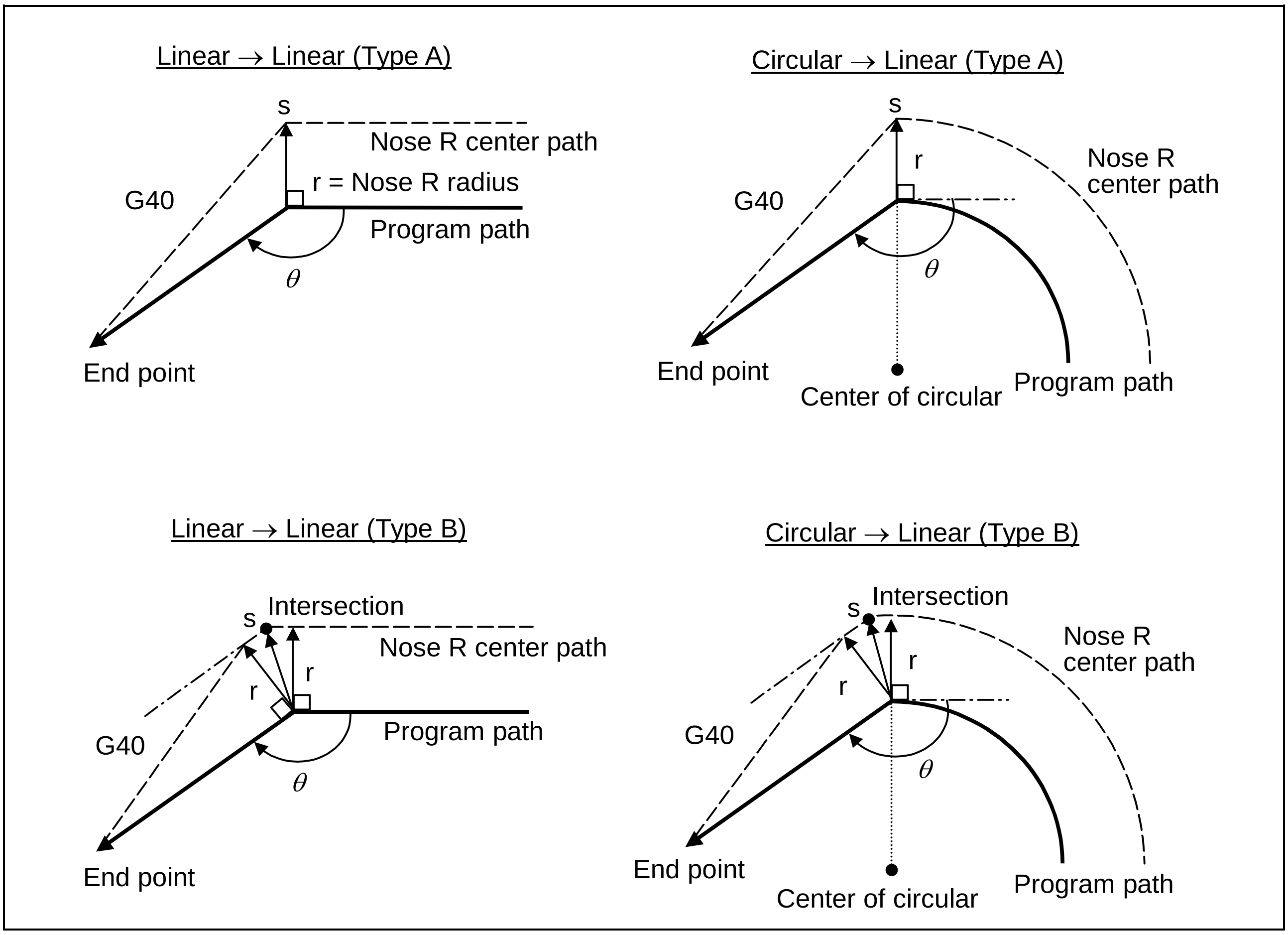


```
      ≀
N1   G01   X_Z_F_ ;
N2   G00   X_Z_ ;
N3   G00   X_Z_ ;
N4   G40 ;
      ≀
```

Type A, Type B



(b)-2 When a G40 command is issued at an outside corner (obtuse angle), in the same block as a movement command


Linear → Linear (Type A)

Circular → Linear (Type A)

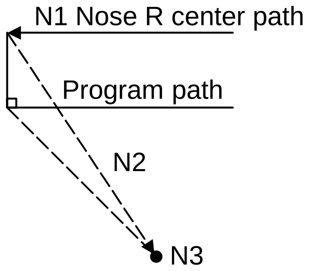
Linear → Linear (Type B)

Circular → Linear (Type B)

(c)-1 When an independent G40 command is issued at an outside corner (acute angle)

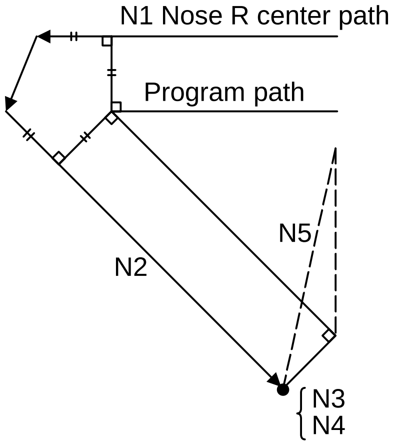
```
   ≀
N1  G01  X_Z_F_ ;
N2  G00  X_Z_ ;
N3  G40 ;
   ≀
```

Type A, Type B

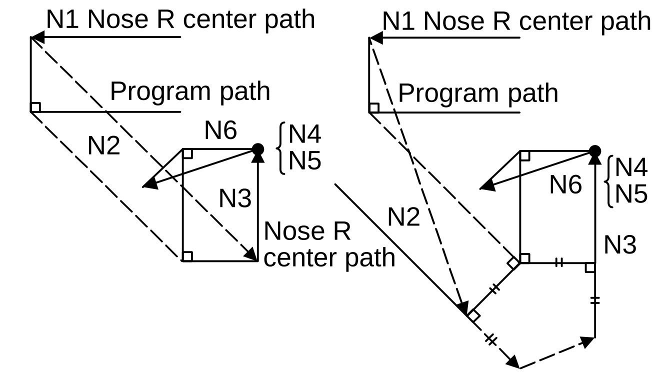


```
   ≀
N1  G01  X_Z_F_ ;
N2  G01  X_Z_ ;
N3  G40 ;
N4  M05 ;
N5  G00  X_Z_ ;
   ≀
```

Type A, Type B



```
   ≀
N1  G01  X_Z_F_ ;
N2  G00  X_Z_ ;
N3  G01  X_Z_ ;
N4  G40 ;
N5  M05 ;
N6  G01  X_Z_ ;
   ≀
```

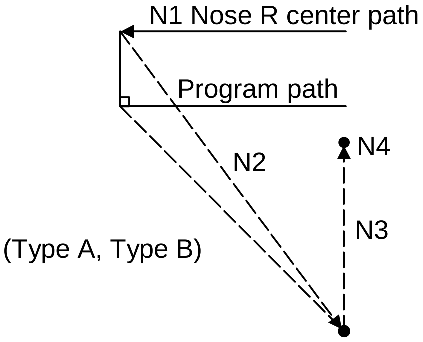


Type A

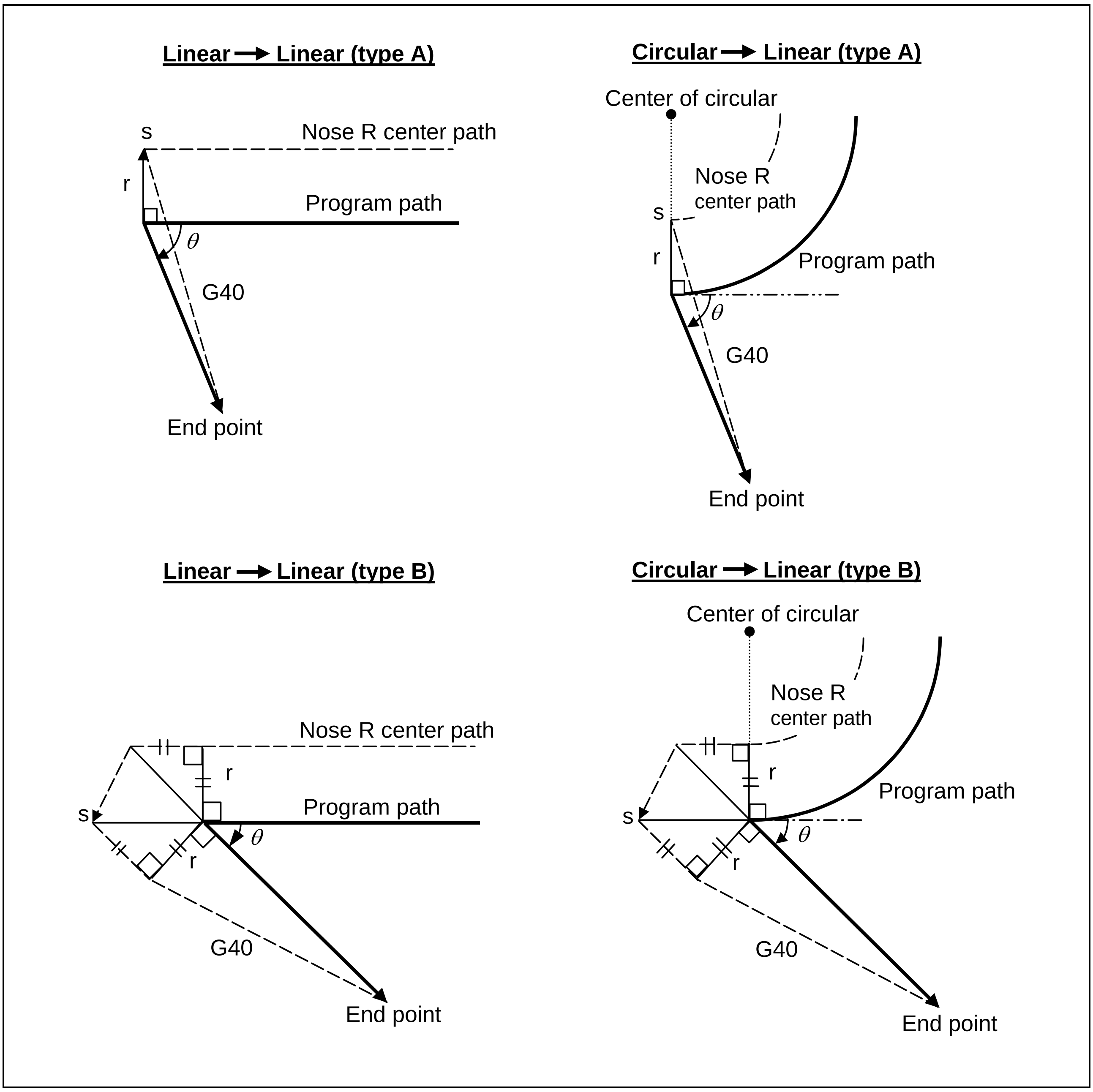
Type B

```
   ≀
N1  G01  X_Z_F_ ;
N2  G00  X_Z_ ;
N3  G00  X_Z_ ;
N4  G40 ;
   ≀
```

Type A, Type B



(c)-2 When a G40 command is issued at an outside corner (acute angle), in the same block as a movement command



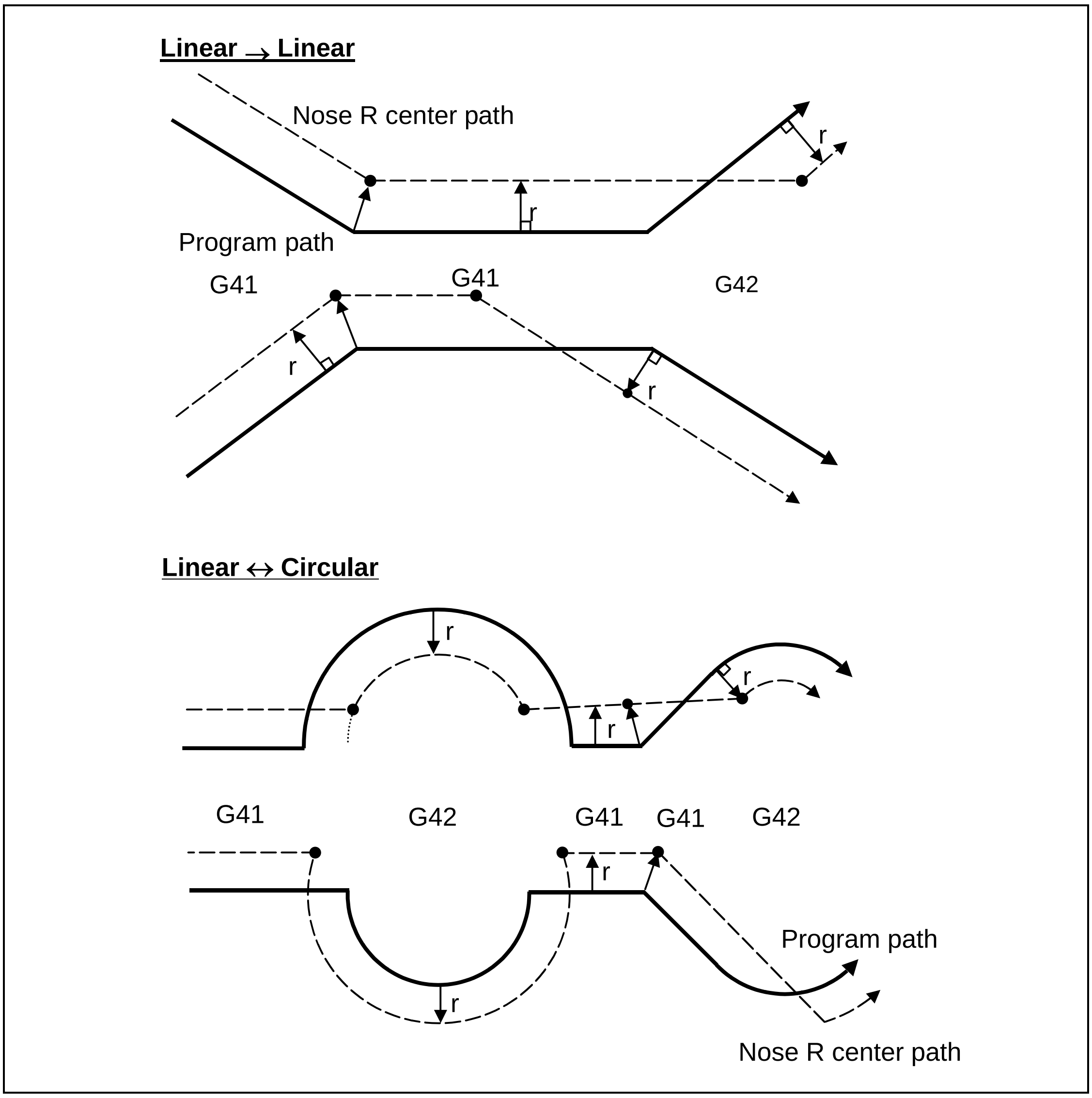
12.4.3 Other operations during tool nose radius compensation

Changing the compensation direction during tool nose radius compensation

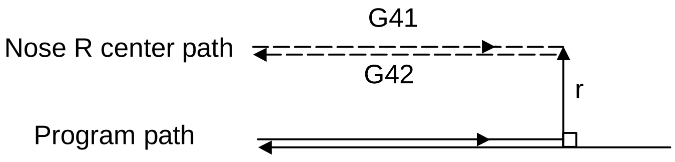
The compensation direction is determined by the tool nose radius compensation commands (G41, G42).

G code	Compensation direction
G41	Left-side compensation
G42	Right-side compensation

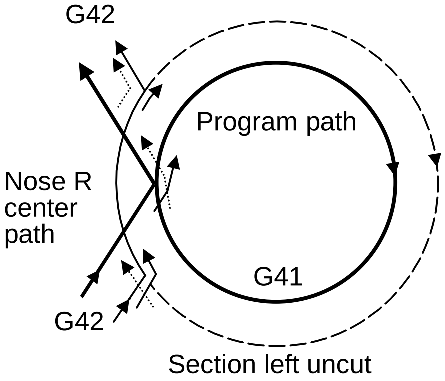
The compensation direction can be changed by changing the compensation command in the compensation mode without the compensation having to be first canceled.
However, no change is possible in the compensation start block and the following block.



Linear return



Arc exceeding 360◦ due to compensation method



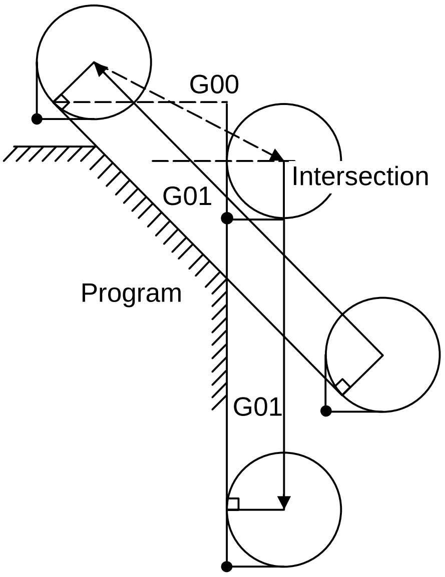
In the cases below, it is possible that the circular may exceed 360°.

a. With offset direction selection based on G41/G42

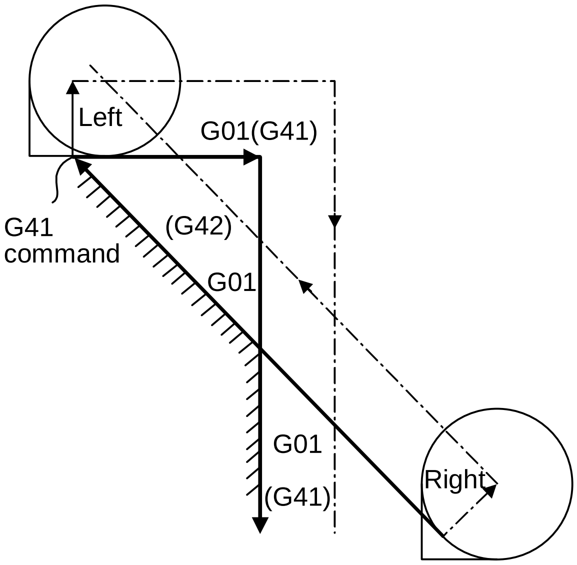
In cases like this, compensation is provided shown in the figure on the left and a section will be left uncut.

Tool nose radius compensation of path closed by G46/G41/G42

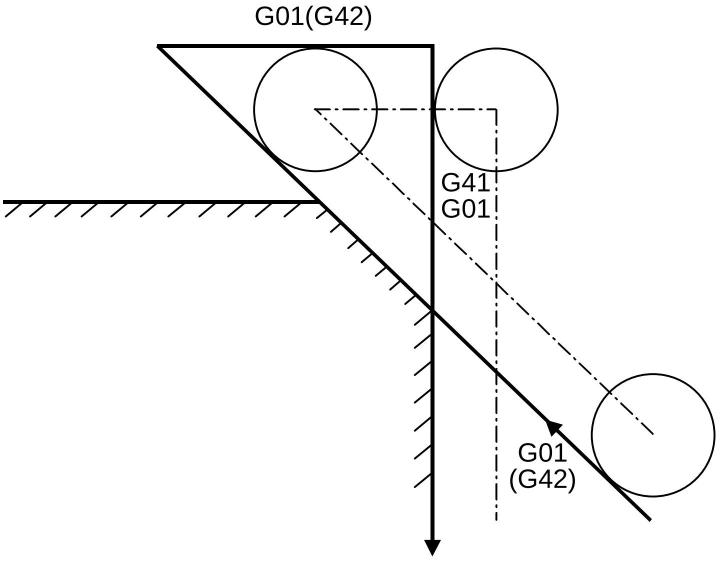
(1) G46 command operation



(2) G42 → G41 command operation



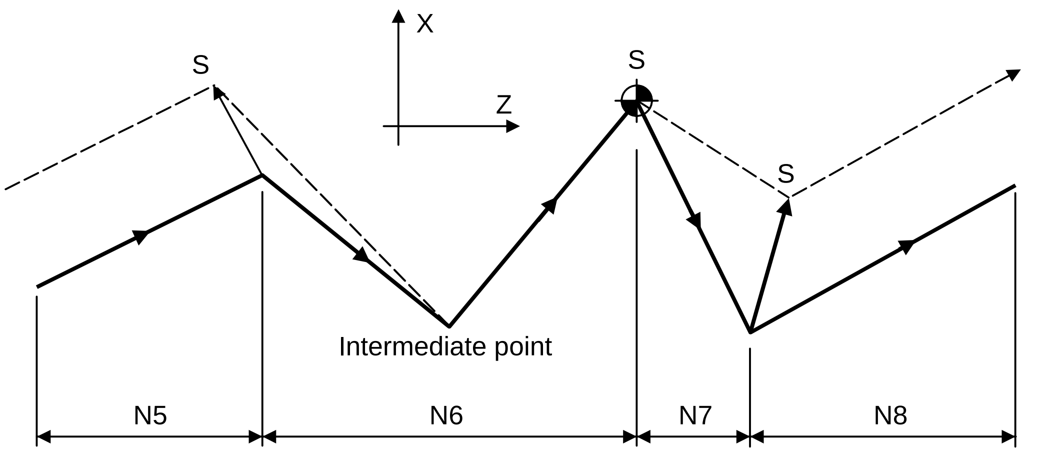
(3) G42 → G41 command operation



Command for eliminating offset vectors temporarily

When the following command is issued in the compensation mode, the offset vectors are temporarily eliminated and a return is then made automatically to the compensation mode.
In this case, the compensation is not canceled, and the tool goes directly from the intersection point vector to the point without vectors or, in other words, to the programmed command point. When a return is made to the compensation mode, it goes directly to the intersection point.

(1) Reference point return command



```
   (G41)          ≀
N5   G01   U 30. W 60.  ;
N6   G28   U-40. W 50.  ;  ←Temporarily no compensation vectors at intermediate
                              point
N7         U-60. W 30.  ;     (Reference point when there is no intermediate point)
N8         U 40. W 70.  ;
                  ≀
```

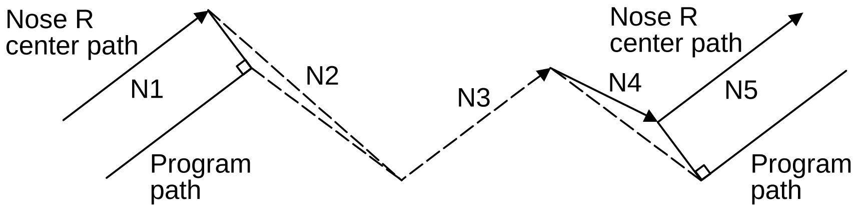
(2) The compensation vector will be eliminated temporarily with the G53 command (basic machine coordinate system selection).

(Note 1) The offset vectors do not change with the coordinate system setting (G92) command.

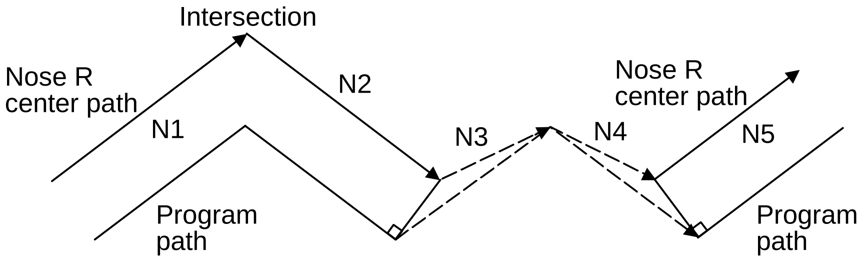
(3) Positioning (G00) commands

Tool nose radius compensation is temporarily canceled for G00 commands.

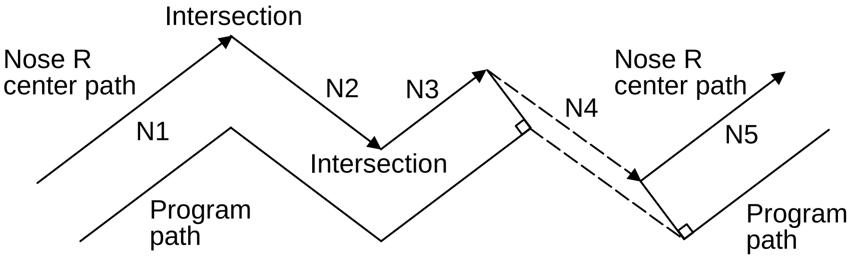
```
     ≀
N1   G01   X_Z_F_ ;
N2   G00   X_Z_ ;
N3   G00   X_Z_ ;
N4   G00   X_Z_ ;
N5   G01   X_Z_ ;
     ≀
```



```
     ≀
N1   G01   X_Z_F_ ;
N2   G01   X_Z_ ;
N3   G00   X_Z_ ;
N4   G00   X_Z_ ;
N5   G01   X_Z_ ;
     ≀
```

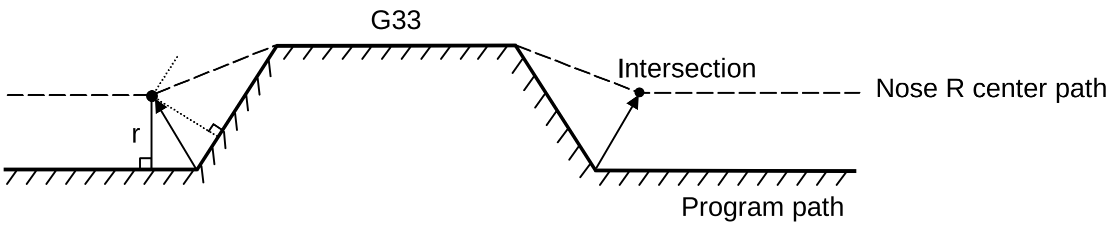


```
     ≀
N1   G01   X_Z_F_ ;
N2   G01   X_Z_ ;
N3   G01   X_Z_ ;
N4   G00   X_Z_ ;
N5   G01   X_Z_ ;
     ≀
```



(4) G33 thread cutting command

Tool nose radius compensation does not apply to the G33 block.



(5) Compound type fixed cycles

When a compound type fixed cycle I command (G70, G71, G72, G73) is assigned, the tool nose radius compensation is temporarily canceled, the finished shape to which tool nose radius compensation has been applied is cut with the compensation canceled and, upon completion, a return is automatically made to the compensation mode.

Blocks without movement

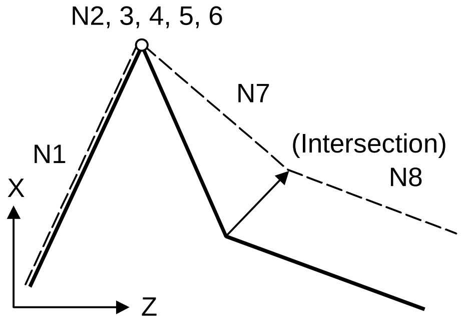
The following blocks are known as blocks without movement.

a.M03 ;………………………..……	M command	No movement
b.S12 ;…………………………..	S command	
c.T0101 ;………………………..	T command	
d.G04 X500 ;……………………	Dwell	
e.G10 P01R50 ;………………..	Offset amount setting	
f.G92 X600. Z500. ;…………..	Coordinate system setting	
g.Y40. ;…………………………	Movement but not on offset plane	
G.00 ;……………………………	G code only	
i.U0 ;…………………………….	Zero movement amount	Movement amount is zero

(1) When commanded at compensation start

Compensation vector cannot be generated when 4 or more blocks continue without movement or when a pre-reading prohibit M code is issued.

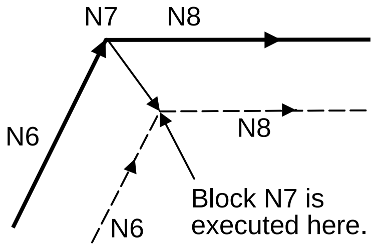
```
N1   U60. W30. T0101 ;
N2   G41 ;          ⎫
N3   G4 X1000 ;     ⎪
N4   F100 ;         ⎬ Block without
N5   S500 ;         ⎪ movement
N6   M3 ;           ⎭
N7   U-50. W20. ;
N8   U-20. W50. ;
```



(2) When command is assigned in the compensation mode

When the blocks without movement follows up to 3 blocks in succession in the compensation mode and there is no pre-reading prohibit M code is issued, the intersection point vectors will be created as usual.

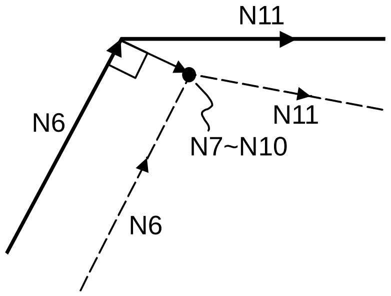
```
N6   U200.  W100.   ;
N7   G04    X1000   ; ….. Block without
                          movement
N8   W200. ;
```



When 4 or more blocks without movement follow in succession or when a pre-reading prohibit M code is issued, the offset vectors are created perpendicularly at the end point of the previous block.

```
N6   U200.    W100.   ;
N7   G4     X1000 ;  ⎫
N8   F100  ;          ⎪
N9   S500  ;          ⎬ Block without
N10  M4     ;         ⎪ movement
N11  W100.    ;       ⎭
```

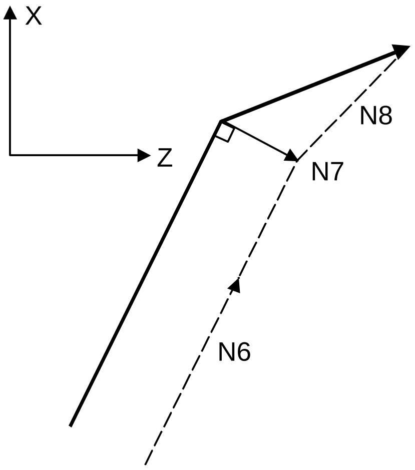
In this case, a cut result



(3) When commanded together with compensation cancel

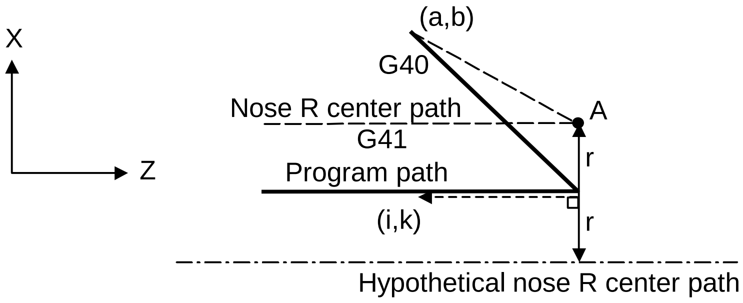
Only the offset vectors are canceled when a block without movement is commanded together with the G40 command.

```
N6   U200. W100.   ;
N7   G40   M5   ;
N8   U50.  W100.   ;
```



When I, J, K are commanded in G40

A perpendicular vector is created in the block before G40.

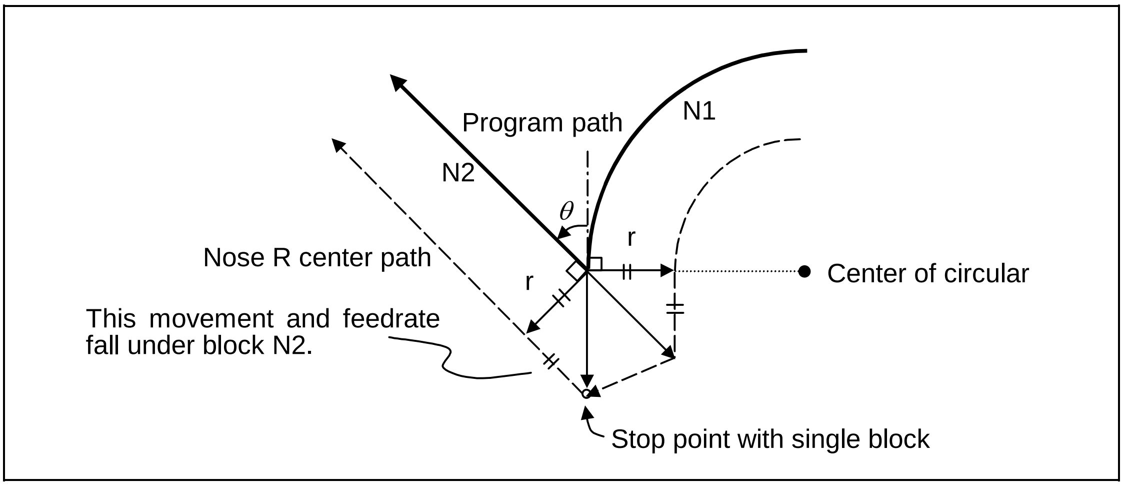


Corner movement

When a multiple number of compensation vectors are created at the joints between movement command blocks, the tool will move in a linear between those vectors. This action is called corner movement.

When the vectors do not coincide, the tool moves in order to machine the corner.

Consequently, operation in the single block mode will execute the previous block + corner movement as a single block and the remaining joining movement + following block will be executed as a single block in the following operation.


Program path
N1
N2
θ
r
r
Nose R center path
Center of circular
This movement and feedrate fall under block N2.
Stop point with single block

12.4.4 G41/G42 commands and I, J, K designation

Function and purpose

The compensation direction can be intentionally changed by issuing the G41/G42 command and I, J, K in the same block.

Command format

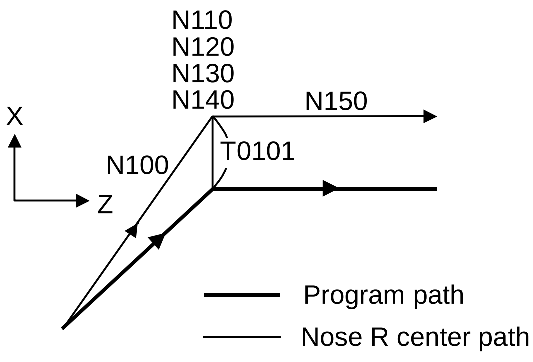
```
G18 (Z-X plane) G41/G42 X_  Z_  I_  K_ ;
```

Assign a linear command (G00, G01) in a movement mode.

I, K type vectors (G18 X-Z plane selection)

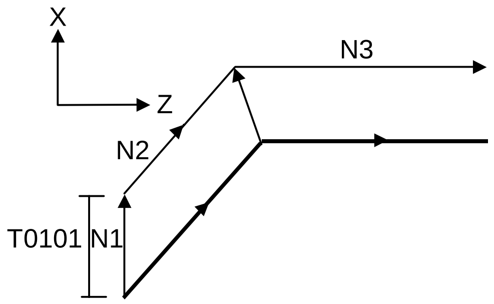
The new I, K type vector (G18 plane) created by this command is now described. (Similar descriptions apply to vector I, J for the G17 plane and to J, K for the G19 plane.)
As shown in the figures below, the vectors with a size equivalent to the offset amount are made to serve as the I, K type compensation vector perpendicularly to the direction designated by I, K without the intersection point of the programmed path being calculated. The I, K vector can be commanded even in the mode (G41/G42 mode in the block before) and even at the compensation start (G40 mode in the block before).

(1) When I, K is commanded at compensation start



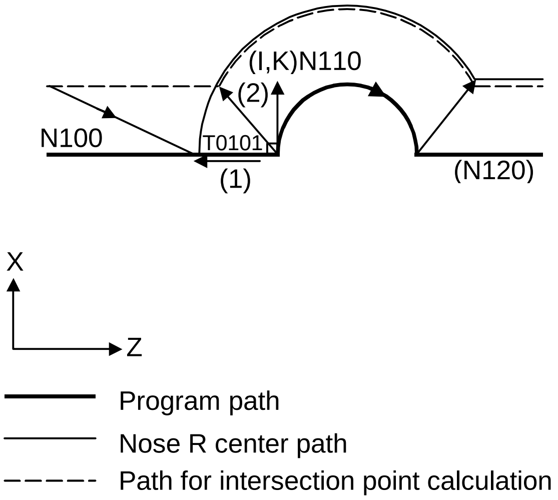
```
                (G40)
                  ≀
N100   G41   U100. W100. K150. T0101 ;
N110   G04   X1000 ;
N120   G01   F1000 ;
N130   S500 ;
N140   M03 ;
N150   Z150. ;
                  ≀
```

(2) When there are no movement commands at the compensation start



```
                (G40)
                  ≀
N1   G41   K150. T0101 ;
N2   U100. W100. ;
N3   W150. ;
                  ≀
```

(3) When I, K has been commanded in the mode (G18 plane)



```
                ≀
          (G18   G41)
N100   G41   T0101 G01 W150. I50. ;
N110   G02   W100. I50. ;
N120   G01   W100.
                ≀
```

Program path

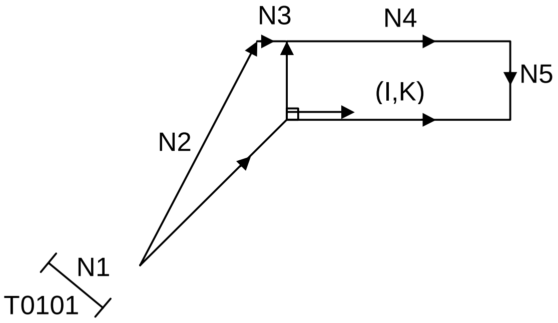
Nose R center path

Path for intersection point calculation

(1) I, K type vector

(2) Intersection point calculation type vector

(4) When I, K has been commanded in a block without movement

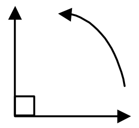
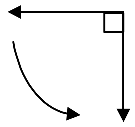


```
N1   G41   T0101   G01   F1000 ;
N2   U100.   W100. ;
N3   G41   K50. ;
N4   W150. ;
N5   G40 ;
```

Direction of offset vectors

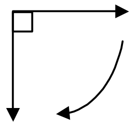
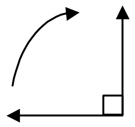
(1) In G41 mode

Direction produced by rotating the direction commanded by I, K through 90° to the left from the forward direction of the Y axis (3rd axis) as seen from the zero point

(Example 1) With K100.	**(Example 2)** With K –100.
Offset vector direction  (0, 100) IK direction	(0, –100) IK direction  Offset vector direction

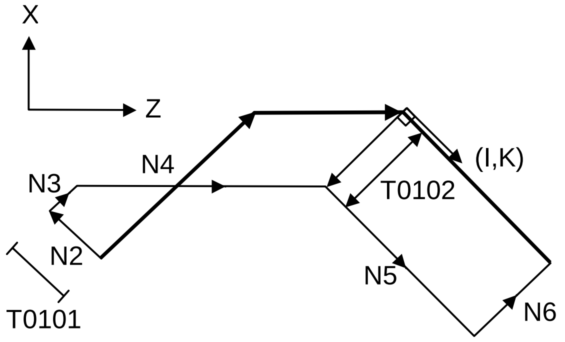
(2) In G42 mode

Direction produced by rotating the direction commanded by I, K through 90° to the right from the forward direction of the Y axis (3rd axis) as seen from the zero point

(Example 1) With K100.	**(Example 2)** With K –100.
(0, 100) IK direction  Offset vector direction	Offset vector direction  (0, –100) IK direction

Selection of offset modal

The G41 or G42 modal can be selected at any time.

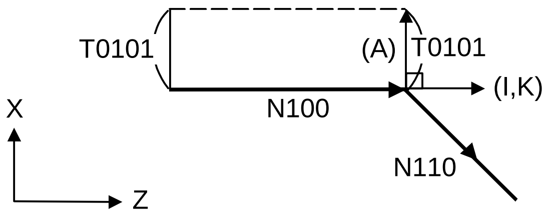


```
N1   G28    X0Z0    ;
N2   G41 T0101 F1000    ;
N3   G01 U100.    W100.    ;
N4   G42    W100. I-100. K100.
     T0102 ;
N5   U-100.    W100.    ;
N6   G40    ;
N7   M02    ;
%
```

Offset amount for offset vectors

The offset amounts are determined by the offset number (modal) in the block with the I, K designation.

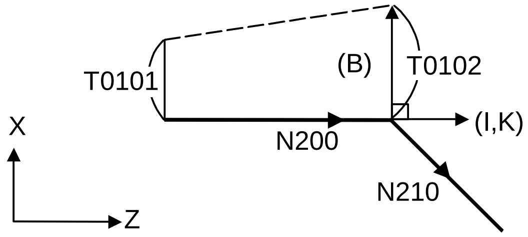
<Example 1>



```
      (G41   T0101)
           ≀
N100   G41   W150. K50.   ;
N110   U-100. W100.   ;
           ≀
```

Vector (A) is the offset amount entered in tool offset number modal 1 in the N100 block.

<Example 2>



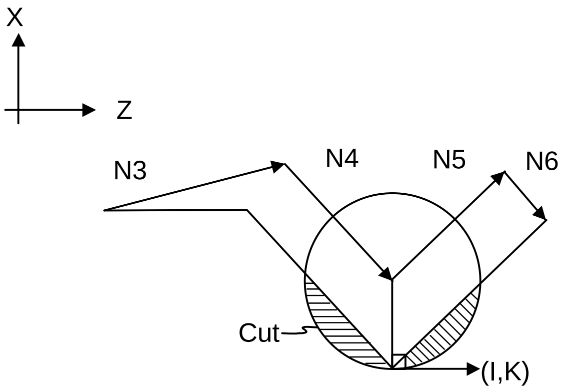
```
      (G41   T0101)
           ≀
N200   G41   W150. K50. T0102 ;
N210   U-100. W100.   ;
           ≀
```

Vector (B) is the offset amount entered in tool offset number modal 2 in the N200 block.

Precautions

(1) Issue the I, K type vector in a linear mode (G0, G1). If it is issued in an arc mode at the start of compensation, program error (P151 G2, 3 CMP. ERR) will result.
An I, K designation in an arc mode functions as an arc center designation in the offset mode.

(2) When the I, K type vector has been designated, it is not deleted (avoidance of interference) even if there is interference. Consequently, overcutting may arise in such a case.



```
N1   G28   X0Z0   ;
N2   G41   T0101   F1000   ;
N3   W100.   ;
N4   G41   U-100.   W100. K10.   ;
N5   U100.   W100.   ;
N6   G40   ;
N7   M02   ;
```

(3) Refer to the following table for the offset methods based on the presence and/or absence of the G41 and G42 commands and I, K (J) command.

G41/G42	I, K (J)	Offset method
No	No	Intersection point calculation type vector
No	Yes	Intersection point calculation type vector
Yes	No	Intersection point calculation type vector
Yes	Yes	I, K type vector No insertion block

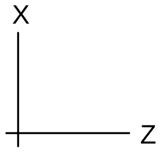
12.4.5 Interrupts during tool nose radius compensation

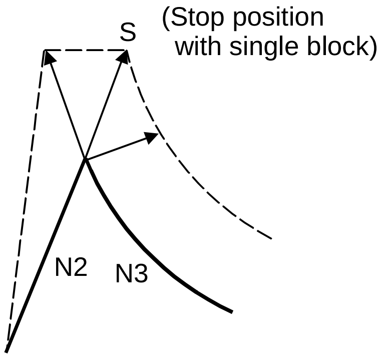
MDI interrupt

Tool nose radius compensation is valid in any automatic operation mode - whether memory or MDI operation.
An interrupt based on MDI will give the result as in the figure blow after block stop during memory operation.

(1) Interrupt without movement (tool path does not change)

```
N1 G41    T0101 ;
N2 U50.    W20.    ;    MDI interrupt
N3 G3    U–40.    W40. R70. ;  | S1000    M3 ;
```

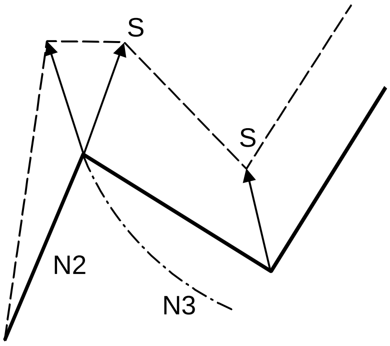




(2) Interrupt with movement
The offset vectors are automatically re-calculated at the movement block after interrupt.

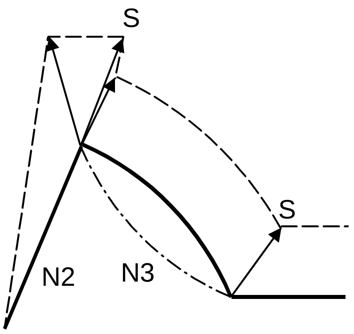
With linear interrupt

```
N1 G41    T0101 ;
N2 U50.    W20.    ;     MDI interrupt
N3 G3    U–40.    W40. R70.    ;|  U–30.    W50.    ;
                                   U50.    W30.    ;
```



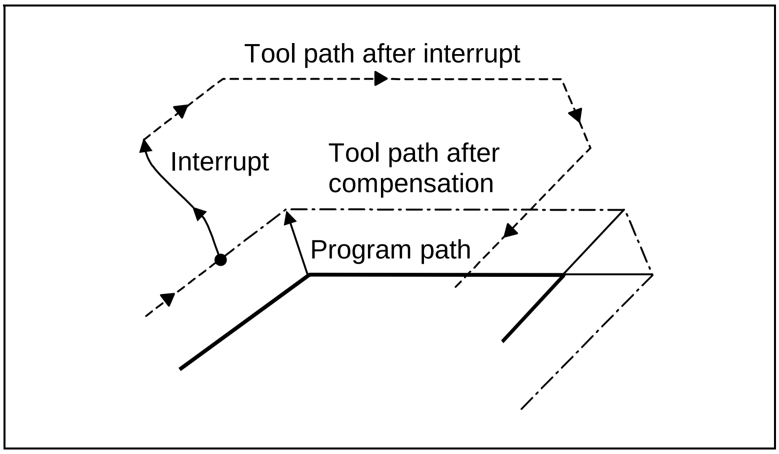
With circular interrupt

```
N1 G41    T0101 ;
                       MDI interrupt
N2 U50.    W20.    ;
N3 G3    U–40.    W40. R70.    ;|  G2    U–40. W40. R70. ;
                                   G1    W40.    ;
```



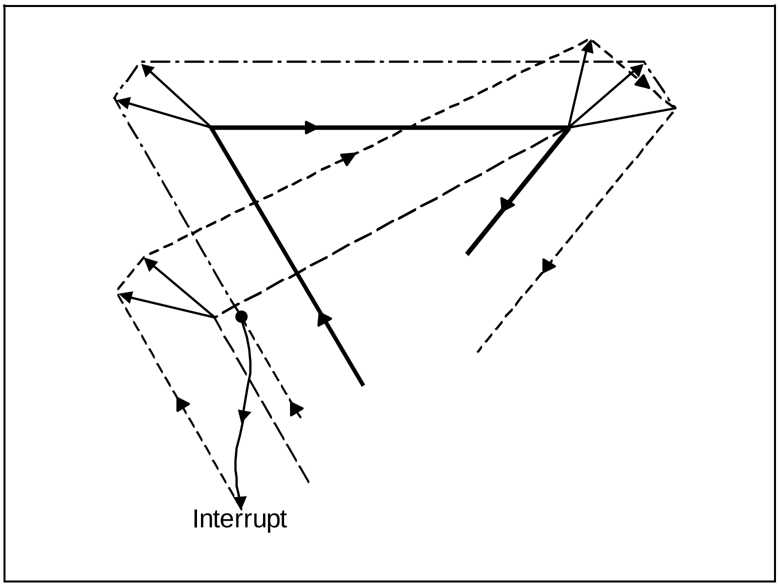
Manual interrupt

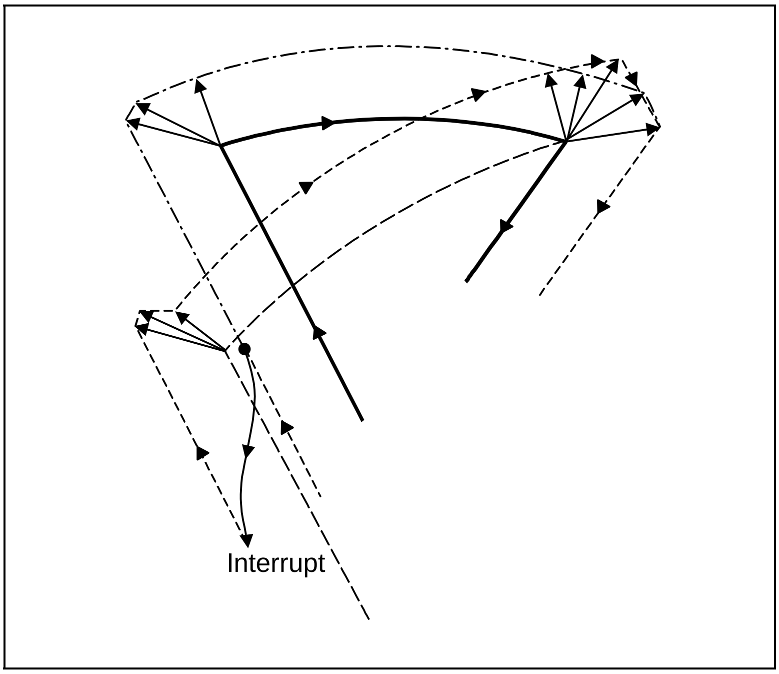
(1) Interrupt with manual absolute OFF.
The tool path is shifted by an amount equivalent to the interrupt amount.



(2) Interrupt with manual absolute ON.
In the incremental value mode, the same operation results as with manual absolute OFF.

In the absolute value mode, however, the tool returns to its original path at the end point of the block following the interrupted block, as shown in the figure.





12.4.6 General precautions for tool nose radius compensation

Assigning the compensation amounts

(1) The compensation amount is normally assigned by designating the number of the compensation amount by the last 1 or 2 digits of the T code. Depending on the machine specifications, the high-order digits may be used. The T code will remain valid once designated until another T code is subsequently commanded.
Besides being used to designate the compensation amounts for tool nose radius compensation, the T codes are also used to designate the offset amounts for tool length offset.

(2) The compensation amounts are normally changed when a different tool has been selected in the compensation cancel mode. However, when an amount is changed in the compensation mode, the vectors at the end point of the block are calculated using the compensation amount designated in that block.

Errors during tool nose radius compensation

(1) An error results when any of the following commands are programmed during tool nose radius compensation.

G17, G18, G19 ("P112" when a plane differing from that applying during the compensation has been commanded)
G31 ("P608")
G74, G75, G76 ("P155")
G81 ~ G89 ("P155")

(2) An error ("P158") results when a tool nose point other than 1 to 8 has been designated in the G46 mode.

(3) An error ("P156") results when the compensation direction is not determined by the movement vector of the initial cutting command even when the tool nose radius compensation operation has started in the G46 mode and 5 blocks have been pre-read.

(4) An error ("P151") results when a circular command is issued in the first or last block of the tool nose radius compensation.

(5) A program error ("P157") results when the offset direction is reversed in the G46 mode. A parameter can be set to move the tool in the same compensation direction. (Control parameter "#8106 G46 NO REV-ERR")

(6) A program error ("P152") results during tool nose radius compensation when the intersection point is not determined with single block skip in the interference block processing.

(7) A program error results when there is an error in one of the pre-read blocks during tool nose radius compensation.

(8) A program error ("P153") results when interference arises under no interference avoidance conditions during tool nose radius compensation.

(9) A program error ("P150") results when a tool nose radius compensation command is issued even though the tool nose radius compensation specification has not been provided.

12.4.7 Interference check

Function and purpose

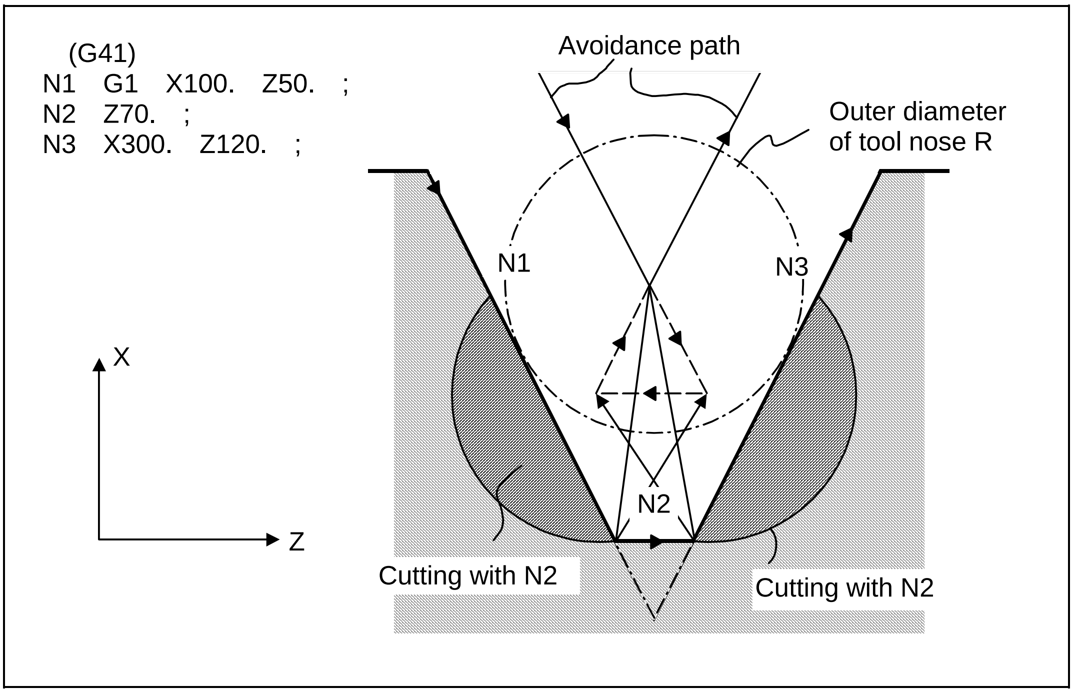
A tool, whose tool nose has been compensated under the tool nose radius compensation function by the usual 2-block pre-read, may sometimes cut into the workpiece. This is known as interference, and interference check is the function which prevents this from occurring.
There are two types of interference check, as indicated below, and each can be selected for use by parameter.

Function	Parameter	Operation
Interference check alarm function	Interference check avoidance OFF Interference check invalid OFF	A program error results before the execution of the block in which the cut arises, and operation stops.
Interference check avoidance function	Interference check avoidance ON Interference check invalid OFF	The tool path is changed so that workpiece is not cut into.
Interference check invalid function	Interference check invalid OFF	Cutting continues as is, even if the workpiece is cut into. Use in the fine segment program.

(Note) #8102 Interference avoidance
#8103 Interference check invalid

Detailed description

(Example)



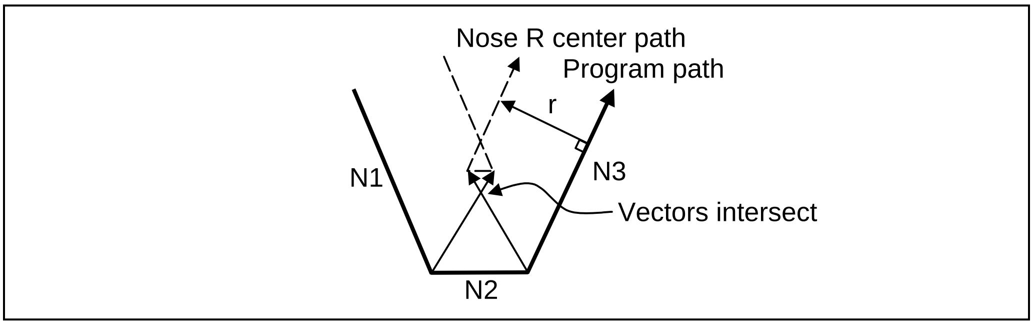
```
  (G41)
N1   G1   X100.   Z50.   ;
N2   Z70.   ;
N3   X300.   Z120.   ;
```

(1) With alarm function
The alarm occurs before N1 is executed and so, using the edit function, N1 can be changed as below and machining can be continued: N1 G1 X–100. Z–20. ;

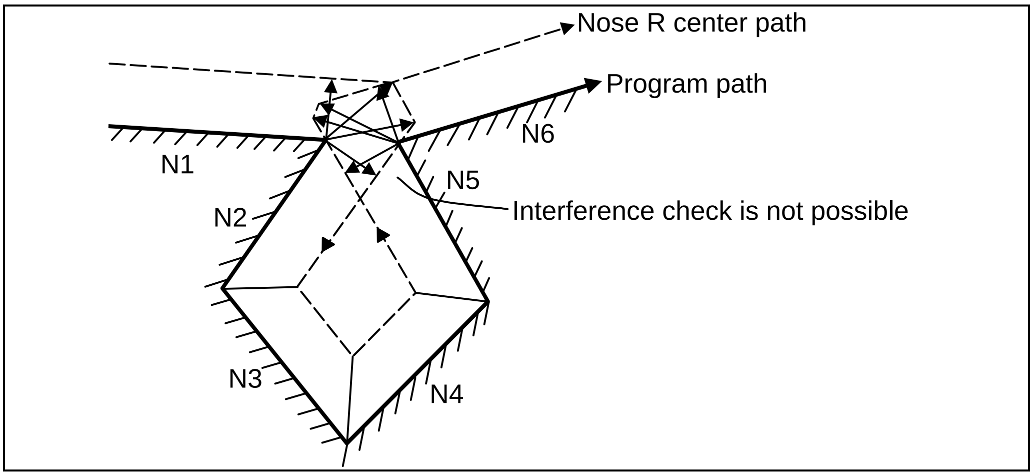
(2) With avoidance function
The intersection point of N1 and N3 is calculated and the interference avoidance vectors are created.

(3) With interference check invalid function
The tool passes while cutting into the straight line between N1 and N3.

(a) Conditions regarded as interference
If there is a movement command in three of the five pre-read blocks, and if the compensation calculation vectors created at the contacts of each movement command intersect, it will be regarded as an interference.

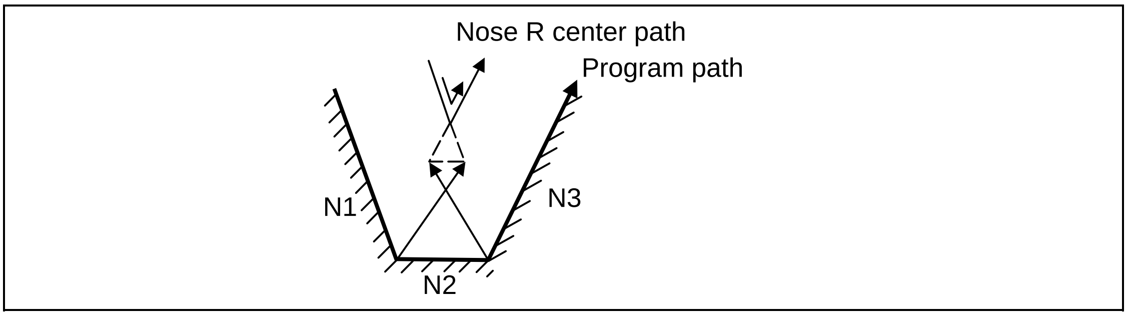


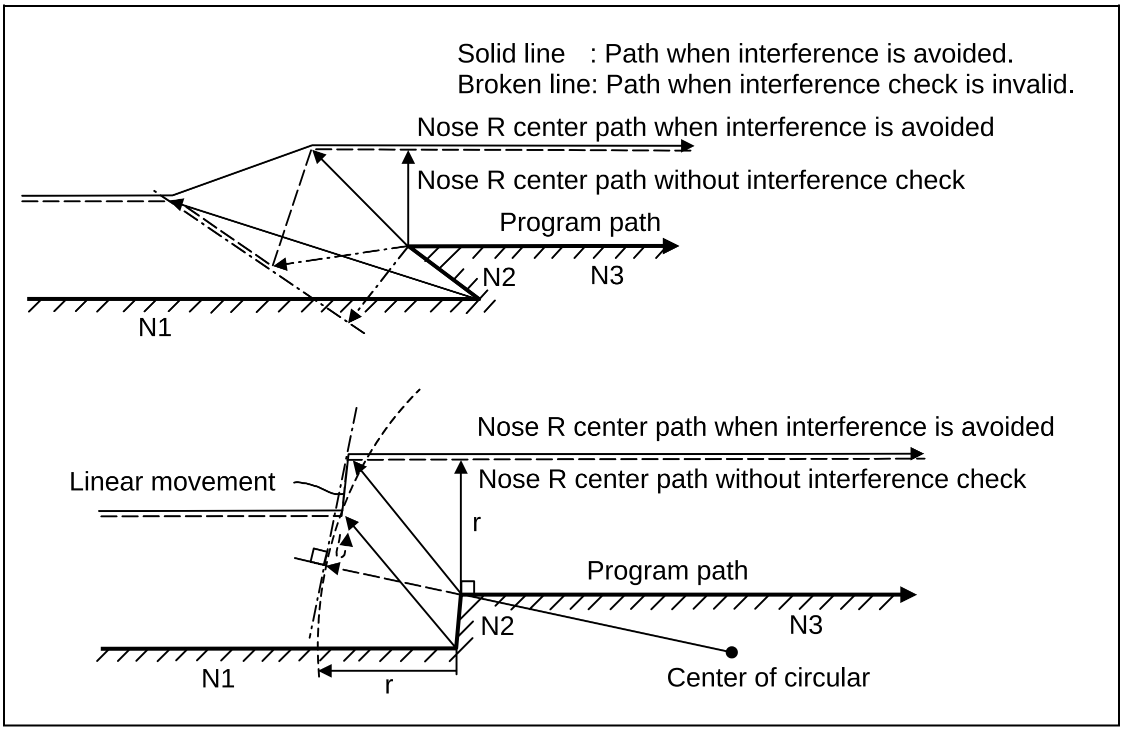
(b) When interference check cannot be executed
(i) When three of the movement command blocks cannot be pre-read
(When there are three or more blocks in the five pre-read blocks that do not have movement)
(ii) When there is an interference following the fourth movement block



Operation during interference avoidance

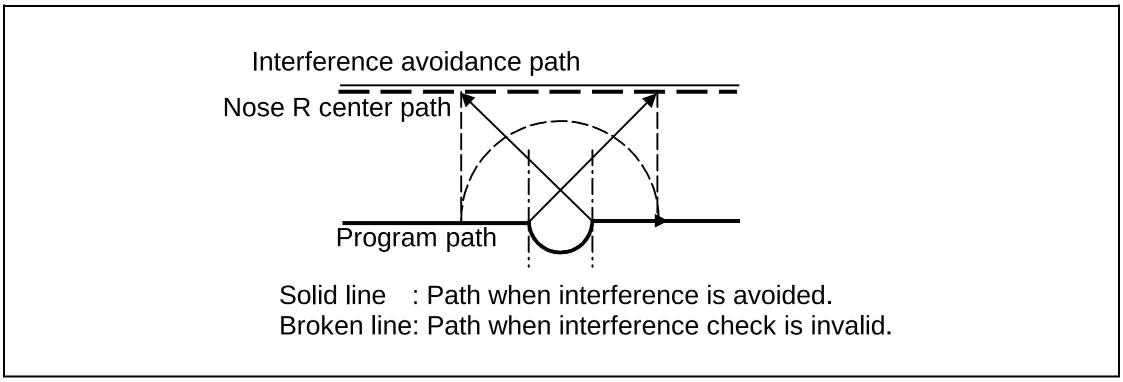
The movement will be as shown below when the interference avoidance check is used.




Solid line : Path when interference is avoided.
Broken line: Path when interference check is invalid.

Nose R center path when interference is avoided
Nose R center path without interference check
Program path
N2
N3
N1
Nose R center path when interference is avoided
Linear movement
Nose R center path without interference check
r
Program path
N2
N3
N1
r
Center of circular

In the case of the figure below, the groove will be left uncut.



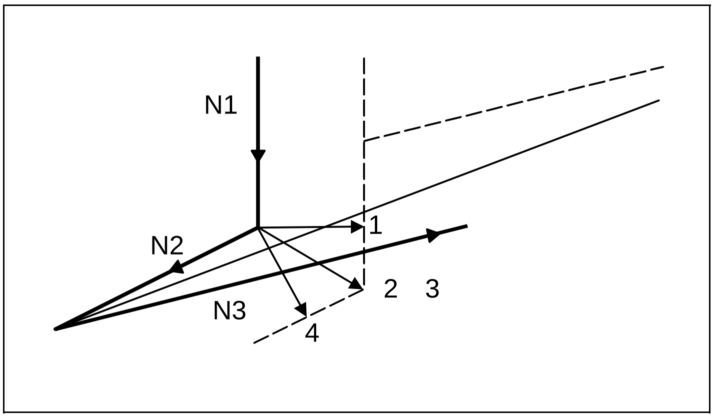
Solid line : Path when interference is avoided.
Broken line: Path when interference check is invalid.

Interference check alarm

The interference check alarm occurs under the following conditions.

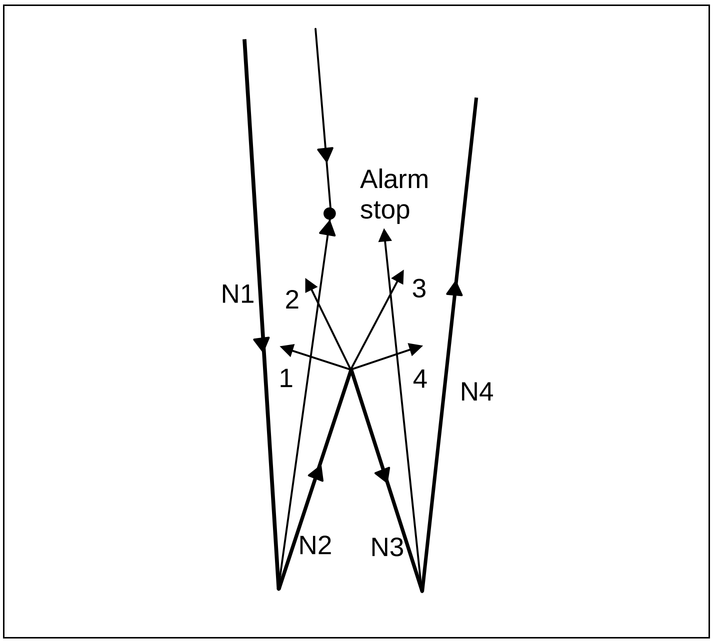
(1) When the interference check alarm function has been selected
(a) When all the vectors at the end block of its own block have been deleted

When, as shown in the figure on the right, vectors 1 to 4 at the end point of the N1 block have all been deleted, program error (P153) results prior to N1 execution.

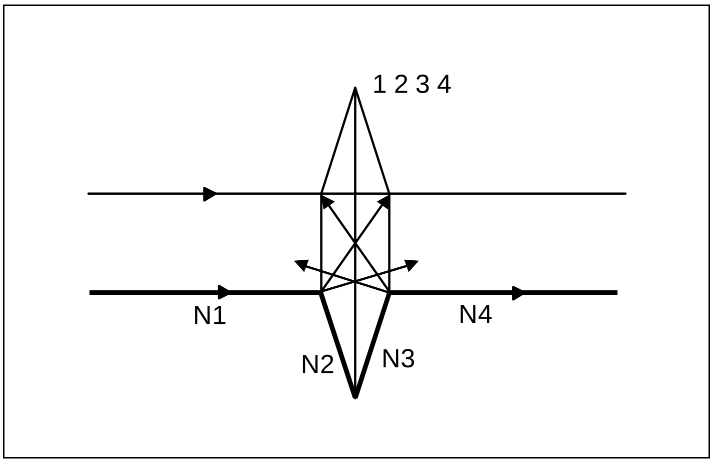


(2) When the interference check avoidance function has been selected
(a) When there are valid vectors at the end point of the following block even when all the vectors at the end point of its own block have been deleted

(i) When, in the figure on the right, the N2 in interference check is conducted, the N2 end point vectors are all deleted but the N3 end point vectors are regarded as valid. Program error (P153) now occurs at the N1 end point.

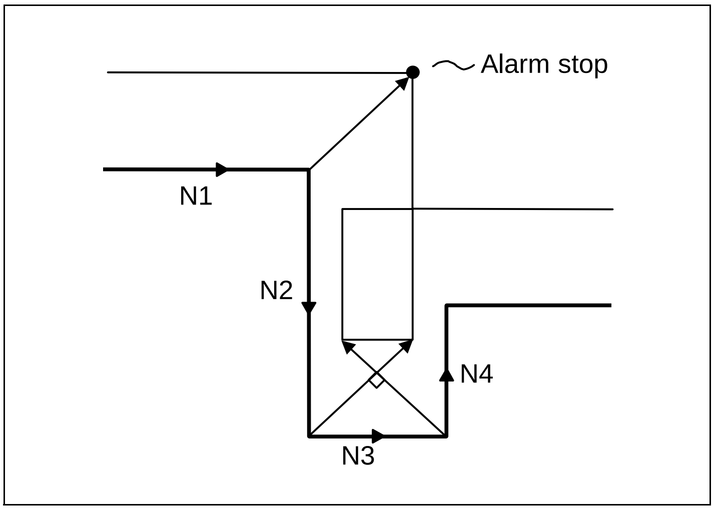


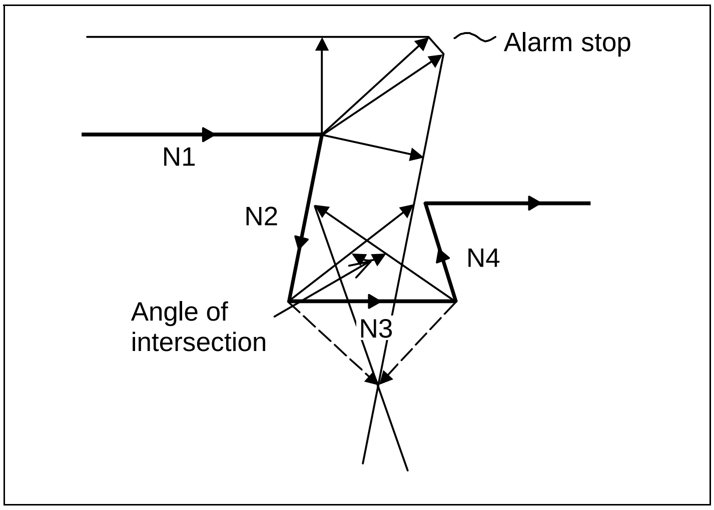
(ii) In a case such as that shown in the figure on the below, the tool will move in the reverse direction at N2. Program error (P153) now occurs prior to N1 execution.



(b) When avoidance vectors cannot be created

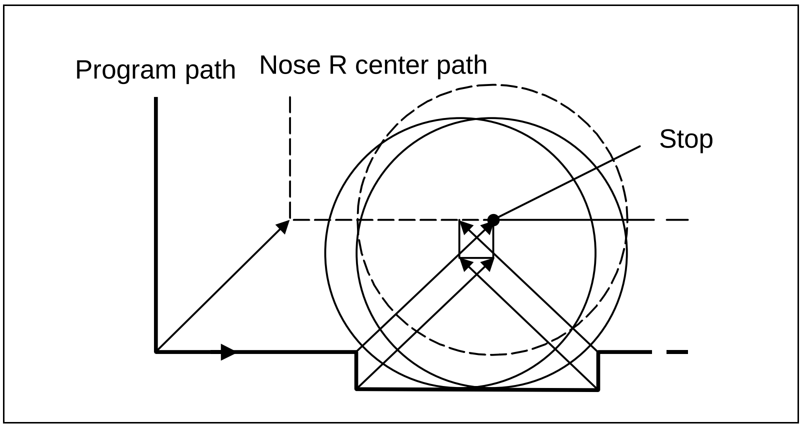
(i) Even when, as in the figure on the below, the conditions for creating the avoidance vectors are met, it may still be impossible to create these vectors or the interference vectors may interfere with N3. As a result, program error (P153) will occur at the N1 end point when the vector intersecting angle is more than 90°.

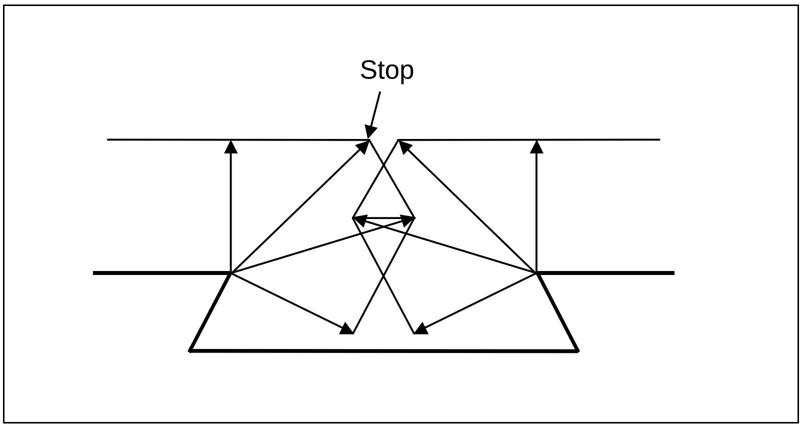




(c) When the program advance direction and the advance direction after compensation are reversed

In the following case, interference is still regarded as occurring even when there is actually no interference.
When grooves which are narrower than the tool nose R diameter or which have parallel or widening walls are programmed.





12.5 Programmed offset input; G10

Function and purpose

The amount of tool offset and workpiece offset can be set or changed by the G10 command. When commanded with absolute values (X,Z,R), the commanded offset amounts serve as the new amounts; when commanded with incremental values (U,W,C), the new offset amounts are equivalent to the commanded amounts plus the current offset amount settings.

Command format

(1) Workpiece offset input (L2)

G10 L2 P_ X_ (U_)Z_ (W_) ;

P	Offset number
X	X-axis offset amount (absolute)
U	X-axis offset amount (incremental)
Z	Z-axis offset amount (absolute)
W	Z-axis offset amount (incremental)

(2) Tool length offset input (L10)

G10 L10 P_ X_ (U_)Z_ (W_)R_ (C_)Q_ ;

P	Offset number
X	X-axis offset amount (absolute)
U	X-axis offset amount (incremental)
Z	Z-axis offset amount (absolute)
W	Z-axis offset amount (incremental)
R	Tool nose radius compensation amount (absolute)
C	Tool nose radius compensation amount (incremental)
Q	Hypothetical tool nose point

(3) Tool nose wear offset input (L11)

G10 L11 P_ X_ (U_)Z_ (W_)R_ (C_)Q_ ;

P	Offset number
X	X-axis offset amount (absolute)
U	X-axis offset amount (incremental)
Z	Z-axis offset amount (absolute)
W	Z-axis offset amount (incremental)
R	Tool nose radius compensation amount (absolute)
C	Tool nose radius compensation amount (incremental)
Q	Hypothetical tool nose point

(4) When there is no L command with tool length offset input (L10) or tool nose wear offset input (L11)
Tool length offset input command : P = 10000 + offset number
Tool nose wear offset input command : P = offset number

(5) Offset input cancel

G11 ;

Detailed description

(1) The following table shows the offset numbers and the setting ranges of the hypothetical tool nose points.

Add ress	Significance of address	Setting range		
		L2	L10	L11
P	Offset number	0:External workpiece offset 1:G54 workpiece offset 2:G55 workpiece offset 3:G56 workpiece offset 4:G57 workpiece offset 5:G58 workpiece offset 6:G59 workpiece offset	When L command is present: 1 to Max. number of offset sets When L command is not present: 10001 to 10000 + Max. number of offset	When L command is/is not present: 1 to Max. number of offset sets
Q	Hypothetical tool nose point	—	0 to 9	

(Note1) The maximum number of offset sets for P (offset number) with tool offset input (L10 or L11) is up to a total of 80 with the addition of options.
(The No. of sets will differ according to the model so check the specifications.)

(2) The setting range for the offset amount is given blow.
Program error (P35) occurs for any value not listed in the table after command unit conversion.
With an incremental value command, the setting range for the offset amount is the sum of the present setting and command value.

Input unit	Tool length offset amount		Tool wear offset amount	
	Metric system	Inch system	Metric system	Inch system
IS - B	±99999.999 (mm)	±9999.9999 (inch)	±99999.999 (mm)	±9999.9999 (inch)
IS - C	±9999.9999 (mm)	±999.99999 (inch)	±999.9999 (mm)	±999.99999 (inch)

Precautions and Restrictions

(1) Offset amount setting range check
The maximum value of the wear offset amount and the maximum additional value for the wear offset input check respectively take precedence for a single-time offset amount in the maximum value and incremental value command of the wear offset amount, and when an amount greater than these values has been commanded, program error (P35) results.

(2) G10 is an unmodal command and is valid only in the commanded block.

(3) Offset input can be performed similarly for the third axis but even when the C axis has been designated as the third axis, address C is treated as an incremental command value of the tool nose radius in the L10 or L11 command.

(4) If an illegal L number or tool compensation No. is commanded, program error (P172 or P170) will result, respectably.

(5) When the P command in the workpiece offset input is a command besides 0 to 6, or the P command is omitted, it will be handled as the currently selected workpiece offset input.

(6) Program error (P35) results when the offset amount exceeds the setting range.

(7) The offset amounts for the external workpiece coordinate system and the workpiece coordinate system are commanded as distances from the basic machine coordinate system zero point.

(8) X, Z and U, W are input together in a single block but when an address that commands the same offset input (X, U or Z, W) is commanded, the address which is input last is valid.

(9) Offset will be input if even one address following G10 L(2/10/11) P_ is commanded. Program error (P33) results when not even a single command has been assigned.

(Example) G10 L10 P3 Z50. ;

↓

```
[Tool length data]
  #      Z
  3    50.000
```

Input as per left

(10) Decimal points are valid for offset amounts.

(11) G40 to G42 are ignored when they have been commanded in the same block as G10.

(12) Do not command G10 in the same block as fixed cycles and subprogram call commands. This will cause malfunctioning and program errors.

(13) When a T command has been issued in the same block as G10 with parameter "#1100 Tmove" as "0", the offset will be accomplished in the following block.

12.6 Tool life management II

Function and purpose

Tool life management divides the tools being used into several groups, and manages the life (usage time, No. of uses) of the tools in each group. When the life is reached, a similar spare tool in the same group will be selected in order. This tool life management function with spare tools allows unmanned operation over a long time.

(1) Number of life-managed tools	1 part system	: Maximum 80 tools,
	2/3 part systems	: Maximum 40 tools/part system
(2) Number of groups	1 part system	: Maximum 80 groups,
	2/3 part systems	: Maximum 40 groups/part system
(3) Group No.	1 to 9999	
(4) Number of tools in one group	Maximum 16 tools	
(5) Life time	0 to 999999 minutes (approx. 16667 hours)	
(6) Number of lives	0 to 999999 times	

The tool life management data can be set from the NC program or from the Tool Life Management screen.
Refer to the Operation manual for the method of setting from the Tool Life Management screen.
When using the NC program, register the data with the same method as program compensation input.

Command format

G10 L3 ;	**Life management data registration start**	
P_ L_ N_ ;	**Registration of group No., life per tool, method**	**First group**
T_ ;	**Registration of tool No.;**	
T_ ;		
P_ L_ N_ ;	**Registration of next group No., life per tool, method**	**Next group**
T_ ;	**Registration of tool No.;**	
T_ ;		
G11 ;	**End of life management data registration**	
P	Group No., (1 to 9999)	
L	Life per tool (0 to 999999 minutes, or 0 to 999999 times)	
N	Method (0:Time management, 1:No. of times management)	
T	Tool No.; the spare tool is selected in the order registered here. (Tool number 1 to 999999. Compensation No. 1 to 80) "T_" (number of tools) follows the specifications.	

Precautions and restrictions

(1) The tool life data is registered by executing the above program in the memory or MDI mode.

(2) When the above program is executed, all data (group No., tool No., life data) registered previously will be deleted. The registered data is held even when the power is turned OFF.

(3) The group No. designated with P does not have to be consecutive, but it should be set in ascending order if possible. This will make monitoring on the screen easier. The group No. cannot be commanded in duplicate.

(4) If the life data L_ is omitted, the life data for that group will be "0". If N_, which designates the method, is omitted, the method for that group will follow the base specification parameter "#1106 Tcount".

(5) Programming with a sequence No. is not possible between G10 L3 and G11.

(6) If the usage data count valid signal (Y78A/Y86A/Y94A) is ON, G10 L3 cannot be commanded. (P177 LIFE COUNT ACT)

Example of program

(1) Format

: T□□□□99 ;	Start use of □□□□ group tool
: :	
T□□□□88 ; : :	Cancel □□□□ group tool offset (Equivalent to TΔΔ00: ΔΔis number of tool being used).
M02 (M30) ;	End of machining program

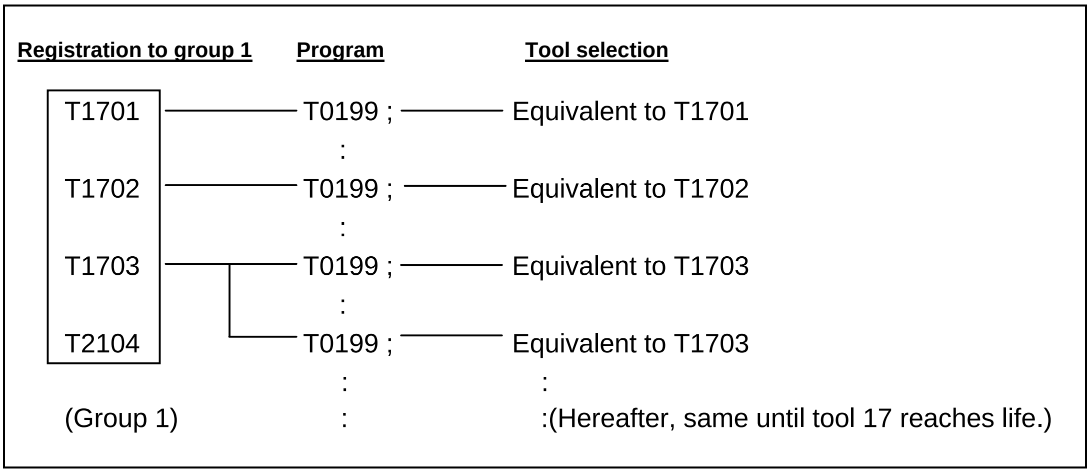
(2) Actual example

: T0119 ;	Start use of group 01 tool
: :	
T0188 ; : :	Cancel group 01 tool offset If the number of the tool being used is 17, this is equivalent to T1700.
T0609 ; : :	Selects tool No. 06 and offset No. 09. * Life management is not carried out for tool 06.
T0600 ; : :	Cancel of group 06 tool offset
T0299 ; : :	Start use of group 02 tool
T0199 ; :	Start use of group 01 tool If the selected tool has several compensation numbers, the second compensation No. is selected.

Example of tool selection operation (When one tool has several compensation numbers)

(1) To use several compensation numbers with one tool, select the next compensation No. for each T□□□□99 command.

(2) If T□□□□99 is commanded for more times than the number of registered compensation numbers, the last compensation No. will be selected, and the operation will continue. (Refer to following.)



(3) If the above program is executed after resetting with M02/M30, or by resetting with external reset, the selection will be made from the head compensation No.

12.6.1 Counting the tool life

Function and purpose

The tool life can be counted with the time-count type or No. of uses-count type. The count method and timing for the No. of uses-count type can be changed to type 2 with the parameter setting (#1277 ext13/bit0).
If the usage data is equivalent to or more than the life data as a result of the count up, a spare tool in the group will be selected with the next group selection command (T□□□□99), and the newly selected tool will be counted.
When all tools in the group have reached their lives and a spare tool cannot be selected, the count will continue.

(1) Counting the time of uses when the time-count type method is selected

In the cutting mode (G01, G02, G03, G31, G33, etc.), the time that the tool is used is counted with 100ms units.
The time is not counted during dwell, machine lock, miscellaneous function lock or dry run. Whether to count or not for a single block can be changed by setting the parameter.

(Note)
- The maximum value for the life is 999999 minutes.
- The data is displayed as a minute unit on the Tool Life Management screen.

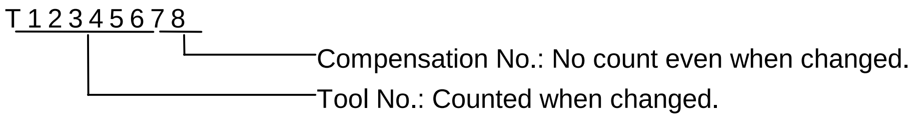
(2) Counting the No. of uses when the No. of uses-count type method is selected

(a) Type 1 (#1277 ext13/bit0: 0)

The No. of uses is counted when the number of the tool being used is changed with the tool selection command (T□□□□99) and when the program is in the cutting mode (excluding machine lock, miscellaneous function lock and dry run states).
The use is not counted if the cutting mode is not entered even once after the No. changes.
Whether to count or not during single block can be changed with the parameter setting.

(Note)
- The maximum value for the life is 999999 times.
- If only the compensation No. of the tool being used changes, a count will not be made.

Example: When T code of tool being used is T12345678


T 1 2 3 4 5 6 7 8
Compensation No.: No count even when changed.
Tool No.: Counted when changed.

<<Operation example>>

Program

```
T0199........  1
 :
T0299
 :
T0199........  2
 :
T0299
 :
T0199........  3
```

Group 01 has been used three times.

Program

```
T0199.......  1
 :
T0199
 :
T0199
```

Group 01 has been used one time.

* The No. of uses is for one program execution. If the program is executed again after resetting, it will be counted.

(b) Type 2 (#1277 ext13/bit0: 1)

(i) Only the group used for cutting from when the machining program starts to when it is reset is incremented by "1". The count is made at the reset.

(ii) If recount M is commanded, the group used up to that point will be incremented by "1" in the counter.

(Note 1) A count is not made in the machine lock, miscellaneous function lock or dry run states.

(Note 2) During single block, select whether to count with the parameter.

(Note 3) The maximum value of the life is 999999 times.

13. Program Support Functions

13.1 Fixed cycles for turning

Function and purpose

When performing rough cutting and other such operations during turning, these functions enable shapes normally commanded in several blocks to be commanded in a single block. In other words, they simplify the machining program. The following types of fixed cycles for turning are available.

G code	Function
G77	Longitudinal turning cycle
G78	Thread cutting cycle
G79	Face turning cycle

Command format

```
G77 X/U_ Z/W_ R_ F_ ;
```

(Same for G78, G79)

Detailed description

(1) Fixed cycle commands are modal G codes and so they are valid until another command in the same modal group or a cancel command is issued.
The following G code cancel commands are available.

G00, G01, G02, G03
G07,
G09,
G10, G11,
G27, G28, G29, G30,
G31,
G33, G34,
G37,
G92,
G52, G53,
G65,

(2) The fixed cycle call becomes the movement command block call.
The movement command block call calls the fixed cycle macro subprogram only when there is an axis movement command during the fixed cycle mode. It is executed until the fixed cycle is canceled.

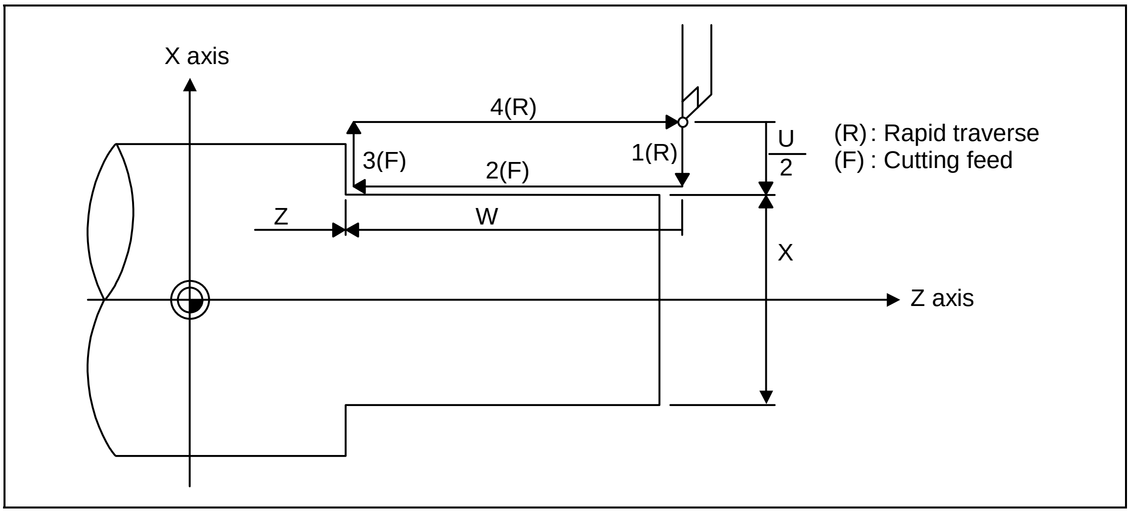
(3) A manual interrupt can be applied while a fixed cycle for turning (G77 ~ G79) is being executed. Upon completion of the interrupt, however, the tool must be returned to the position where the manual interrupt was applied and then the fixed cycle for turning should be resumed.
If it is resumed without the tool having been returned, all subsequent operations will deviate by an amount equivalent to the manual interrupt.

13.1.1 Longitudinal cutting cycle; G77

Straight cutting

This function enables continuous straight cutting in the longitudinal direction using the following command.

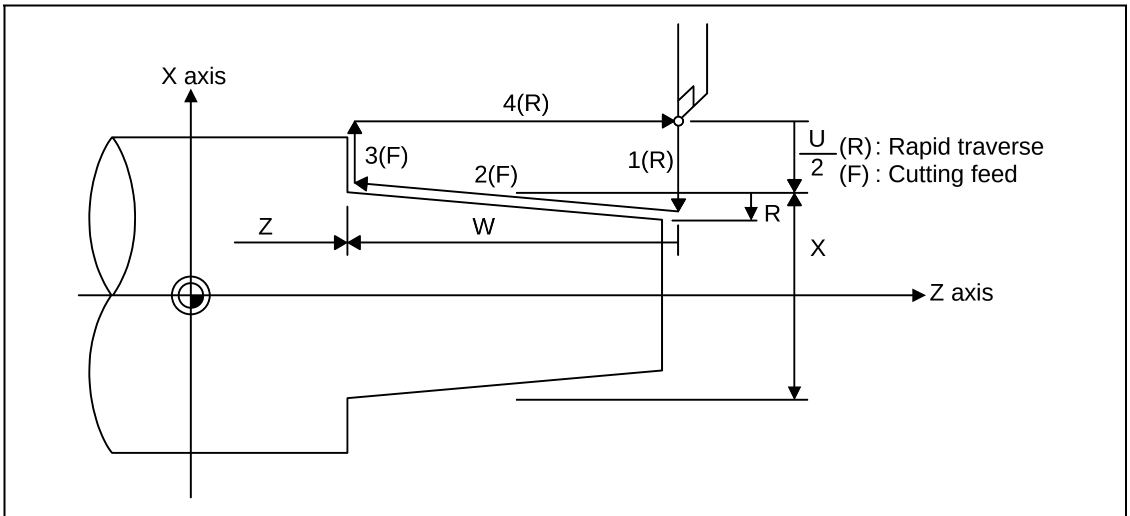
G77 X/U_ Z/W_ F_ ;



Taper cutting

This function enables continuous taper cutting in the longitudinal direction using the following command.

G77 X/U_ Z/W_ R_ F_ ;

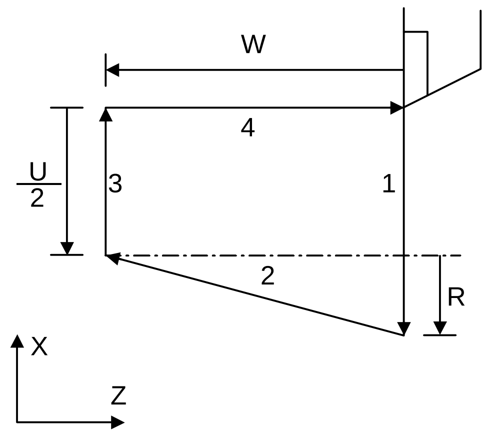


R: Taper depth (radius designation, incremental value, sign required)

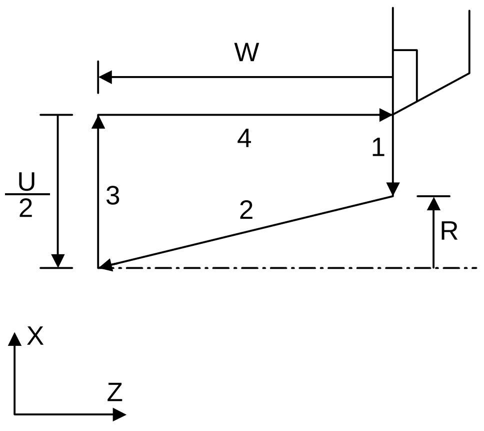
With a single block, the tool stops at the end points of operations 1, 2, 3 and 4.

Depending on the U, W and R signs, the following shapes are created.

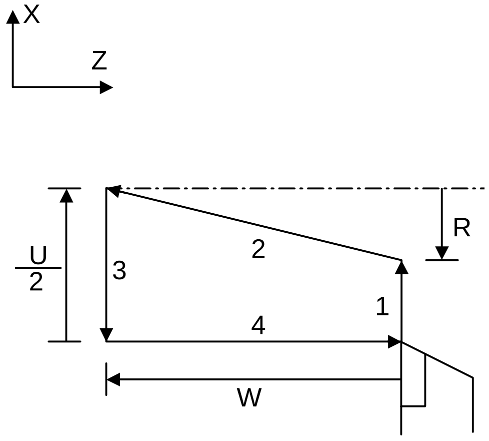
(1) U < 0, W < 0, R < 0



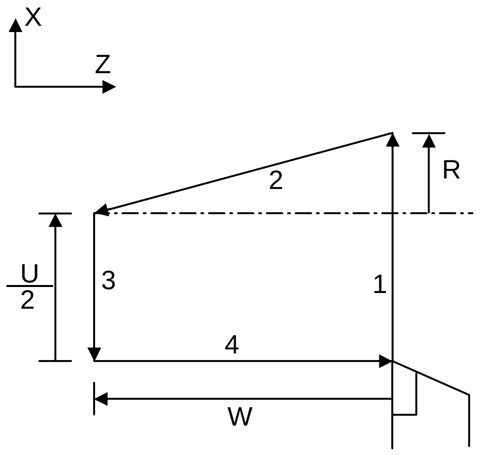
(2) U < 0, W < 0, R > 0



(3) U > 0, W < 0, R < 0



(4) U > 0, W < 0, R > 0



Program error (P191) results with shapes (2) and (3) unless the following condition is satisfied.

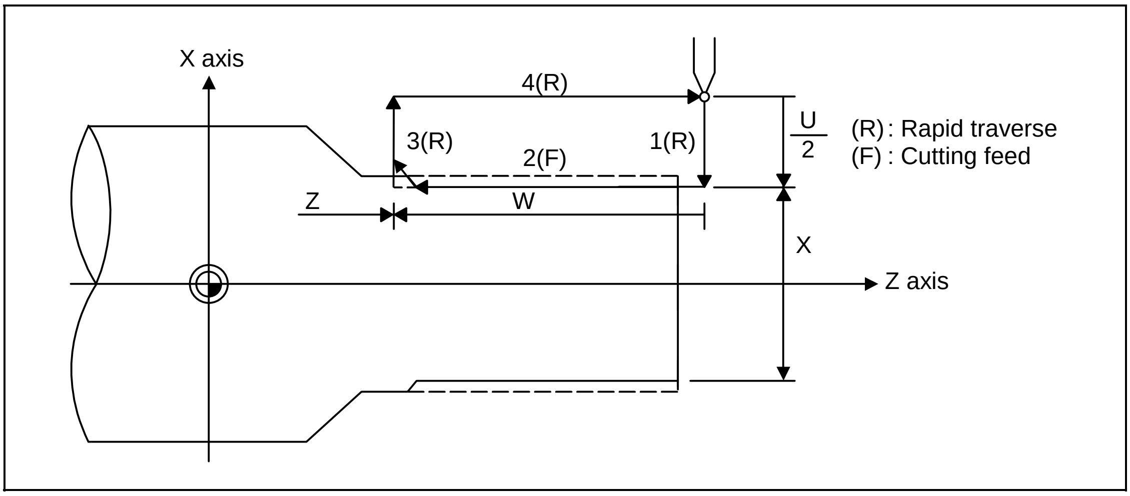
$|u/2| \geq |r|$

13.1.2 Thread cutting cycle; G78

Straight thread cutting

This function enables straight thread cutting using the following command.

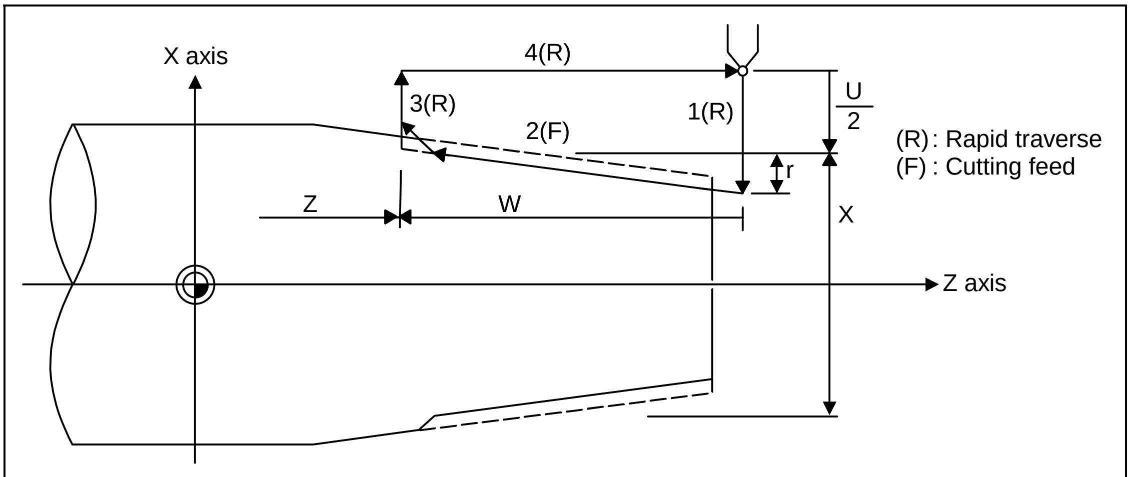
G78 X/U_ Z/W_ F/E_ ;



Taper thread cutting

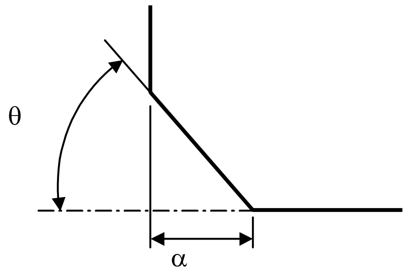
This function enables taper thread cutting using the following command.

G78 X/U_ Z/W_ R_ F/E_ ;



R: Taper depth (radius designation, incremental value, sign required)

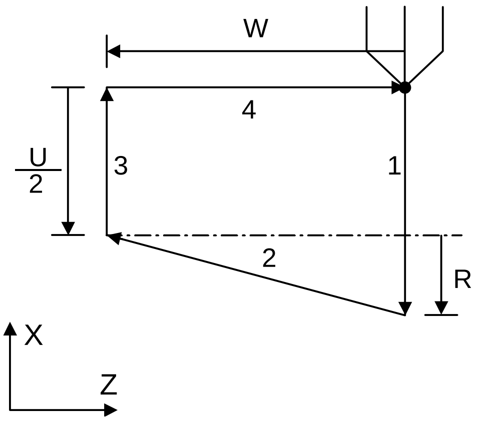
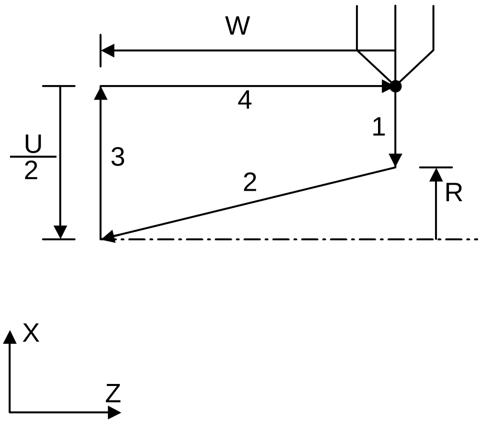
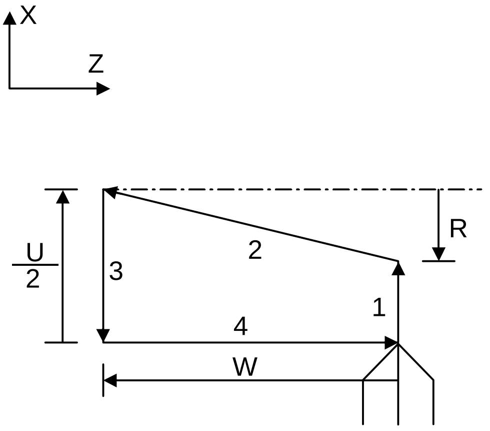
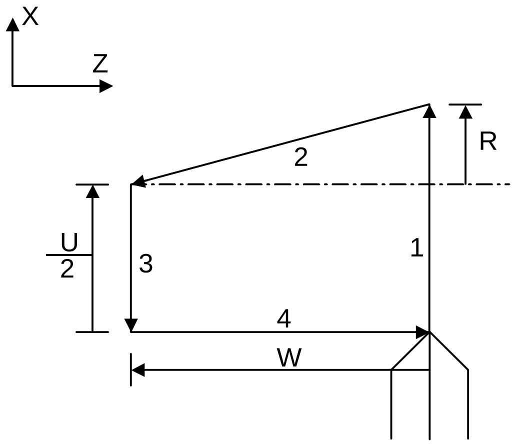
Details for chamfering

	α : Chamfering amount of thread If the thread lead is assumed to be L, then the parameter can be set in 0.1L units from 0 to 12.7L. θ : Chamfering angle of thread The parameter can be set in 1° units from 0 to 89°

With a single block, the tool stops at the end points of operations 1, 3 and 4.

When the feed hold function is applied during a thread cutting cycle, automatic operation will stop if no thread is then being cut, or if applied in the interval from the execution of the thread cutting command to the axis movement. If thread cutting is proceeding when the function is applied, the operation stops at the next movement completion position (completion of operation 3) of the thread cutting.
The dry run valid/invalid status does not change during thread cutting.

Depending on the U, W and R signs, the following shapes are created.

(1) U < 0, W < 0, R < 0	**(2) U < 0, W < 0, R > 0**
	
(3) U > 0, W < 0, R < 0	**(4) U > 0, W < 0, R > 0**
	

Program error (P191) results with shape (2) and (3) unless the following condition is satisfied.

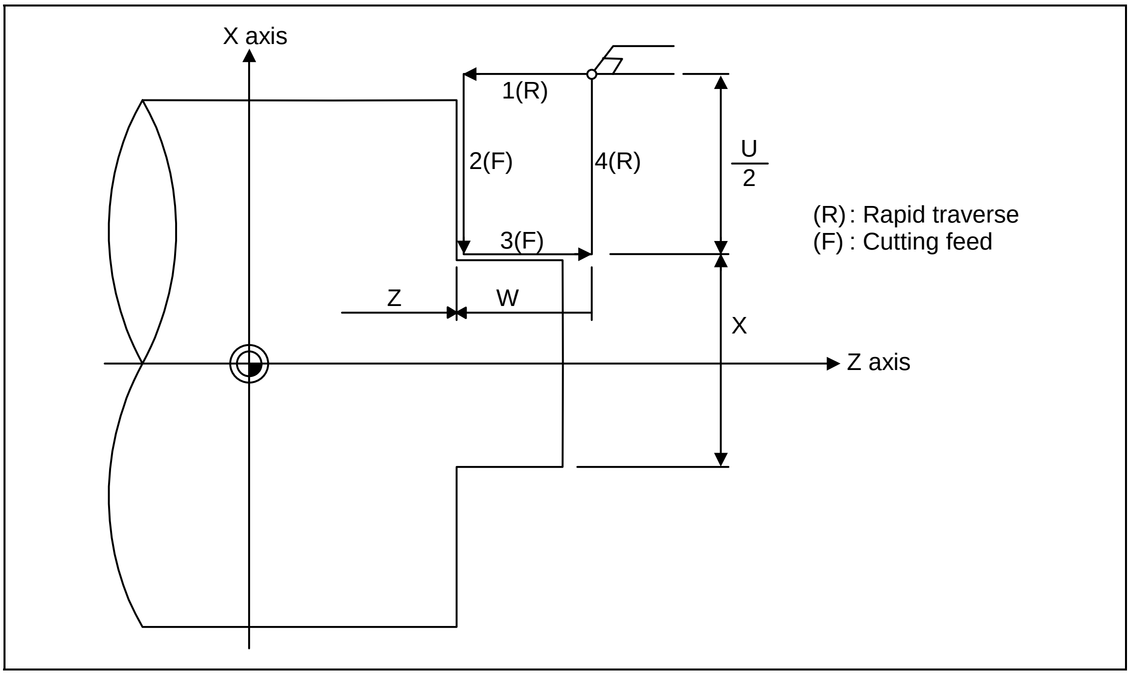
$| u/2 | \geq | r |$

13.1.3 Face cutting cycle; G79

Straight cutting

This function enables continuous straight cutting in the face direction using the following command.

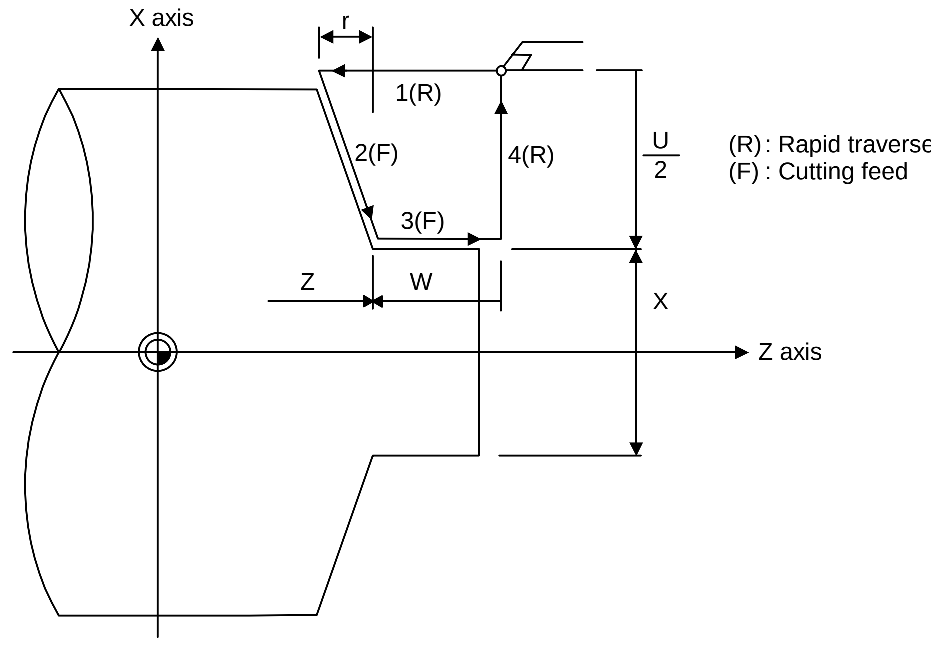
G79 X/U_ Z/W_ F_ ;



Taper cutting

This function enables continuous taper thread cutting using the following command.

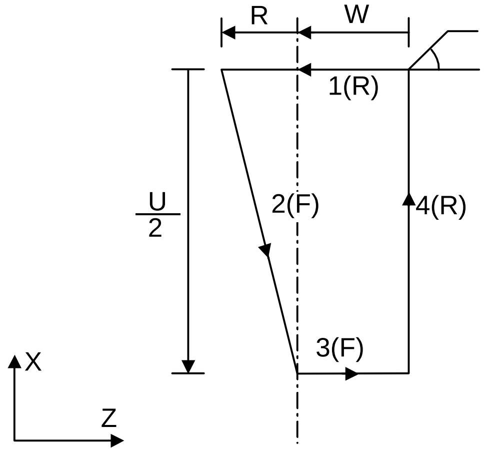
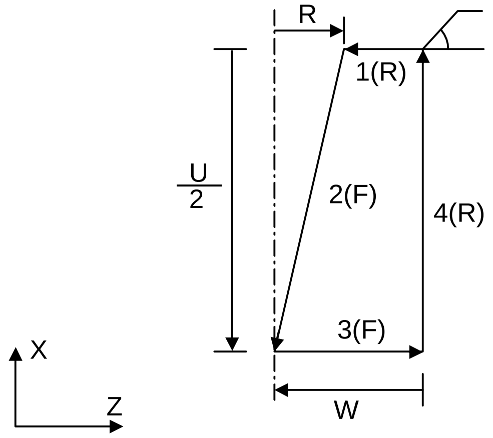
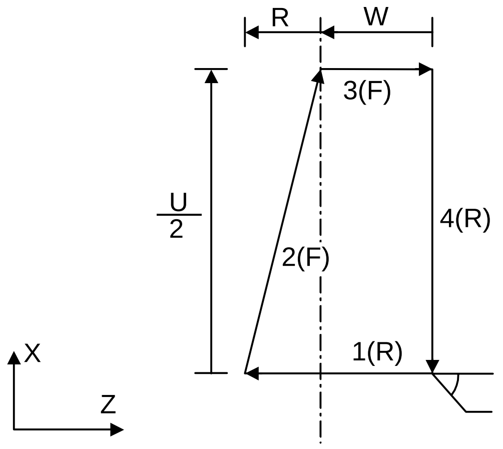
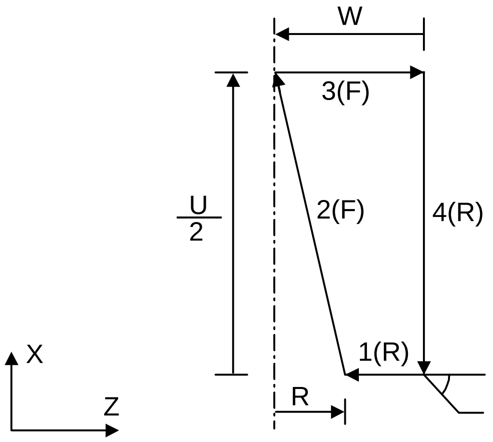
G79 X/U_ Z/W_ R_ F_ ;



R: Taper depth (radius designation, incremental value, sign required)

With a single block, the tool stops at the end points of operations 1, 2, 3 and 4.

Depending on the U, W and R signs, the following shapes are created.

(1) U < 0, W < 0, R < 0	**(2) U < 0, W < 0, R > 0**
	
(3) U > 0, W < 0, R < 0	**(4) U > 0, W < 0, R > 0**
	

Program error (P191) results with shapes (2) and (3) unless the following condition is satisfied.

$| w | \geq | r |$

13.2 Compound type fixed cycles

Function and purpose

These functions enable prepared fixed cycle to be executed by commanding the corresponding program in a block.
The types of fixed cycles are listed below.

G code	Function	
G70	Finishing cycle	Compound type fixed cycles I
G71	Longitudinal rough cutting cycle (finished shape chamfering)	
G72	Face rough cutting cycle (finished shape chamfering)	
G73	Formed material rough cutting cycle	
G74	Face cut-off cycle	Compound type fixed cycles II
G75	Longitudinal cut-off cycle	
G76	Compound type thread cutting cycle	

If, with any of the above functions for the compound type fixed cycle I (G70 ~ G73), the finished shape program has not been entered in the memory, the function cannot be used.

Command format

```
G70    A_ P_ Q_ ;

G71    U_ R_ ;
G71    A_ P_ Q_ U_ W_ F_ S_ T_ ;

G72    W_ R_ ;
G72    A_ P_ Q_ U_ W_ F_ S_ T_ ;

G73    U_ W_ R_ ;
G73    A_ P_ Q_ U_ W_ F_ S_ T_ ;

G74    R_ ;
G74    X (U)_ Z (W)_ P_ Q_ R_ F_ ;
(Same for G75)

G76    P_ R_ ;
G76    X (U)_ Z (W)_ P_ Q_ R_ F_ ;
```

Detailed description

(1) The A, P and Q commands of the compound type fixed cycles I are described below.

(a) When the A command is not present, P and Q in the program now being executed are called.
When the A command is present and the P command is not present, the head block of the program designated by the A command is treated as the P command.

(b) When the Q command is not present, operation continues until the M99 command is located.
When both the Q and M99 commands are not present, operation continues until the final block in the finished shape program.

13.2.1 Longitudinal rough cutting cycle; G71

Function and purpose

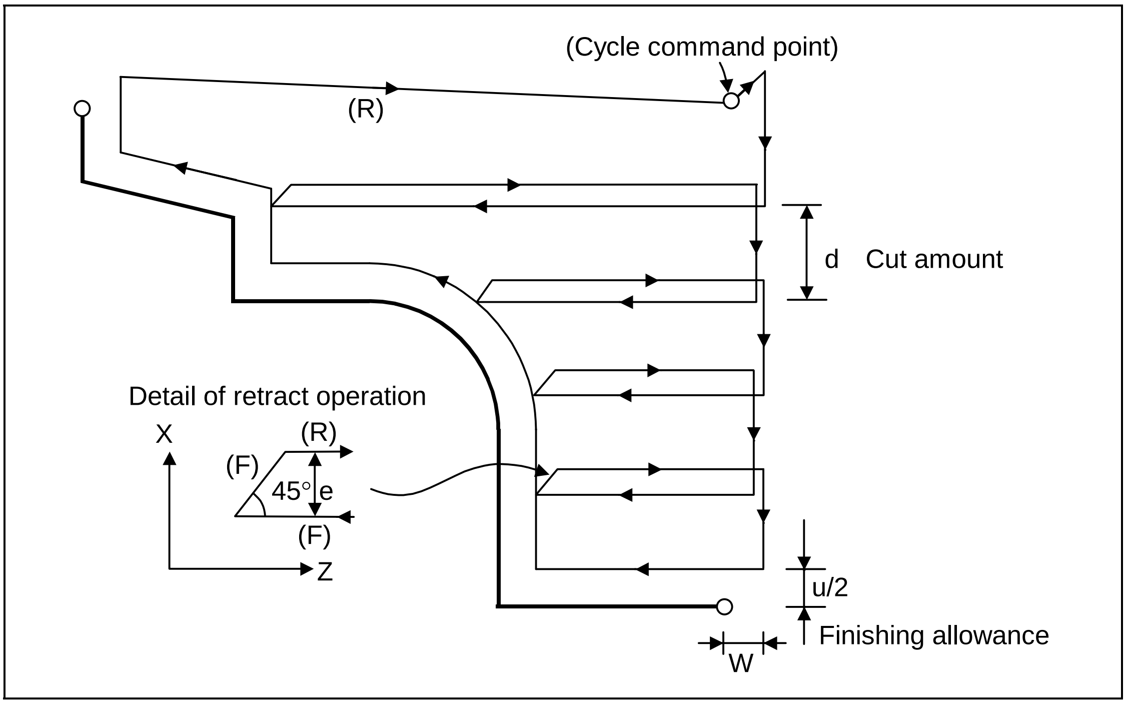
This function calls the finished shape program and, while automatically calculating the tool path, performs rough cutting in the longitudinal direction.

Command format

G71 Ud Re ;
G71 Aa Pp Qq Uu Ww Ff Ss Tt ;

Ud Cut amount "d" (cut amount without P, Q commands) (modal)
Re Retract amount "e" (modal)
Aa Finished shape program number (program being executed when omitted)
Pp Finished shape start sequence number (program head when omitted)
Qq Finished shape end sequence number (up to end of program when omitted)
Up to M99 command when M99 comes first even if Q command is present
Uu X-axis direction finishing allowance (diameter or radius designation)
Ww Z-axis direction finishing allowance
Ff Cutting feedrate
Ss Spindle speed
Tt Tool command

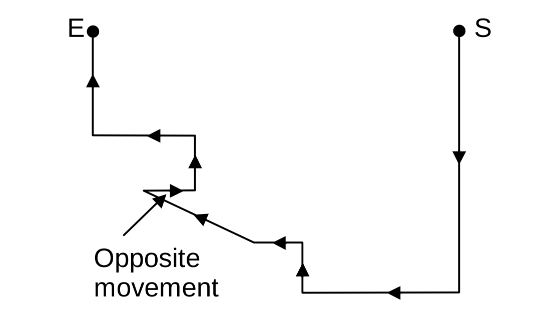
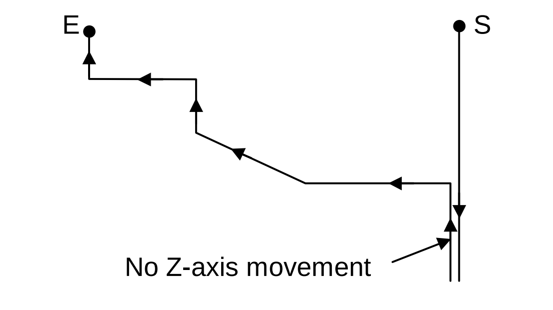
The F, S and T commands in the finished shape program are ignored, and the value in the rough cutting cycle command or a value prior to it is validated.



(Note) The U command applied to the finishing allowance when it is in the same block as the A, P and Q commands.

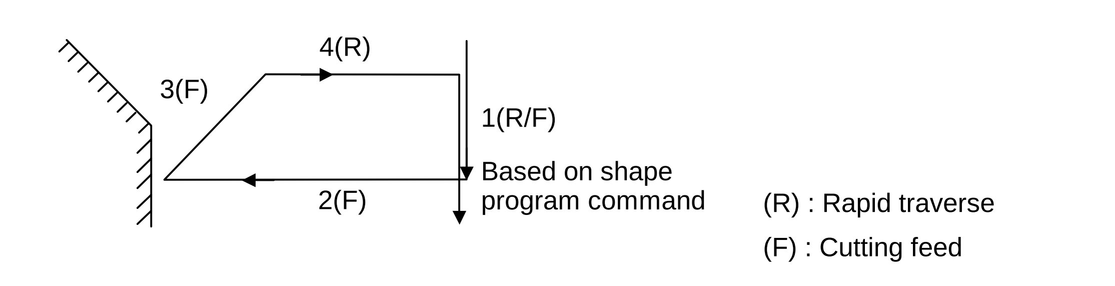
Cutting shape

It must be ensured that the finished shape changes monotonically (increase or decrease only) in both the X- and Z-axis directions. Program error (P203) occurs with the following shapes.

When there is movement away from the Z axis	When there is no Z axis movement in the second block
	

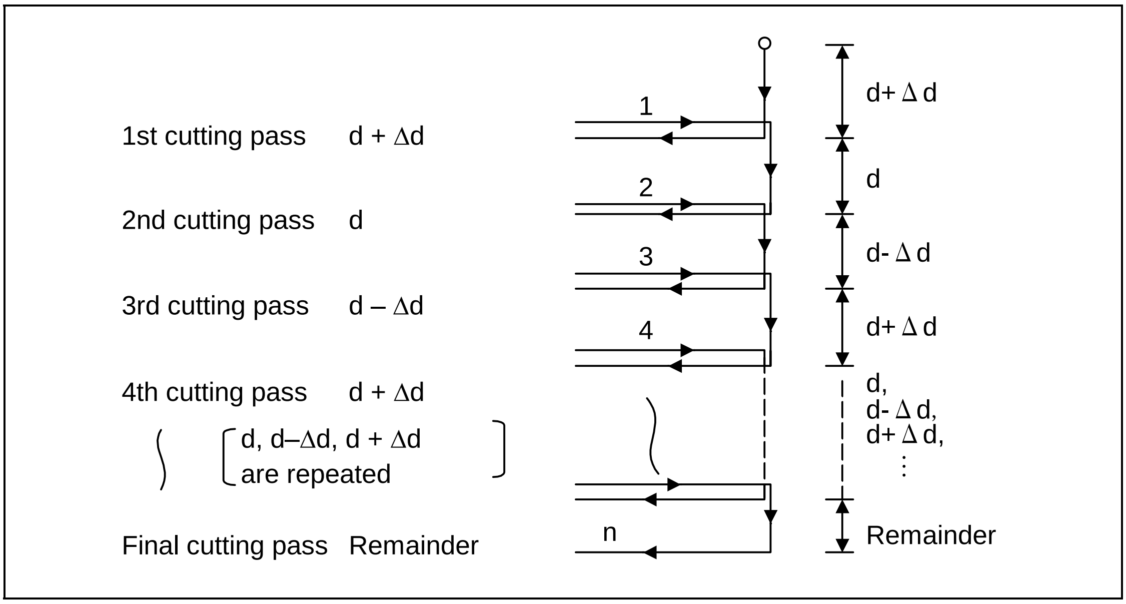
Configuration of a cycle

A cycle is composed as shown below.



Cut amount

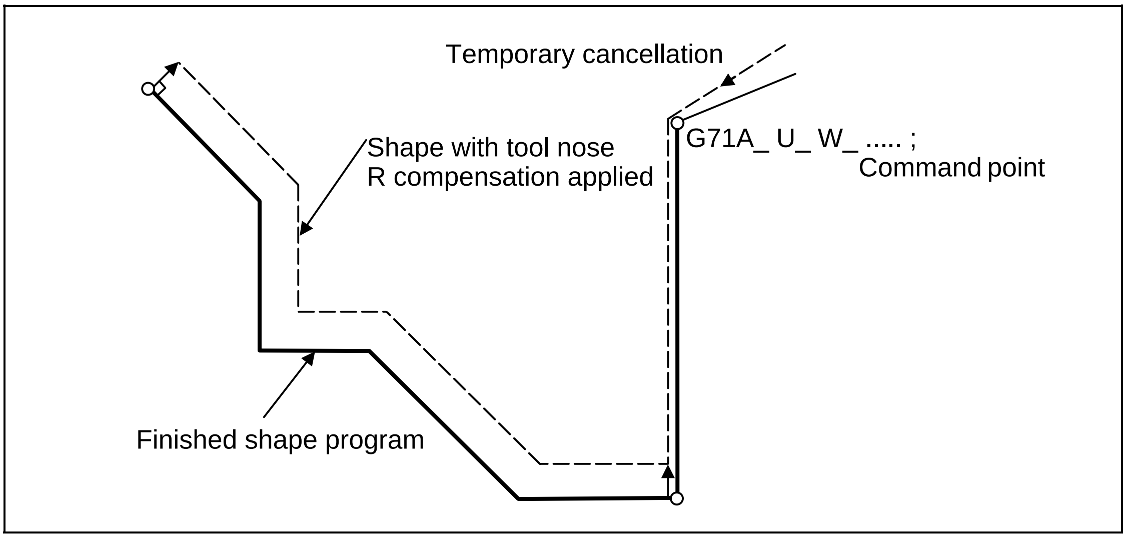
The cut amount is designated by "d". However, it is possible to change the cut amount with each cutting pass by setting the cut change amount (Δd) using a parameter (#8017 G71 DELTA-D). Program error (P204) results when the amount of one cut commanded in the program is deeper than the cutting depth of the final shape, in other words, when "d" is less than "Δd".



Tool nose R compensation

When this cycle is commanded with the tool nose R compensation mode still in force, tool nose R compensation is applied to the finished shape program covered by this cycle and the cycle is executed for this shape.

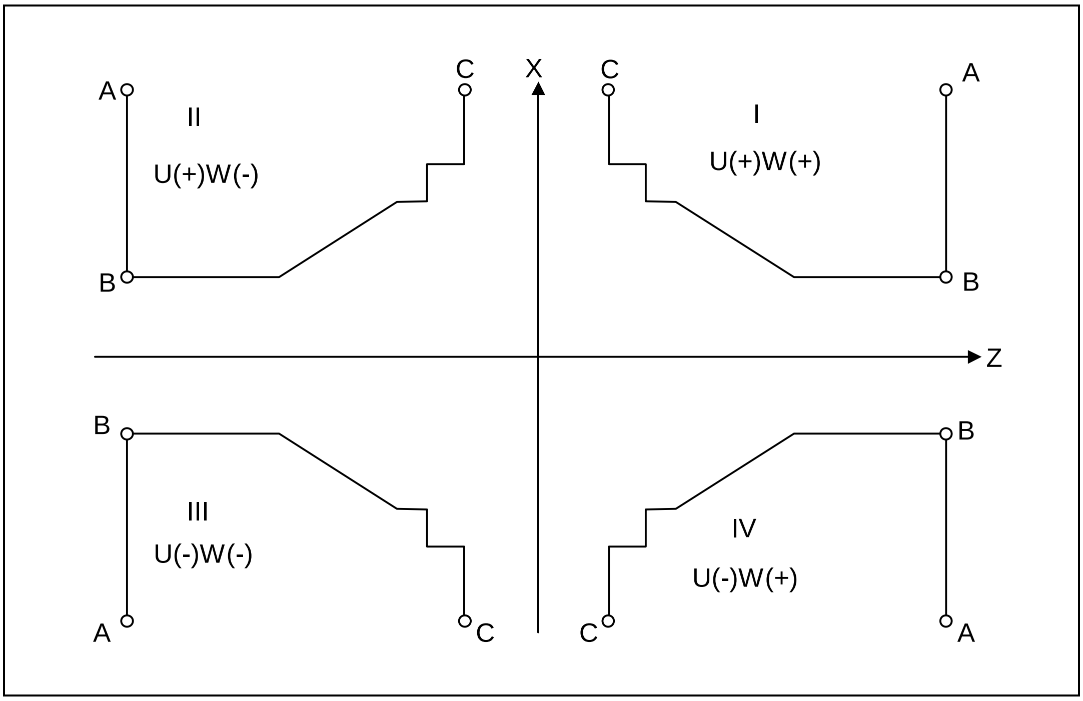
However, when this cycle is commanded with the tool nose R compensation mode still in force, the mode is temporarily canceled immediately before the cycle and it starts up with the finished shape program, the end block of this program serves as the pre-read prohibit block, and then compensation is applied to the shape and executed.



Others

(1) After the cutting, the remainder is made the cut amount. However, if this amount is less than the value set by parameter (#8016 G71 MINIMUM), finishing rough cutting is executed and the workpiece is not cut.

(2) Finishing allowance direction
The finishing allowance direction is determined by the shape as follows. A→B→C apply for the finishing program.



13.2.2 Face rough cutting cycle; G72

Function and purpose

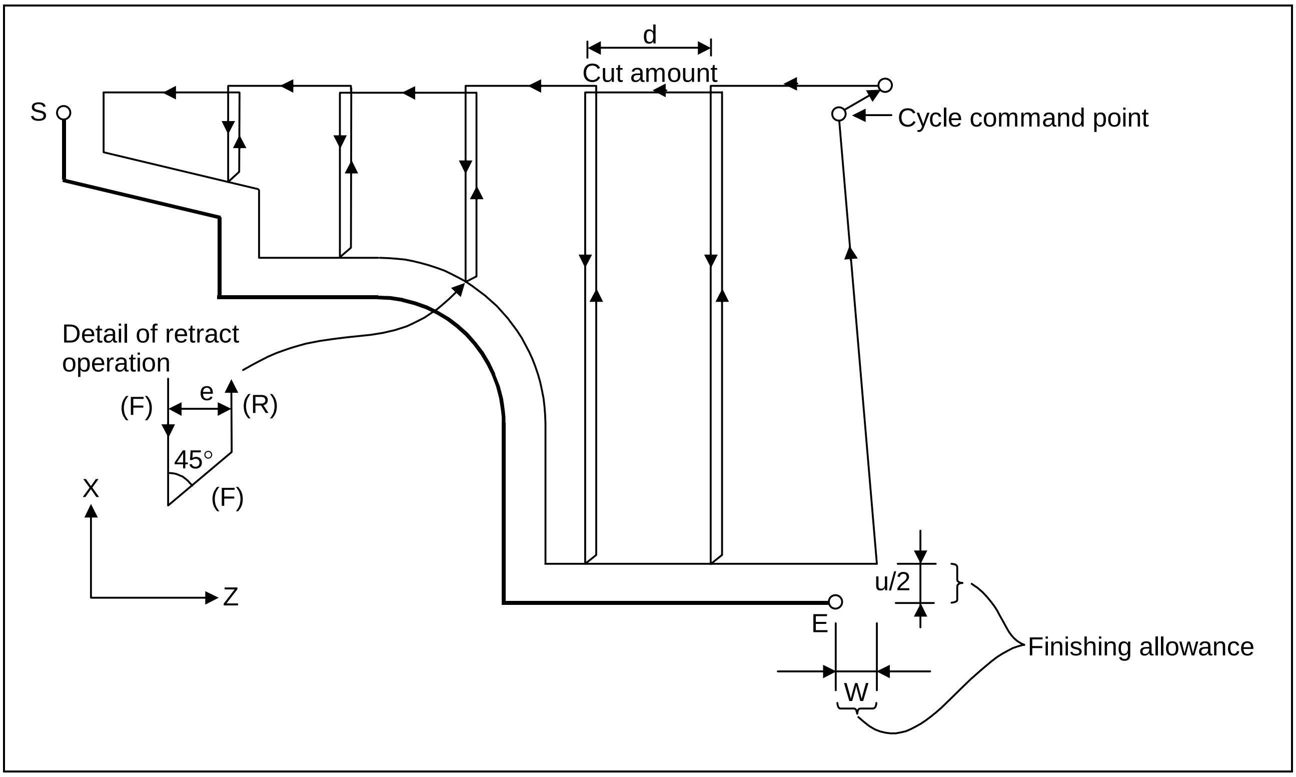
This function calls the finished shape program and, while automatically calculating the path, performs rough cutting in the face direction.

Command format

G72 Wd Re ;
G72 Aa Pp Qq Uu Ww Ff Ss Tt ;

Wd	Cut amount "d" (cut amount without P, Q commands) (modal)
Re	Retract amount "e" (modal)
Aa	Finished shape program number (program being executed when omitted)
Pp	Finished shape start sequence number (program head when omitted)
Qq	Finished shape end sequence number (up to end of program when omitted) Up to M99 command when M99 comes first even if Q command is present
Uu	X-axis direction finishing allowance (diameter or radius designation)
Ww	Z-axis direction finishing allowance
Ff	Cutting feedrate
Ss	Spindle speed
Tt	Tool command

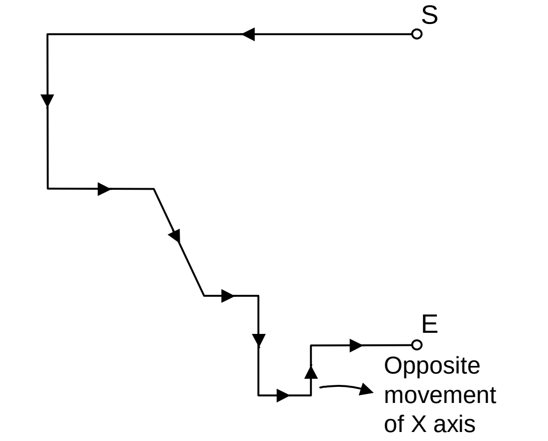
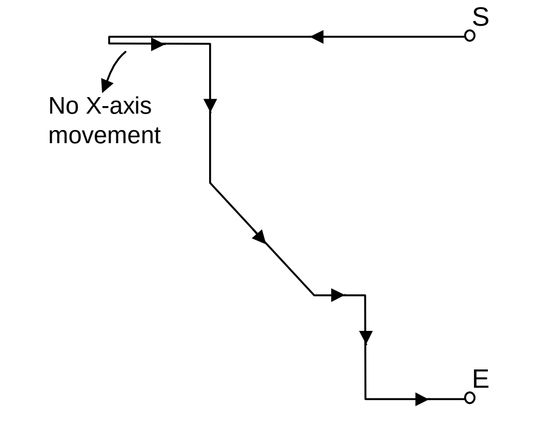
The F, S and T commands in the finished shape program are ignored, and the value in the rough cutting cycle command or a value prior to it is validated.



(Note) The U command applied to the finishing allowance when it is in the same block as the A, P and Q commands.

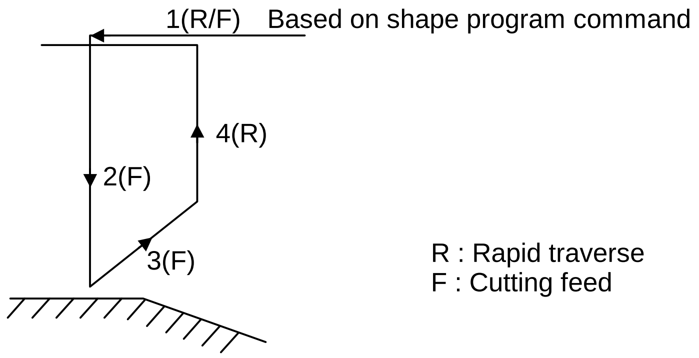
Cutting shape

It must be ensured that the finished shape changes monotonically (increase or decrease only) in both the X- and Z-axis directions. Program error (P203) occurs with the following shapes.

When there is movement away from the X axis	When there is no X axis movement in the second block
	

Configuration of a cycle

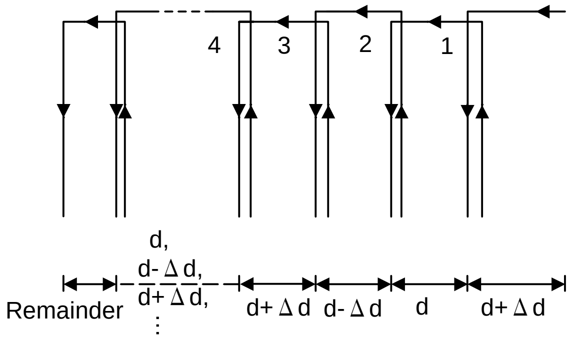
A cycle is composed as below.



Cut amount

The cut amount is designated by "d". However, it is possible to change the cut amount with each cutting pass by setting the cut change amount (Δd) using a parameter (#8017 G71 DELTA-D).

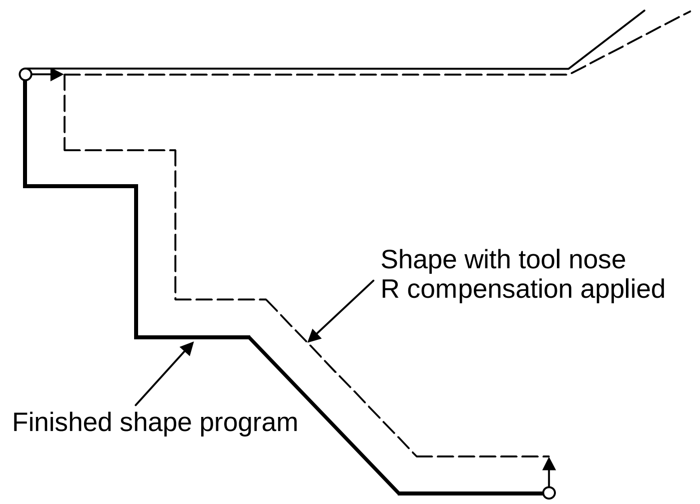
1st cutting pass	d + Δd
2nd cutting pass	d
3rd cutting pass	d – Δd
4th cutting pass	d + Δd
⟆	[d, d–Δd, d + Δd are repeated]
Final cutting pass	Remainder



Tool nose R compensation

When this cycle is commanded with the tool nose R compensation mode still in force, tool nose R compensation is applied to the finished shape program covered by this cycle and the cycle is executed for this shape.

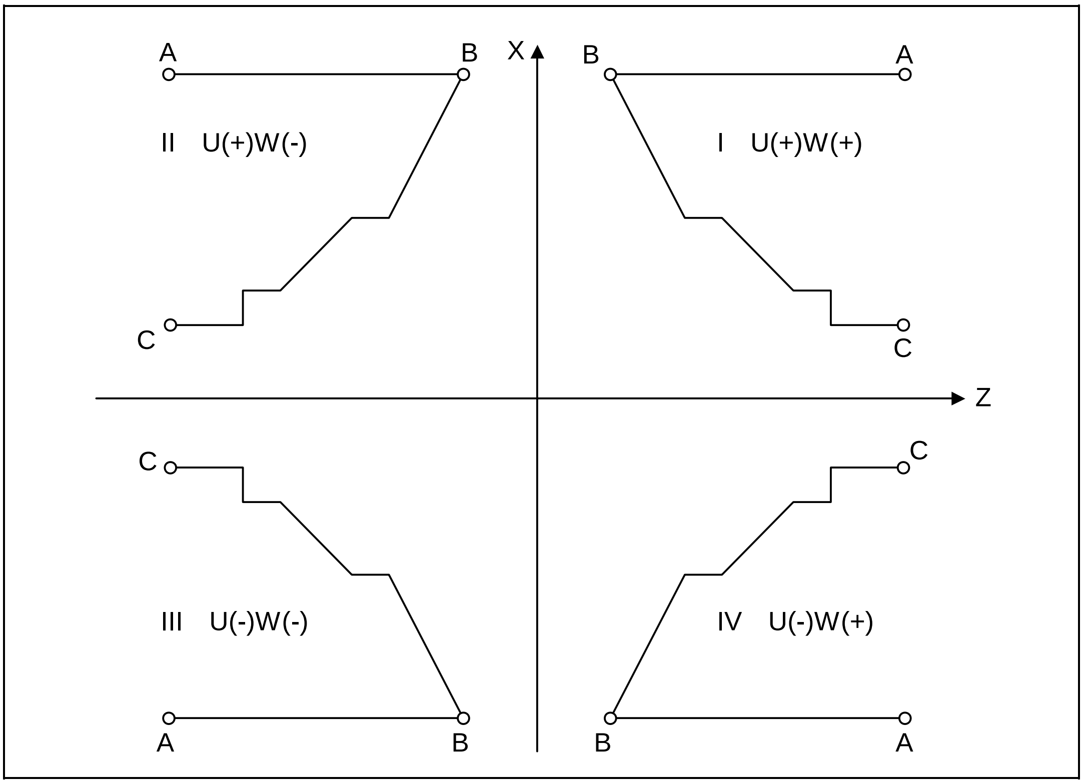
However, when this cycle is commanded with the tool nose R compensation mode still in force, the mode is temporarily canceled immediately before the cycle and it starts up with the finished shape program, the end block of this program serves as the pre-read prohibit block, and then compensation is applied to the shape and executed.



Others

(1) After the cutting, the remainder is made the cut amount. However, if this amount is less than the value set by parameter (#8016 G71 MINIMUM), this cycle is not executed.

(2) Finishing allowance direction
The finishing allowance direction is determined by the shape as follows.



13.2.3 Formed material rough cutting cycle; G73

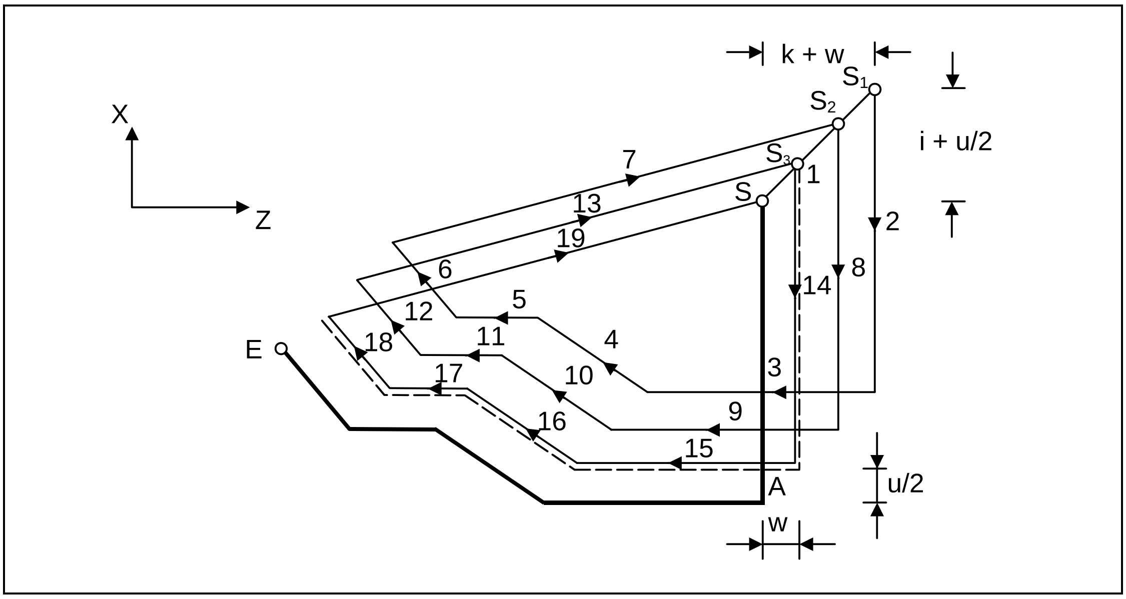
Function and purpose

This calls the finished shape program, automatically calculates the path and performs rough cutting while cutting the workpiece into the finished shape.

Command format

G73 Ui Wk Rd ;
G73 Aa Pp Qq Uu Ww Ff Ss Tt ;

Ui	X-axis direction cutting allowance	i	• Cutting allowances when P, Q commands are not present • Modal data • Sign is ignored • Radius designation applies to the cutting allowance.
Wk	Z-axis direction cutting allowance	k	
Rd	Number of divisions	d	
Aa	Finished shape program number		(program being executed when omitted)
Pp	Finished shape start sequence number		(program head when omitted)
Qq	Finished shape end sequence number		(up to end of program or M99 when omitted) Note that this is up to M99 when M99 comes first, even when there is a Qq command.
Uu	X-axis direction finishing allowance	u	• Cutting allowance when P, Q commands are present • Sign is ignored. • Diameter/radius designation changes in accordance with the parameters (#1019 dia). • The shift direction is determined by the shape. For details, refer to the "finishing allowance direction" for G71.
Ww	Z-axis direction finishing allowance	w	
Ff	Cutting feedrate (F function)		The F, S and T commands in the finished shape program are ignored and the value in the rough cutting cycle command or previous value is valid.
Ss	Spindle speed (S function)		
Tt	Tool command (T function)		



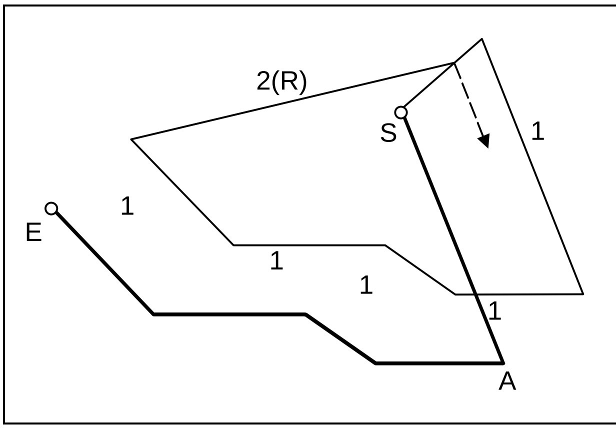
(Note) With a single block, operation stops at the end point of each block.

Finished shape

In the program, S → A → E in the previous program are commanded.
The section between A and E must be a shape with monotonous changes in both the X axis and Z axis directions.

1 cycle configuration

A cycle is configured as shown below.



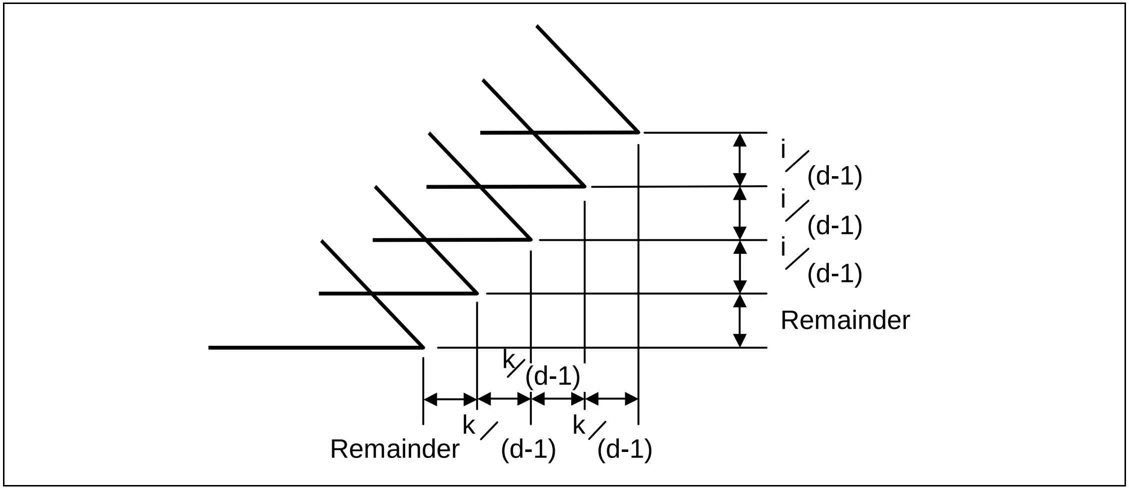
Operation 1 :
Based on shape program with shape profiling
Operation 2 :
Rapid traverse on return

Cut amount

The cut amount is the value produced by dividing the cutting allowances (i, k) by the number of divisions (d–1).

X axis direction i/(d–1)
Z axis direction k/(d–1)

When divisions cannot be made, chamfering is performed and adjustment is made at the final pass.



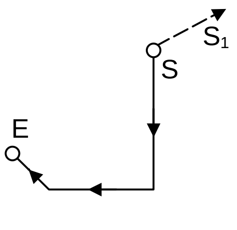
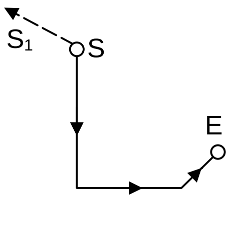
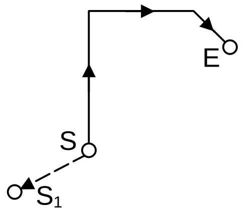
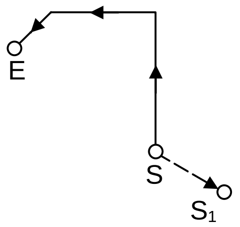
Tool nose R compensation

When this cycle is commanded with the tool nose R compensation mode still in force, tool nose R compensation is applied to the finished shape program covered by this cycle and the cycle is executed for this shape.
However, when this cycle is commanded with the tool nose R compensation mode still in force, the compensation is temporarily canceled immediately before this cycle and started at the head block of the finished shape program.

Others

(1) Cutting direction

The shift direction for the cutting is determined by the shape in the finishing program, as shown in the table below.

	1	2	3	4
Drawing				
Initial X axis	"–" direction	–	+	+
Complete Z axis	"–" direction	+	+	–
X axis cutting	"+" direction	+	–	–
Z axis cutting	"+" direction	–	–	+

13.2.4 Finishing cycle; G70

Function and purpose

After rough cutting have been carried out by the G71 ~ G73 commands, finishing cutting can be performed by the following command.

Command format

G70 A_ P_ Q_ ;

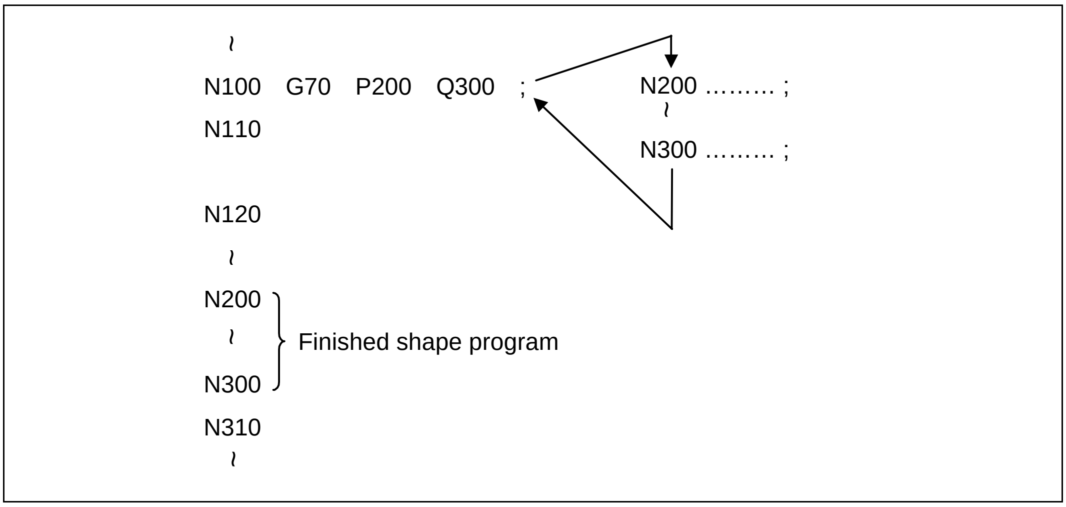
A	Finished shape program number (program being executed when omitted)
P	Finished shape start sequence number (program head when omitted)
Q	Finished shape end sequence number (up to end of program when omitted) Note that this is up to M99 when M99 comes first, even when there is a Q command.

Detailed description

(1) The F, S and T commands in the finished shape program are valid during the finishing cycle.

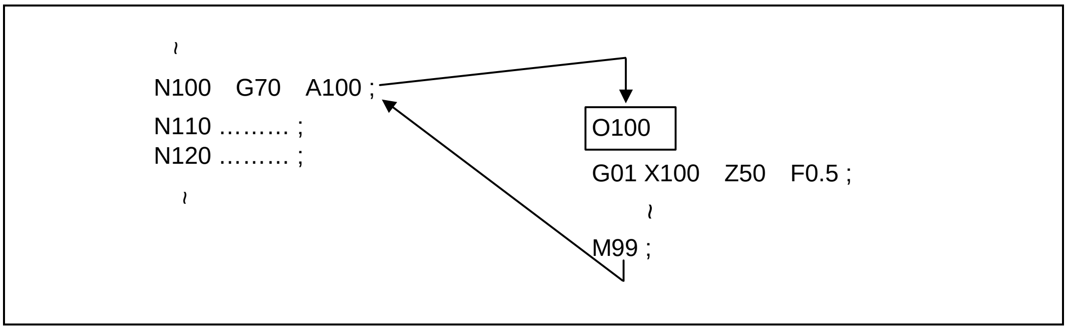
(2) When the G70 cycle is completed, the tool returns to the start point by rapid traverse and the next block is read.

(Example 1) When a sequence number is designated



```
  ≀
N100   G70   P200   Q300   ;            N200 ……… ;
N110                                      ≀
                                        N300 ……… ;

N120
  ≀
N200 ⎫
  ≀  ⎬ Finished shape program
N300 ⎭
N310
  ≀
```

(Example 2) When a program number is designated



```
  ≀
N100   G70   A100 ;
N110 ……… ;                        O100
N120 ……… ;
  ≀                                G01 X100   Z50   F0.5 ;
                                     ≀
                                   M99 ;
```

If the N100 cycle is executed in either Example 1 or Example 2, the N110 block is executed next.

13.2.5 Face cut-off cycle; G74

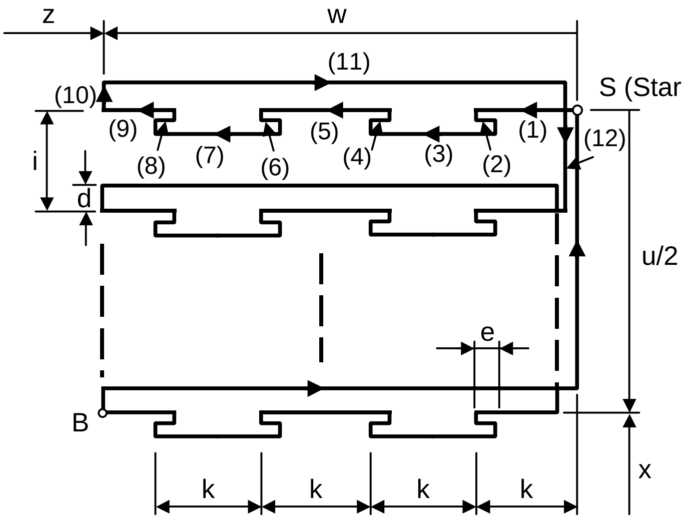
Function and purpose

The G74 fixed cycle automatically enters a groove in the face direction of the workpiece by commanding the coordinates of the groove end point, cut amount, cutter shift amount and cutter escape at the bottom of the cut.
The machining program commands are as follows.

Command format

G74 Re ;
C74 X/(U)x Z/(w)z Pi Qk Rd Ff ;

Re Return amount (no X/U, P commands) (modal)
X/Ux B point X coordinate (absolute/incremental value)
Z/Wz B point Z coordinate (absolute/incremental value)
Pi Tool shift amount (radius designation, incremental value, sign not required)
Qk Cut amount (radius designation, incremental value, sign not required)
Rd Escape at the bottom of the cut (When there is no sign, escapes even at the bottom of the first cut. When a - sign is attached, the tool escapes from the second cut without escaping the first cut.)
Ff Feedrate



- Operation (9) as well as operation (12) immediately before the final cycle are executed with the remainder amount.
- Operations (2), (4), (6), (8), (10), (11) and (12) are executed at the rapid traverse rate.

Single block stop

Operation stops at each block from (1) to (12).

Others

(1) When X/U and P are omitted or when the values of "x" and "i" are zero, operation will apply to the Z axis only. Note that when there is an Rd command and no sign, the tool will escape at the bottom of the cut.

(2) A case where the X/U or Z/W command is not present is treated as the assignment of a parameter setting command (G74 Re). Even when G74 Pi Qk Rd ; is commanded, Rd is regarded as Re, and the return amount is set.

(3) The escape direction does not change when a - sign is attached to the Rd command, or when there is no sign.

(4) A program error (P204) results in the following cases.

(a) When " i " is zero or P has not been commanded even though X/U has been commanded.

(b) When tool shift amount " i " is greater than the "x" movement amount.

(c) When the escape amount "d" is greater than the shift amount " i ".

(d) When the return amount "e" is greater than the cut amount "k".

(e) When the cut in amount "k" is larger than the hole depth "w".

13.2.6 Longitudinal cut-off cycle; G75

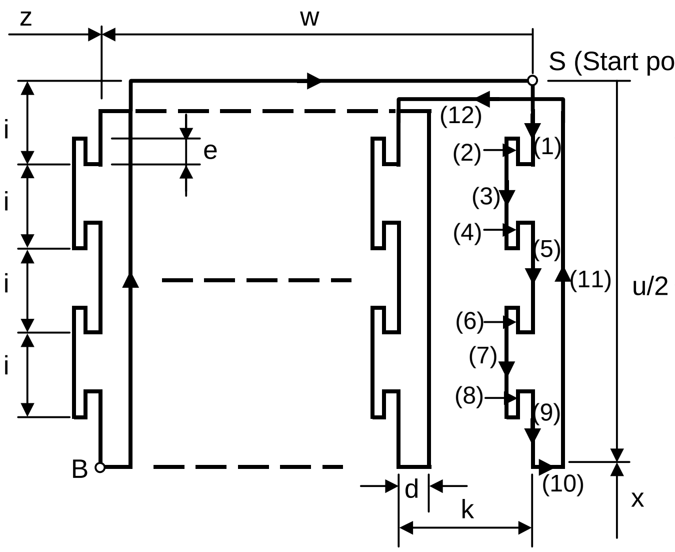
Function and purpose

The G75 fixed cycle automatically enters a groove in the longitudinal direction of the workpiece by commanding the coordinates of the groove end point, cut amount, cutter shift amount and cutter escape at the bottom of the cut.

Command format

G75 Re ;
C75 X/(U)x Z/(w)z Pi Qk Rd Ff ;

Re	Return amount (no X/U, P commands) (modal)
X/Ux	B point X coordinate (absolute/incremental value)
Z/Wz	B point Z coordinate (absolute/incremental value)
Pi	Cut amount (radius designation, incremental value, sign not required)
Qk	Tool shift amount (radius designation, incremental value, sign not required)
Rd	Escape at the bottom of the cut (When there is no sign, escapes even at the bottom of the first cut. When a - sign is attached, the tool escapes from the second cut without escaping the first cut.)
Ff	Feedrate



- Operation (9) as well as operation (12) immediately before the final cycle are executed with the remainder amount.
- Operations (2), (4), (6), (8), (10), (11) and (12) are executed at the rapid traverse rate.

Single block stop

Operation stops at each block from (1) to (12).

Others

(1) When Z/W and Q are omitted or when the values of "z" and "k" are zero, operation will apply to the X axis only (slitting). Note that when there is an Rd command and no sign, the tool will escape at the bottom of the cut.

(2) A case where both the X/U and Z/W commands are not present is treated as the assignment of a parameter setting command (G75 Re). Even when G75 Pi Qk Rd ; is commanded, Rd is regarded as Re, and the return amount is set.

(3) The escape direction does not change when a - sign is attached to the Rd command, or when there is no sign.

(4) A program error (P204) results in the following cases.

(a) When "k" is zero or Q has not been commanded even though Z/W has been commanded.

(b) When tool shift amount "k" is greater than the "z" movement amount.

(c) When the escape amount "d" is greater than the shift amount "k".

(d) When the return amount "e" is greater than the cut amount " i ".

(e) When the cut in amount "i" is larger than the hole depth "u/2".

13.2.7 Compound type thread cutting cycle; G76

Function and purpose

The G76 fixed cycle enables the workpiece to be cut at the desired angle by designating the thread cutting start point and end point, and it automatically cuts so that the cutting cross section (cutting torque) per cutting pass is constant.
Various longitudinal direction threads can be cut by bearing in mind the command value for the thread end point coordinate and taper height component.

Command format

G76 Pmra Rd ;
G75 X/U Z/W Ri Pk QΔd Fℓ ;

m Number of cutting passes for finishing: 00 ~ 99 (times) (modal)

r Chamfering amount: 00 ~ 99 (0.1mm/rev) (modal)
The chamfering width based on thread lead "/ " is designated by a 2-digit integer without decimal point from 0.0 to 9.9.

a Tool nose angle (thread angle): 00 ~ 99 (°) (modal)
The angle from 0° to 99° is assigned in 1° units.
"m", "r" and "a" are commanded in succession in address P.
(Example) When m=5, r=1.5 and a=0° P is 051500 and the leading and trailing zeroes cannot be omitted.

d Finishing allowance 0 ~ 9999 (µm) (modal)

X/U X-axis end point coordinate of thread
The X coordinate of the end point for the thread is commanded by an absolute or incremental value.

Z/W Z-axis end point coordinate of thread
The Z coordinate of the end point for the thread is commanded by an absolute or incremental value.

i Taper height component (radius value) for thread straight thread when "i" is zero

k Thread height
This is commanded by a positive radial value.

Δd Cut amount
The cut amount of the first cutting pass is commanded by a positive radius value.

ℓ Thread lead

(Note 1) The two above G76 commands cannot be placed in the same block.
The data commanded by P, Q and R are automatically identified according to the presence or absence of the X/U and Z/W axis addresses.

(Note 2) Parameter settings can be used for the above "r" modal data but these parameter (#8014 chamfer amount) settings are rewritten by the program commands.

(Note 3) The chamfering amount designation is valid even for thread cutting fixed cycles.

(Note 4) Program error (P204) results in the following cases.

(a) When "a" is outside the rating

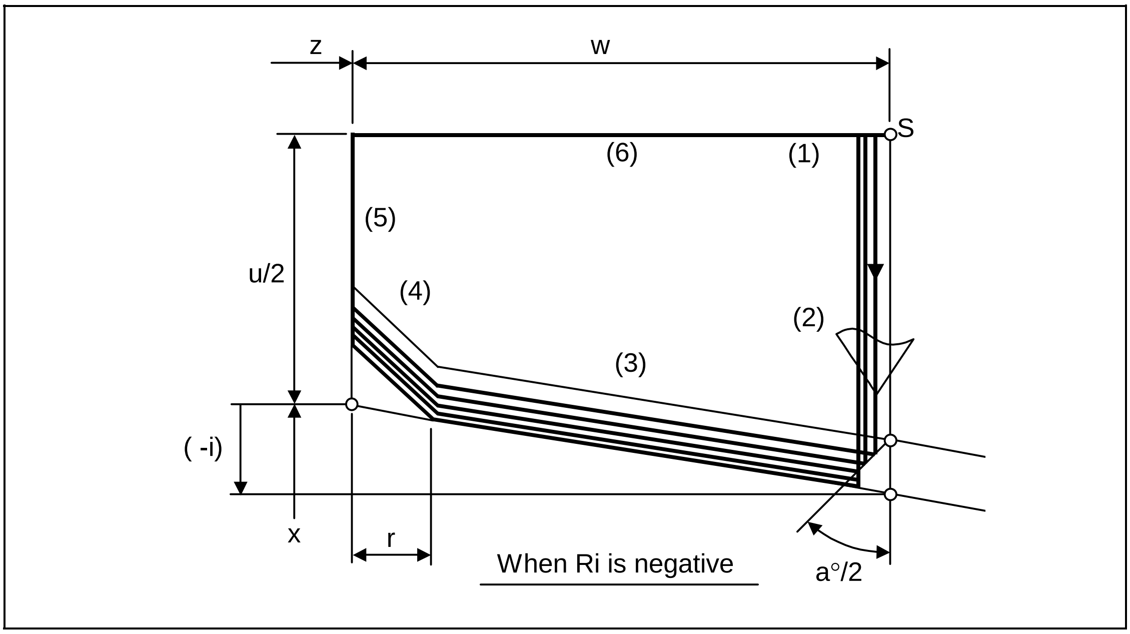
(b) When both the X and Z commands have not been issued or when the start and end point coordinates are the same for either the X or Z command.

(c) When the thread is greater than the movement of the X axis at the thread bottom

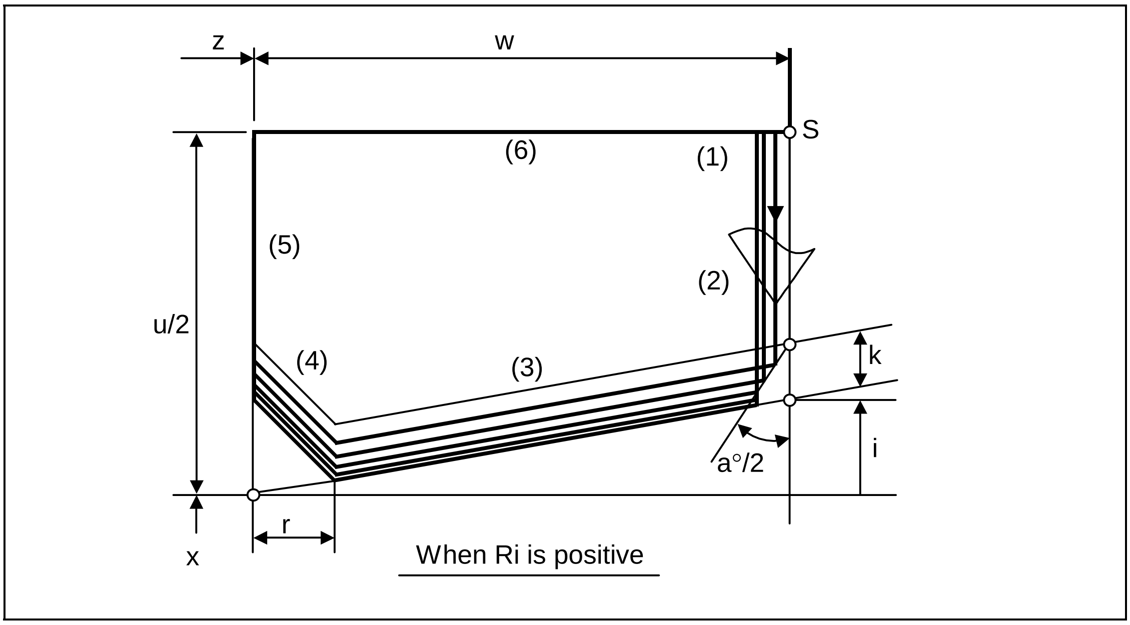
(Note 5) The precautions for the thread cutting command (G33) and thread cutting cycle (G78) should be observed.

1 cycle configuration

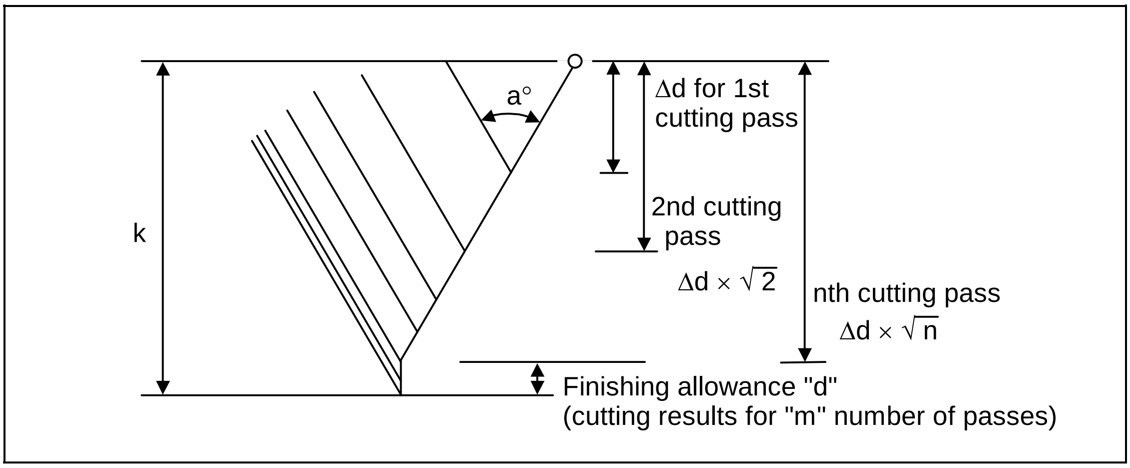
The tool moves at rapid traverse for operations (1), (2), (5) and (6) in the cycle and at the cutting feed based on the F designation for operations (3) and (4).



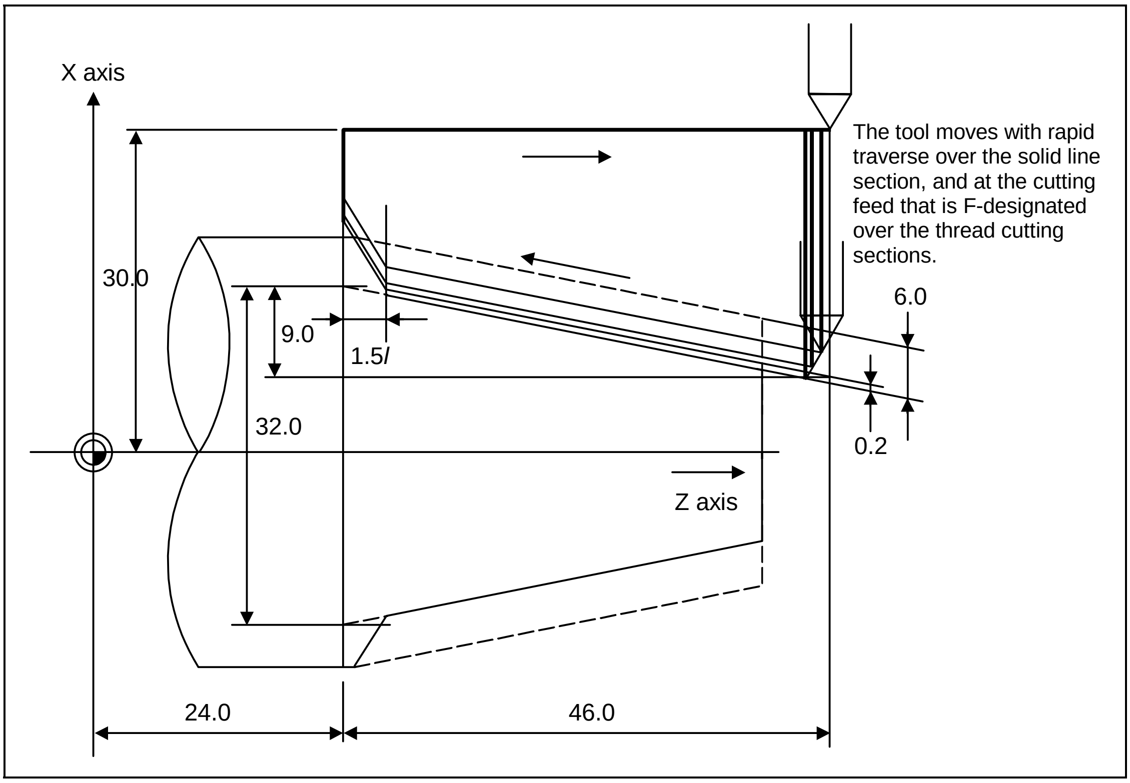
When Ri is negative



When Ri is positive



Example of program


X axis
The tool moves with rapid traverse over the solid line section, and at the cutting feed that is F-designated over the thread cutting sections.
30.0
6.0
9.0
1.5/
32.0
0.2
Z axis
24.0
46.0

G76 P011560 R0.2 ;
G76 U–28.0 W–46.0 R9.0 P6.0 Q3.5 F4.0 ;

Interrupt operation

(1) When the feed hold button is pressed while G76 is being executed, automatic operation will stop upon completion of a block without thread cutting if thread cutting is ongoing. (The automatic operation pause lamp lights immediately in the feed hold mode and it goes off when automatic operation stops.)
If feed hold is applied when no thread is then being cut, or if applied in the interval from the execution of the thread cutting command to the axis movement, the automatic operation pause lamp will turn ON, and the automatic operation will pause.

(2) The tool stops upon completion of operations (1), (4) and (5) when the mode is switched to another automatic operation mode during the G76 command execution, when automatic operation is changed to manual operations or when single block operation is conducted.

(3) The dry run valid/invalid status during G76 execution does not change during thread cutting.

13.2.8 Precautions for compound type fixed cycles; G70 ~ G76

Precautions

(1) Command all required parameters in a compound type fixed cycle command block.

(2) Provided that the finished shape program has been entered in the memory, compound fixed cycle I commands can be executed in the memory or MDI operation mode.

(3) When executing a G70 ~ G73 command, ensure that the sequence number of the finished shape program which is stop with P and Q is not duplicated in that program.

(4) The finished shape program specified by P and Q in the G71 ~ G73 blocks should be prepared so that the maximum number of blocks is 50 for all the commands for corner chamfering, corner rounding and other commands including the automatic insertion blocks based on tool nose R compensation. If this number is exceeded, program error (P202) results.

(5) The finished shape program which is designated by the G71 ~ G73 blocks should be a program with monotonous changes (increases or reductions only) for both the X and Z axes.

(6) Blocks without movement in the finished shape program are ignored.

(7) N, F, S, M, and T commands in the finished shape program are ignored.

(8) When any of the following commands are present in a finished shape program, program error (P201) results.

(a) Commands related to reference point return (G27, G28, G29, G30)

(b) Thread cutting (G33)

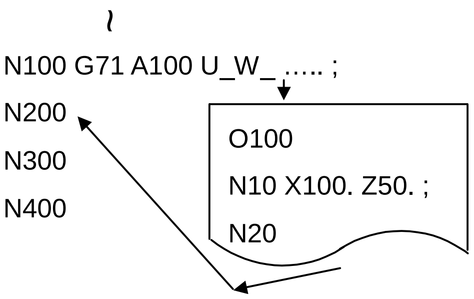
(c) Fixed cycles

(d) Skip functions (G31, G37)

(9) If subprogram call or macro call commands are present in the finished shape program, these commands will also be executed.

(10) Except for thread cutting cycles, operation stops at the end (start) point of each block in the single block mode.

(11) Remember that, depending on whether the sequence or program number is designated, the next block upon completion of the G71, G72 or G73 command will differ.

(a) When the sequence number is designated	(b) When the program number is designated
The next block is the next block designated by Q.	The next block is the next block of the cycle command.
≀ N100 G71P200 Q500 U_W_ ….. ; N200 N300 N400 Finished shape program N500 N600	≀ N100 G71 A100 U_W_ ….. ; N200 N300 N400 O100 N10 X100. Z50. ; N20
Operation moves to the N600 block upon completion of the cycle.	Operation moves to the N200 block upon completion of the cycle.

(12) The next block applying upon completion of the G70 command is the next block of the command block.

```
 ≀
N100 ......   ;
N200 ;
N300 ;
N400 ;
N500 ;
 ≀
N1000   G70   P200   Q500   ;   (or G70   A100 ;)
N1100   ...... ;
 ≀
```

Operation moves to the N1100 block upon completion of the G70 command.

(13) It is possible to apply a manual interrupt while a compound type fixed cycle command (G70 ~ G76) is being executed. However, upon completion of the interrupt, the tool must first be returned to the position where the interrupt was applied and then the compound type fixed cycle must be restarted.
If it is restarted without the tool having been returned, all subsequent movements will deviate by an amount equivalent to the manual interrupt amount.

(14) Compound type fixed cycle commands are unmodal commands and so they must be issued every time they are required.

(15) Program error (P203) results with the G71 and G72 commands even when, because of tool nose R compensation, there is no further movement of the Z axis in the second block or the Z axis has moved in the opposite direction.

13.3 Hole drilling fixed cycles; G80 ~ G89

Function and purpose

These fixed cycles are used for predetermined sequences of machining operations such as normal positioning, hole drilling, boring and tapping which are specified in a block. The various sequences available using these functions are listed in the table below.

G code	Hole drilling axis	Hole drilling start	Operation at hole bottom	Return operation	Application
G80	–	–	–	–	Cancel
G83	Z	Cutting feed, intermittent feed	In-position check Dwell	Rapid traverse	Deep hole drilling cycle 1
G84	Z	Cutting feed	In-position check Dwell, spindle reverse rotation	Cutting feed	Tapping cycle
G85	Z	Cutting feed	In-position check Dwell	Cutting feed	Boring cycle
G87	X	Cutting feed, intermittent feed	In-position check Dwell	Rapid traverse	Deep hole drilling cycle 1
G88	X	Cutting feed	In-position check Dwell, spindle reverse rotation	Cutting feed	Tapping cycle
G89	X	Cutting feed	In-position check Dwell	Cutting feed	Boring cycle
G83.2	Z/X	Cutting feed, intermittent feed	In-position check Dwell	Rapid traverse	Deep hole drilling cycle 2

A fixed cycle mode is canceled when the G80 or any G command in the 01 group is issued. The various data will also be cleared simultaneously to zero.

Command format

(1) Face hole drilling

G8Δ X/U_ C/H_ Z/W_ R_ Q_ P_ F_ K_ S_ ,S_ M_ ;	
G8Δ	Hole machining mode (G83, G84, G85)
X/U_ C/H_	Hole positioning data
Z/W_ R_ Q_ P_ F_	Hole machining data
K_	Number of repetitions
S_	Spindle rotation speed
,S_	Spindle rotation speed at return
M_	Miscellaneous command

(2) Longitudinal hole drilling

G8* Z/W_ C/H_ X/U_ R_ Q_ P_ F_ K_ S_ ,S_ M_ ;	
G8*****	Hole machining mode (G87, G88, G89)
Z/W_ C/H_	Hole positioning data
X/U_ R_ Q_ P_ F_	Hole machining data
K_	Number of repetitions
S_	Spindle rotation speed
,S_	Spindle rotation speed at return
M_	Miscellaneous command

(3) Cancel

G80 ;

(4) Data outline and corresponding addresses

(a) Hole machining modes : These are the fixed cycle modes for drilling (G83, G87), tapping (G84, G88) and boring (G85, G89).
These are modal commands and once they have been issued, they will remain valid until another hole machining mode command, the cancel command for the hole drilling fixed cycle or a G command in the 01 group is issued.

(b) Hole positioning data : These are for the positioning of the X (Z) and C axes.
These are unmodal data, and they are commanded block by block when the same hole machining mode is to be executed continuously.

(c) Hole machining data : These are the actual machining mode.
Except for Q, they are modal. Q in the G83 or G87 command is unmodal and is commanded block by block as required.

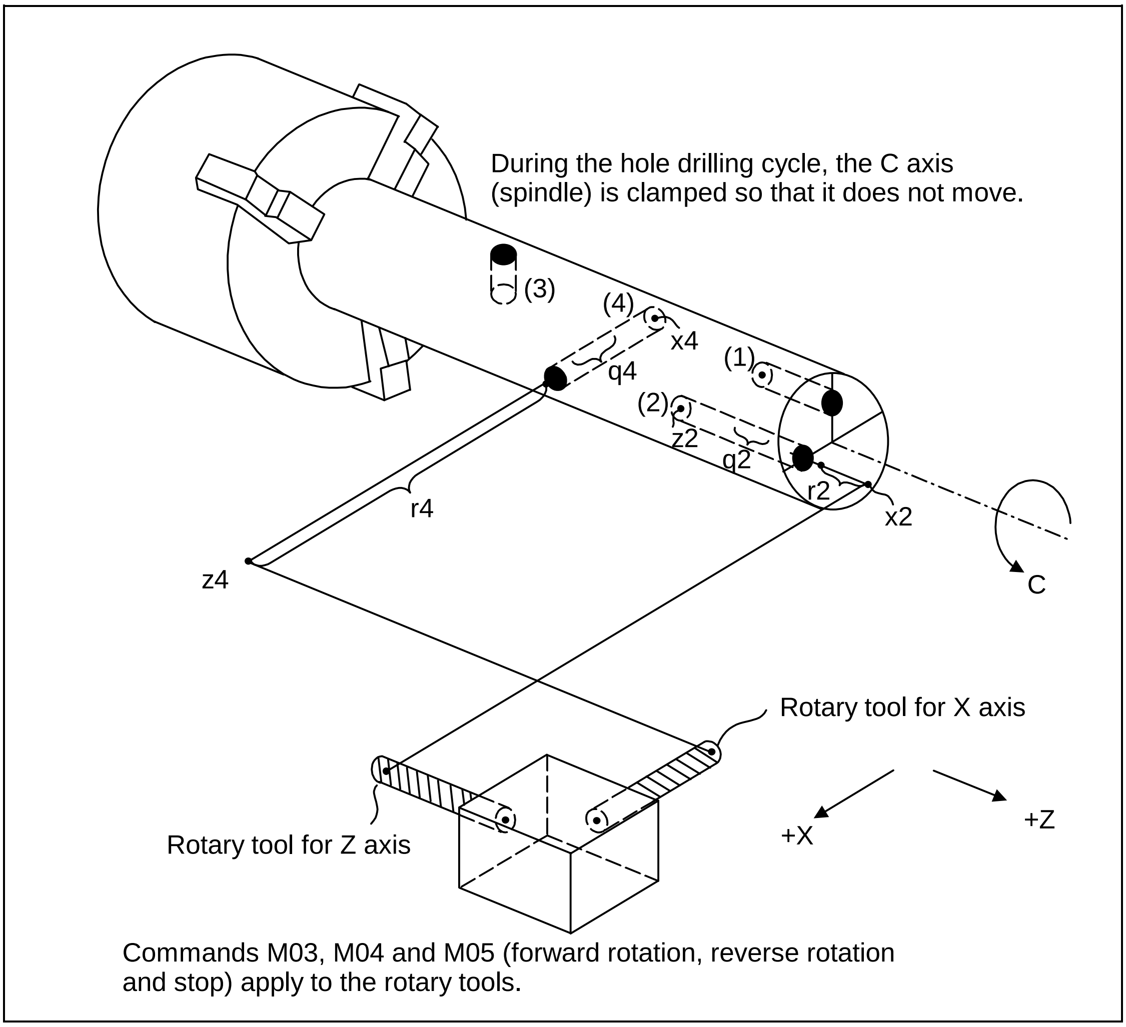
(d) Number of repetitions : This number is designated for machining holes at equal intervals when the same cycle is to be repeated.
The setting range is from 0 to 9999; the decimal point is not valid.
The number is unmodal and is valid only in the block in which it has been assigned.
When this number is not designated, it is treated as K1. When K0 is designated, the hole machining data are stored in the memory but no holes will be machined.

Address	Significance
G	Selection of hole machining cycle sequence (G80, G83, G84, G85, G87, G88, G89)
∗ X/U (Z/W), C/H	Designation of hole position initial point (absolute/incremental value)
∗ Z/W (X/U)	Designation of hole bottom position (absolute/incremental value from R point)
R	Designation of R point position (incremental value from initial point) (sign ignored)
Q	Designation of cut amount for each cutting pass with G83 (G87); always incremental value, radius value (sign ignored)
P	Designation of dwell time at hole bottom point; relationship between time and designated value is same as for G04 designation
F	Designation of feedrate for cutting feed
K	Designation of number of repetitions, 0 ~ 9999 (standard value = 1)
S	Designation of spindle rotation speed
,S	Designation of spindle rotation speed at return
,R	Designation of synchronous tapping/asynchronous tapping
M	Designation of M code to perform C-axis clamp at G83(G87)
L	Number of repetitions for fixed cycle (0 to 9999)

∗ : Addresses in parentheses apply for commands G87, G88 and G89.

Detailed description

The hole drilling axes for the hole drilling fixed cycle and the positioning are shown in the outline drawing below.



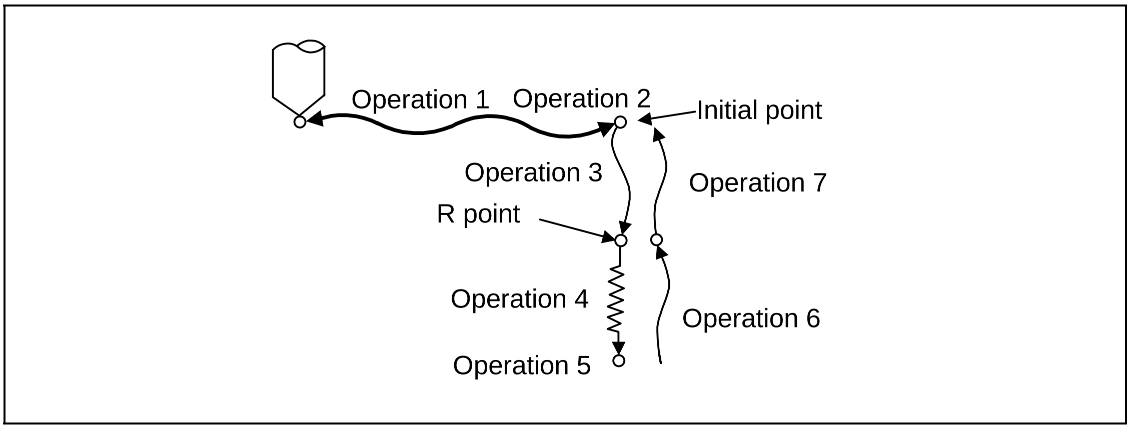
During the hole drilling cycle, the C axis (spindle) is clamped so that it does not move.

Commands M03, M04 and M05 (forward rotation, reverse rotation and stop) apply to the rotary tools.

(1) G83 Xx_1 Cc_1 Zz_1 Rr_1 Qq_1 Pp_1 Ff_1 Kk_1 ;
(2) G83 Xx_2 Cc_2 Zz_2 Rr_2 Qq_2 Pp_2 Ff_2 Kk_2 ;
(3) G87 Zz_3 Cc_3 Xx_3 Rr_3 Qq_3 Pp_3 Ff_3 Kk_3 ;
(4) G87 Zz_4 Cc_4 Xx_4 Rr_4 Qq_4 Pp_4 Ff_4 Kk_4 ;

Example of operation

There are 7 actual operations which are each described in turn below.



Operation 1 :	This denotes the positioning (by rapid traverse) of the tool to the X (Z) and C axis initial point. If ",I" (Positioning axis in-position width) is commanded, in-position check will be carried out after the block completes.
Operation 2 :	This is output provided that the M code for C-axis clamping is issued.
Operation 3 :	The tool is positioned as far as the R point by rapid traverse.
Operation 4 :	Hole machining is conducted by cutting feed. If ",J" (Hole drilling axis in-position width) is commanded, in-position check will be carried out after the block completes. Note that in case of deep drilling cycle 1 or 2, in-position check will not be carried out halfway for the hole drilling. It will be carried out at designated hole bottom position (the last hole drilling).
Operation 5 :	This operation takes place at the hole bottom position and it differs according to the fixed cycle mode. Possible actions include rotary tool reverse rotation (M04), rotary tool forward rotation (M03) and dwell.
Operation 6 :	The tool is retracted as far as the R point.
Operation 7 :	The tool is returned as far as the initial point at the rapid traverse rate.

(Operations 6 and 7 may be a single operation depending on the fixed cycle mode.)

Whether the fixed cycle is to be completed at operation 6 or 7 can be selected by the following G commands.

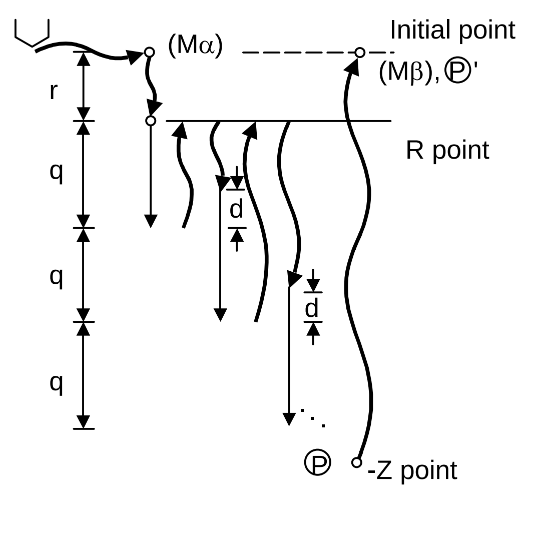
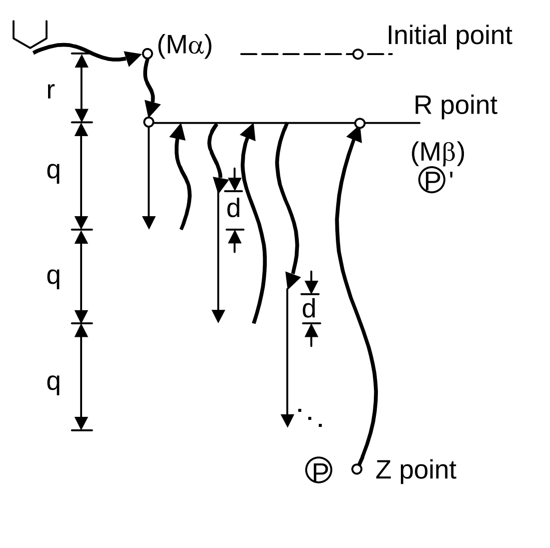
G98 ..... Initial level return
G99 ..... R point level return

These G commands are modal. Once, for instance, G98 is designated, the G98 mode will remain valid until the G99 command is issued. The G98 mode is established in the initialized state when the NC unit is ready to operate.

13.3.1 Face deep hole drilling cycle 1; G83 (Longitudinal deep hole drilling cycle 1; G87)

When the Q command is present (deep hole drilling)

G83 (G87) X(z)__ C_ Z(x)__ Rr Qq Pp Ff Kk Mm ;

G98 mode	G99 mode
	

(1) Return amount "d" is set by the setup parameter (#8013 G83 return). The tool returns at rapid traverse.

(2) (Mα) : The M code (Mm) is output when there is a C-axis clamping M code command (Mm).

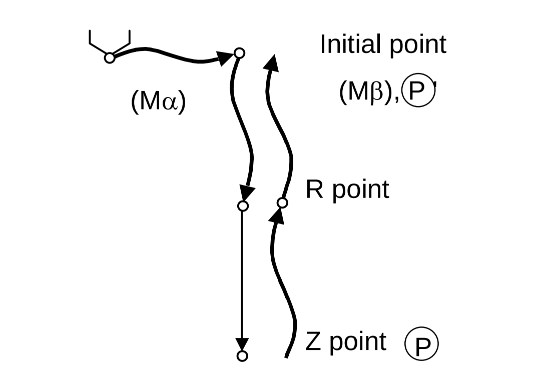
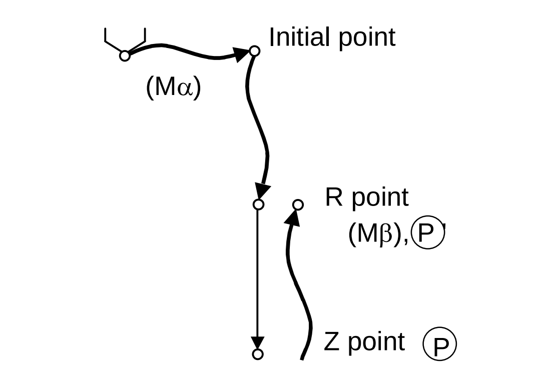
(3) (Mβ) : The C-axis unclamping M code (C-axis clamp M code + 1 = Mm + 1) is output when there is a C-axis clamping M code command (Mm).

(4) Ⓟ : Dwell is performed for the duration equivalent to the time designated by P.

(5) Ⓟ' : After the C-axis unclamping M code (Mm+2) has been output, dwell is performed for the duration equivalent to the time set by the parameter (#1184 clmp_ D).

When the Q command is not present (drilling)

G83 (G87) X(z)__ C__ Z(x)__ Rr Pp Ff Kk Mm ;

G98 mode	G99 mode
	

See "When the Q command is present (deep hole drilling)" for details on Mα, Mβ, Ⓟ and Ⓟ' .

13.3.2 Face tapping cycle; G84 (Longitudinal tapping cycle; G88)

Detailed description

(1) Selecting with a program command

Tap cycle ",R0/1" command

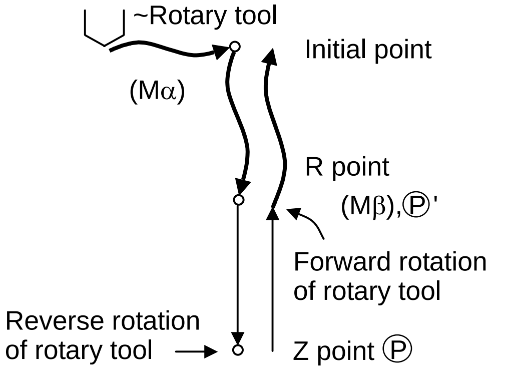
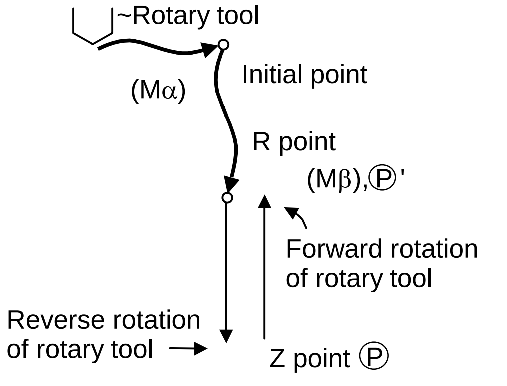
G84 (G88) Xx1 Cc1 Zz1 Rr1 Pp1 Ff1 Kk1 Ss1 ,Ss2 ,Rr2 Mm1 ;
When r2 = 1, the synchronous tap mode is entered, and when r2 = 0, the asynchronous tap mode is entered.

(2) Selecting with parameters

[Base specifications parameters]

#	Items		Details	Setting range (unit)
1229	set01 (bit4)	Synchronous tap	0: Handles the G88 and G84 tap cycles as the tap cycles with a floating tap chuck. 1: Handles the G88 and G84 tap cycles as the tap cycles without a floating tap chuck.	0/1

The tap command will be the synchronous tap cycle when this parameter is turned ON.

G98 mode	G99 mode
 ~Rotary tool Initial point (Mα) R point (Mβ),Ⓟ' Forward rotation of rotary tool Reverse rotation of rotary tool Z point Ⓟ	 ~Rotary tool Initial point (Mα) R point (Mβ),Ⓟ' Forward rotation of rotary tool Reverse rotation of rotary tool Z point Ⓟ

(a) See Section 13.5.1"When the Q command is present (deep hole drilling)" for details on Mα, Mβ, Ⓟ and Ⓟ' .

(b) When G84 (G88) is executed, the override will be canceled and the override will automatically be set to 100%.

(c) Dry run is valid when the control parameter "G00 DRY RUN" is ON and is valid for the positioning command. If the feed hold button is pressed during G84 (G88) execution, block stop occurs after returning completes.

(d) During single block operation, the axis will not stop at the turning point of tap cycle.

(e) During the G84 (G88) modal, the "Tapping" NC output signal will be output.

(f) During the G84 (G88) synchronous tapping modal, the M3, M4, S code, etc. will not be output.

(g) The tool stops at the reference point and the rotary tool forward rotation signal is output.

(h) The rotation of the rotary tool is reversed at the hole bottom and tapping is performed.

(i) Before the rotary tool reverse (M04) or forward rotation (M03) signal is output, the fixed cycle subprograms should be edited if the rotary tool stop (M05) command is required.

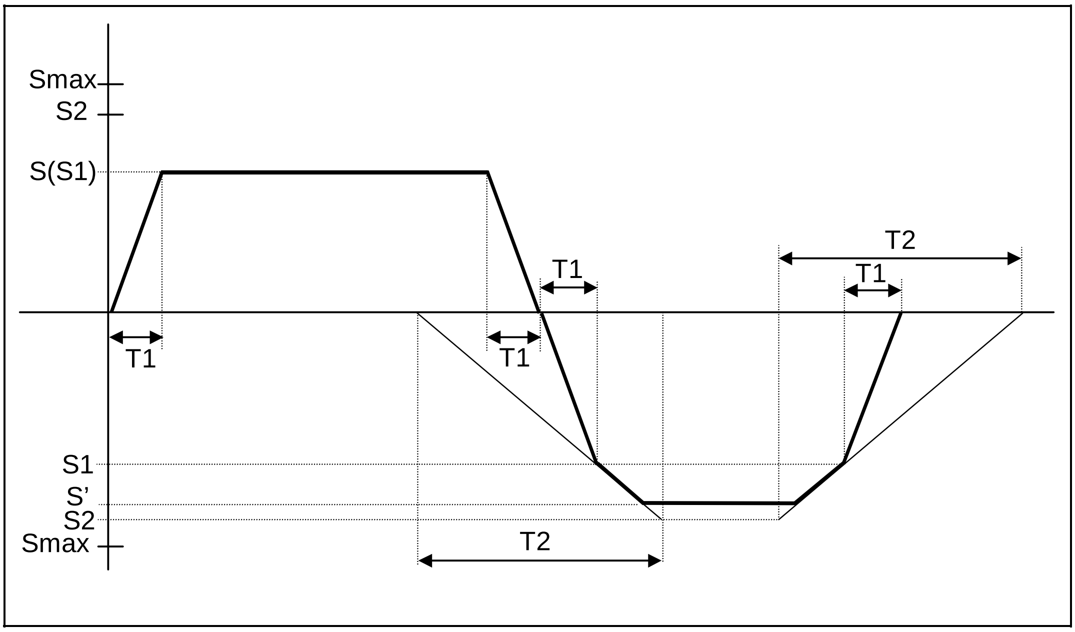
Canceling synchronous tap selection

The synchronous tap selection is canceled when the reset, G80 (hole drilling fixed cycle cancel), 01 group G code or other fixed cycle G code is commanded.

Spindle acceleration/deceleration pattern during synchronous tap

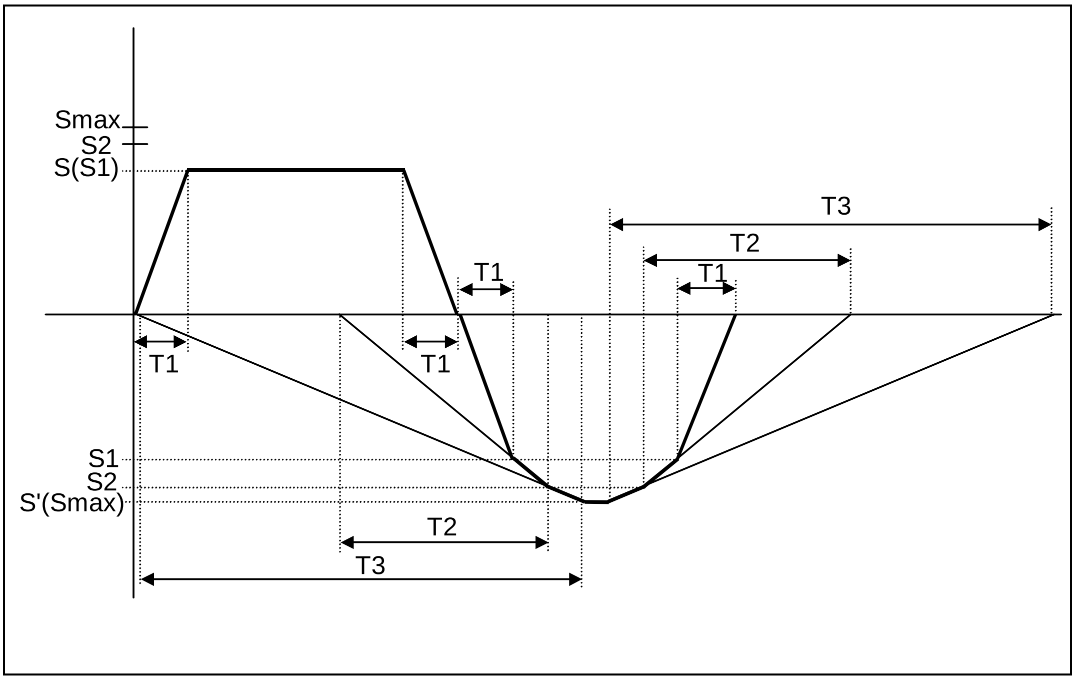
This function allows spindle acceleration/deceleration pattern to be approached to the speed loop acceleration/deceleration pattern by dividing the spindle and drilling axis acceleration/ deceleration pattern into up to three stages during synchronous tapping.
The acceleration/deceleration pattern can be set up to three stages for each gear.
When returning from the hole bottom, rapid return is possible depending on the spindle rotation speed during return. The spindle rotation speed during return is held as modal information.

(1) When tap rotation speed < spindle rotation speed during return ≤ synchronous tap changeover spindle rotation speed 2



S	: Command spindle rotation speed
S'	: Spindle rotation speed during return
S1	: Tap rotation speed (spindle base specification parameters #3013 to #3016)
S2	: Synchronous tap changeover spindle rotation speed 2 (spindle base specification parameters #3037 to #3040)
Smax	: Maximum rotation speed (spindle base specification parameters #3005 to #3008)
T1	: Tap time constant (spindle base specification parameters #3017 to #3020)
T2	: Synchronous tap changeover time constant 2 (spindle base specification parameters #3041 to #3044)

(2) When synchronous tap changeover spindle rotation speed 2 < spindle rotation speed during return

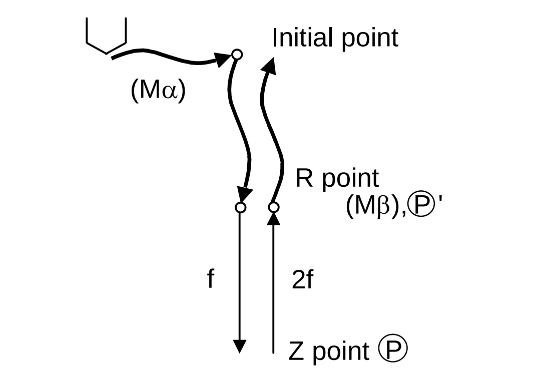
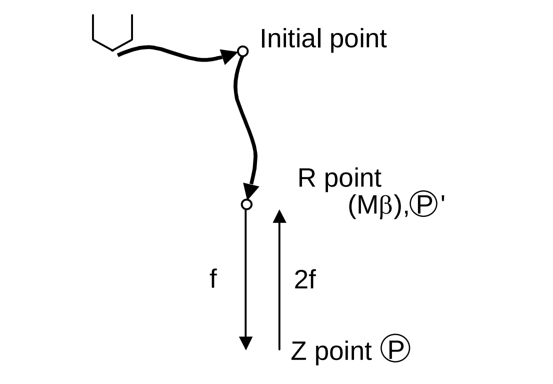


S : Command spindle rotation speed
S' : Spindle rotation speed during return
S1 : Tap rotation speed (spindle base specification parameters #3013 to #3016)
S2 : Synchronous tap changeover spindle rotation speed 2
(spindle base specification parameters #3037 to #3040)
Smax : Maximum rotation speed (spindle base specification parameters #3005 to #3008)
T1 : Tap time constant (spindle base specification parameters #3017 to #3020)
T2 : Synchronous tap changeover time constant 2
(spindle base specification parameters #3041 to #3044)
T3 : Synchronous tap changeover time constant 3
(spindle base specification parameters #3045 to #3048)

13.3.3 Face boring cycle; G85 (Longitudinal boring cycle; G89)

Detailed description

G85 (G89) X (z)_ C_ Z (x)_ R_ P_ F_ K_ M_ ;

G98 mode	G99 mode
 Initial point (Mα) R point (Mβ),Ⓟ' f 2f Z point Ⓟ	

(1) See Section 13.5.1 "When the Q command is present (deep hole drilling)" for details on Mα, Mβ, Ⓟ and Ⓟ' .

(2) The tool returns to the R point at a cutting feedrate which is double the designated feedrate command. However, it does not exceed the maximum cutting feedrate.

13.3.4 Deep hole drilling cycle 2; G83.2

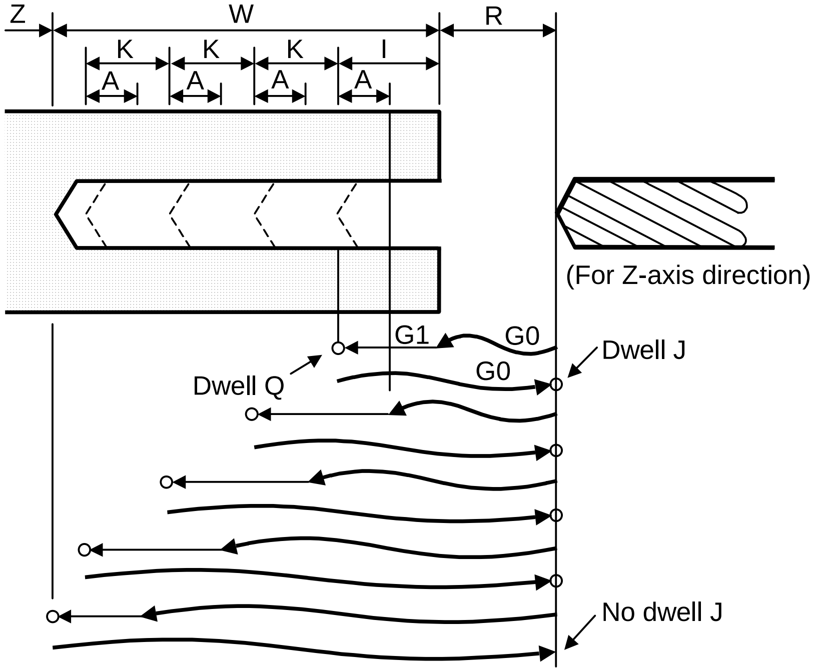
Function and purpose

The deep hole drilling cycle 2 drills deep holes in the X-axis or Z-axis direction by commanding the X or Z coordinate of the end point and the cut amount with cutting feed.

Command format

G83.2 W/Z/U/X_ R_ I_ K_ A_ Q_ J_ F_ ;	
W/Z/U/X	Incremental value from hole drilling start point/coordinates of hole bottom (with sign)
R	Incremental value (sign ignored) from present position up to hole drilling start point, always radius value with incremental value.
I	Cut amount of first cutting pass (sign ignored), always radius value with incremental value.
K	Cut amount of second and subsequent cutting passes (sign ignored), always radial value with incremental value.
A	Drill stop safety distance for second and subsequent cutting passes (sign ignored), always radial value with incremental value.
Q	Dwell time at cut point (sign ignored, decimal point invalid)
J	Dwell time at return point (sign ignored, decimal point invalid)
F	Cutting feedrate

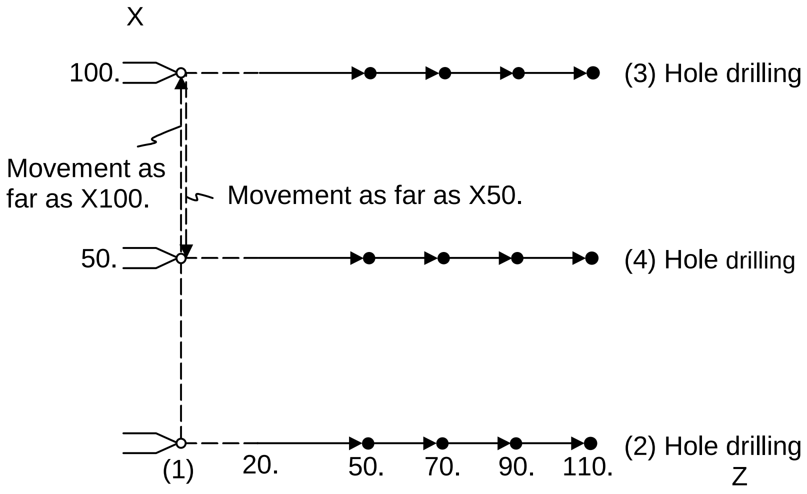
Operation



Example of program (when deep hole drilling cycle 2 is used as a modal command)

G28 XZ ;	
G0 X0. Z0. ;...	(1)
G83.2 Z110. R20. I30. K20. A5. Q1000 J500. F300. ;	(2)
X100. ;..	(3)
X50. ;..	(4)
M02 ;	

Operation



Detailed description

(1) When the drill stop safety distance (address "A") command is not given, the parameter #8013 return parameter setting value is used.

(2) The deep hole drilling cycle 2 is a modal command and so it will remain valid until a command in the same modal group or the cancel command (G80) is issued.

(3) If the command either for the cut amount (address "I") for the first cutting pass or the cut amount (address "K") for the second and subsequent passes is not present (including a command value of zero), the command value which is present will be used and the operation will be executed with both I and K equal to the command value.
If both commands are not present, hole drilling is conducted once as far as the hole bottom.

(4) When the axis address of the hole drilling axes has been commanded a multiple number of times in a block, the address commanded last is valid.

(5) The deep hole drilling fixed cycle 2 is also canceled by any G code in the 01 group except G80. If it is commanded in the same block as the fixed cycle, the fixed cycle will be ignored.
m = 01 group code, n = hole drilling fixed cycle code

$$\text{(a)}\ \underbrace{\text{Gm}}_{\text{Executed}}\ \ \underbrace{\text{Gn}}_{\text{Ignored}}\ \ \underbrace{\text{X(z)\_\_}\ \ \text{C\_\_}\ \ \text{Z(x)\_\_}}_{\text{Executed}}\ \ \underbrace{\text{R\_\_}\ \ \text{I\_\_}\ \ \text{K\_\_}\ \ \text{A\_\_}\ \ \text{Q\_\_}\ \ \text{J\_\_}}_{\text{Ignored}}\ \ \underbrace{\text{F\_\_}}_{\text{Memorized}}\ ;$$

$$\text{(b)}\ \underbrace{\text{Gn}}_{\text{Ignored}}\ \ \underbrace{\text{Gm}\ \ \text{X(z)\_\_}\ \ \text{C\_\_}\ \ \text{Z(x)\_\_}}_{\text{Executed}}\ \ \underbrace{\text{R\_\_}\ \ \text{I\_\_}\ \ \text{K\_\_}\ \ \text{A\_\_}\ \ \text{Q\_\_}\ \ \text{J\_\_}}_{\text{Ignored}}\ \ \underbrace{\text{F\_\_}}_{\text{Memorized}}\ ;$$

(Examples) G01 G83.2 Z50. R–10. I8. K10. A3. Q1000 J500 F100. ;
G83.2 G01 Z50. R–10. I8. K10. A3. Q1000 J500 F100. ;
In both cases, G01 Z50. F100. is executed.

(6) When a miscellaneous command is issued in the same block as the deep hole drilling cycle 2 command, it is output at the same time as the initial positioning.

(7) When a tool length offset command (T function) is issued in the deep hole drilling cycle 2 mode, execution will follow the tool length offset function.

(8) If the basic axis, additional axis or R data are in the block during the deep hole drilling cycle 2 mode, hole drilling is performed; if the data are not present, no holes are machined.
Even if the X-axis data are present, no holes will be machined if the dwell (G04) time command is present in the block.

(9) Command the hole machining data (A, I, K, Q, J) in the block (including the basic axis, additional axis or R data) in which the hole drilling operation is conducted.
Even if they are commanded in a block with no hole drilling operation, the modal data will not be updated.

(10) A program error (P33) results with the following commands.

(a) When both the X hole drilling axis (command address X or U) and the Z hole drilling axis (command address Z or W) have been commanded.

(b) When any axis except X or Z (any command address except X, U, Z and W) has been commanded.

(11) When the feed hold button is pressed while the deep hole drilling cycle 2 is being executed, feed hold results at that point, and when automatic operation is restarted, the remainder is executed.

(12) When an interrupt based on manual operation is performed during the feed hold (manual absolute switch ON), the operation in the deep hole drilling cycle 2 modal is shifted from the automatic operation restart by an amount equivalent to the movement caused by the interrupt.

(13) With single block operation, block stop results upon completion of the deep hole drilling cycle 2 command.

13.3.5 Hole drilling fixed cycle cancel; G80

Detailed description

This cancels the hole drilling fixed cycle (G83, G84, G85, G87, G88, G89). The hole machining mode and hole machining data are both canceled.

13.3.6 Precautions when using a hole drilling fixed cycle

Precautions

(1) When a G84 or G88 fixed cycle is commanded, the rotary tool must be rotated in the specified direction beforehand by the previous miscellaneous functions (M3, M4).

(2) If there is data for the basic axis, additional axis or R in the same block during fixed cycle mode, hole drilling is carried out. If there is no data, the hole drilling is not carried out.
Note that even with X axis data, if that block is a dwell (G04) time command, the hole drilling is not carried out.

(3) Command hole machining data (Q, P) in the block in which hole drilling is carried out (block containing data for the basic axis, additional axis or R).
The modal data is not updated in blocks without hole drilling, even if these data are commanded.

(4) The F modal may change when a reset is applied during execution of G85 (G89).

(5) The hole drilling fixed cycle is also canceled by 01 group G codes other than G80. If these are commanded in the same block as the fixed cycle, the fixed cycle will be ignored.
m = 01 group code   n = hole drilling fixed cycle code

(a) $\underbrace{\text{Gm}}_{\text{Executed}}\ \underbrace{\text{Gn}}_{\text{Ignored}}\ \underbrace{\text{X(z)\_\_ \quad C\_\_ \quad Z(x)\_\_}}_{\text{Executed}}\ \underbrace{\text{R\_\_ \quad Q\_\_ \quad P\_\_ \quad K\_\_}}_{\text{Ignored}}\ \underbrace{\text{F\_\_}}_{\text{Memorized}}\ ;$

(b) $\underbrace{\text{Gn}}_{\text{Ignored}}\ \underbrace{\text{Gm \quad X(z)\_\_ \quad C\_\_ \quad Z(x)\_\_}}_{\text{Executed}}\ \underbrace{\text{R\_\_ \quad Q\_\_ \quad P\_\_ \quad K\_\_}}_{\text{Ignored}}\ \underbrace{\text{F\_\_}}_{\text{Memorized}}\ ;$

(Examples) G01 G83 X100. C30. Z50. R-10. Q10. P1 F100. ;
G83 G01 X100. C30. Z50. R-10. Q10. P1 F100. ;
In both cases, G01X100. C30. Z50. F100 is executed..

(6) When miscellaneous functions are commanded in the same block as fixed cycle commands, they are output simultaneously with the initial positioning.
Note that when the M code of the C axis clamp set in the parameters (#1183 clmp_M) is commanded in the same block, the M code is output after positioning (Operation 2).
Once the axis has returned to the return point (G98 mode: initial point/G99 mode: R point) after hole drilling, the M code of the C axis clamp (clamp M + 1)is output, and the axis dwells for the time set in the parameters (#1184 clmp_D).
When the No. of rotations is designated, M codes other than that of the C axis clamp carry out the control above for the first rotation only.
C axis clamp/unclamp M commands work in modal, and are output every rotation until canceled by the fixed cycle cancel command.

(7) When tool length offset commands (T functions) are commanded in the hole drilling fixed cycle, they are executed according to the tool length offset function.

(8) A program error (P155) will result when a hole drilling fixed cycle is commanded during nose R compensation.

(9) For the G code list 1, the initial point level return is fixed. The return level cannot be changed with a G98/G99 command. Note that a separate function will be executed if G98/G99 is commanded.

(10) In a block where the movement direction of any axis reverses as shown below, the servo system load will greatly increase so do not command the in-position width in the machining program.

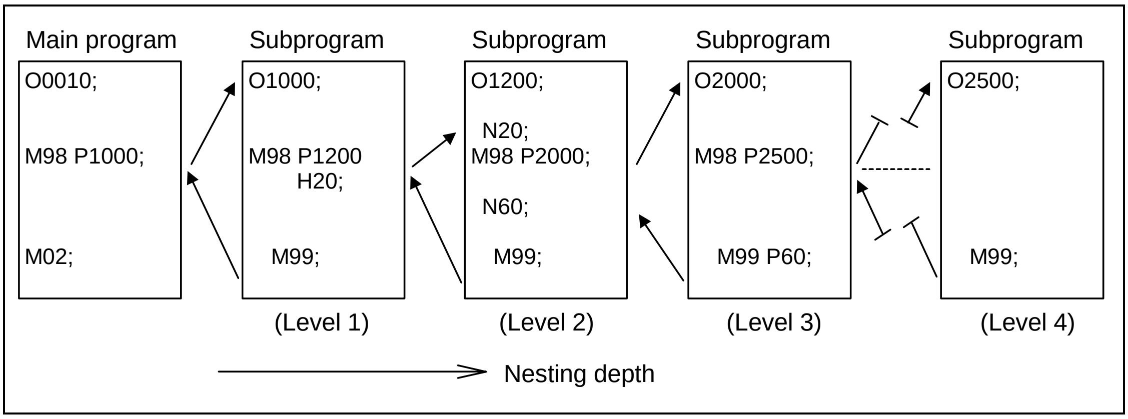
```
G0  X100. ,I10.0 ;
X–200. ;
```

13.4 Subprogram control; M98, M99

13.4.1 Calling subprogram with M98 and M99 commands

Function and purpose

Fixed sequences or repeatedly used parameters can be stored in the memory as subprograms which can then be called from the main program when required. M98 serves to call subprograms and M99 serves to return operation from the subprogram to the main program. Furthermore, it is possible to call other subprograms from particular subprograms and the nesting depth can include as many as 8 levels.



The table below shows the functions which can be executed by adding and combining the subprogram control functions and fixed cycle functions.

	Case 1	Case 2	Case 3	Case 4
1. Subprogram control	No	Yes	Yes	No
2. Fixed cycles	No	No	Yes	Yes
Function				
1. Memory operation	○	○	○	○
2. Subprogram call	×	○	○	×
3. Subprogram variable designation **(Note 2)**	×	○	○	×
4. Subprogram nesting level call **(Note 3)**	×	○	○	×
5. Fixed cycles	×	×	○	○
6. Subprogram editing for fixed cycle	×	×	○	○

(Note 1) "○" denotes a function which can be used and "×" a function which cannot be used.

(Note 2) Variables cannot be transferred with the M98 command but variable commands in subprograms can be used provided that the variable command option is available.

(Note 3) A maximum of 8 nesting levels form the nesting depth.

Command format

Subprogram call

M98 P_ H_ L_ ;

M98 Subprogram call command

P_ Program number of subprogram to be called (own program if omitted)
P can be omitted only during memory operation and MDI operation.
(Max. 8 digits)

H_ Sequence number in subprogram to be called (head block if omitted)
(Max. 5 digits)

L_ Number of subprogram repetitions
(When omitted, this is interpreted at L1, and is not executed when L0.)
(Between 1 and 9999 times according to 4-digit value.)
For instance, M98 P1 L3 ; is equivalent to the following:
M98 P1 ;
M98 P1 ;
M98 P1 ;

Return to main program from subprogram

M99 P_ H_ Q_ R_ L_ ;

M99 Subprogram return command

P_ Sequence number of return destination (return to the block that following the calling block if omitted)

H_ Program number of return destination (return to the main program at calling if omitted)

Q_ Sequence number to start searching of return destination (the block that follows the calling block will be handled as the search start position if omitted)

R_ Sequence number to finish searching of return destination (the block that precedes the calling block will be handled as the search finish position if omitted)

L_ Number of times after repetition number has been changed ("-1" if omitted)

Creating and entering subprograms

Subprograms have the same format as machining programs for normal memory operation except that the subprogram completion instruction M99 (P_ L_) ; is entered as an independent block at the last block.

```
○ΔΔΔΔΔΔΔΔ           ;  )    Program number as subprogram number
...............................  ;  |
...............................  ;  |
        :                        |    Main body of subprogram
        :                        |
        :                        |
...............................  ;  |
M99 ;                            |    Subprogram return command
% (EOR)                          )    Entry completion code
```

(1) The above program is entered by editing operations at the setting and display unit. For further details, refer to the section on program editing in the Instruction Manual.

(2) Only those subprograms numbers ranging from 1 to 99999999 designated by the optional specifications can be used.

(3) Up to 8 nesting levels can be used for calling programs from subprograms, and program error (P230) results if this number is exceeded.

(4) No distinction between main programs and subprograms is made since they are entered in the sequence in which they were read. This means that main programs and subprograms should not be given the same numbers. (If they are, error "E11" appears during entry.)

```
  ;
O○○○○ ;
................................ ;
  :
  :
 M99  ;
 %
  ;
```

Subprogram A

```
O ΔΔΔΔ  ;
................................ ;
  :
  :
 M99  ;
  %
  ;
```

Subprogram B

```
O ****  ;
................................ ;
  :
  :
 M99  ;
  %
  ;
```

Subprogram C

(5) Main programs can be entered in the memory or programmed by MDI operation but subprograms must be entered in the memory.

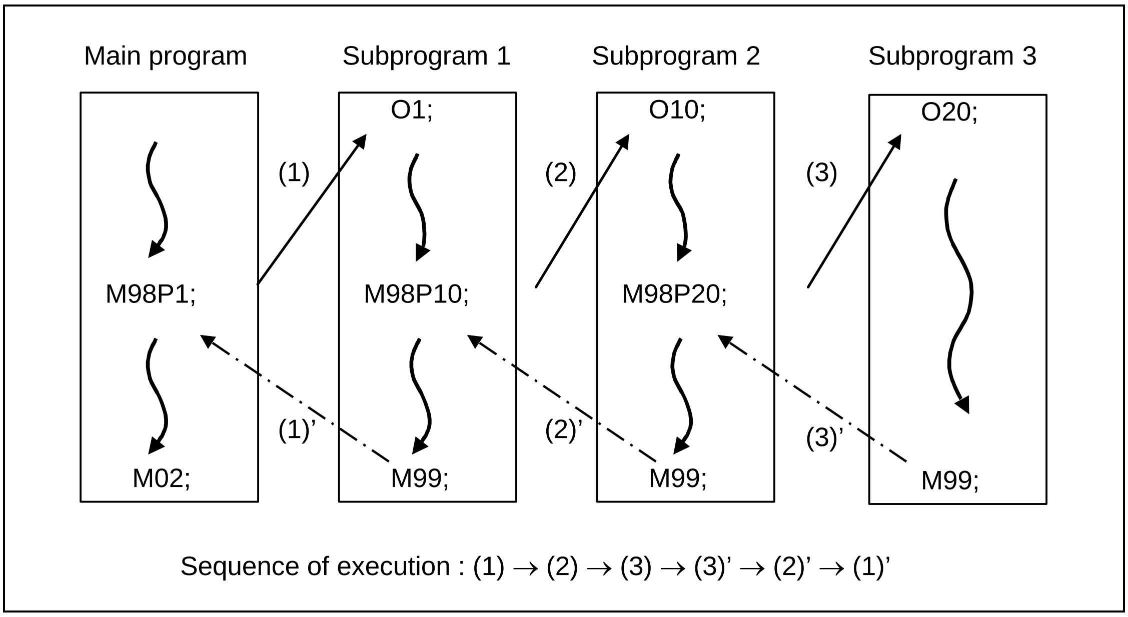
(6) Besides the M98 command, subprogram nesting is subject to the following commands:
- G65 : Macro call
- G66 : Modal call
- G66.1 : Modal call
- G code call
- Miscellaneous function call
- MDI interrupt
- Automatic tool length measurement
- Macro interrupt
- Multi-step skip function

(7) Subprogram nesting is not subject to the following commands which can be called even beyond the 8th nesting level.
- Fixed cycles
- Pattern cycles

(8) When the subprogram is to be repeatedly used, it will be repeatedly executed for l_1 times provided that "M98 Pp_1 Ll_1 ;" is programmed.

Example of program 1

When there are 3 subprogram calls (known as 3 nesting levels)

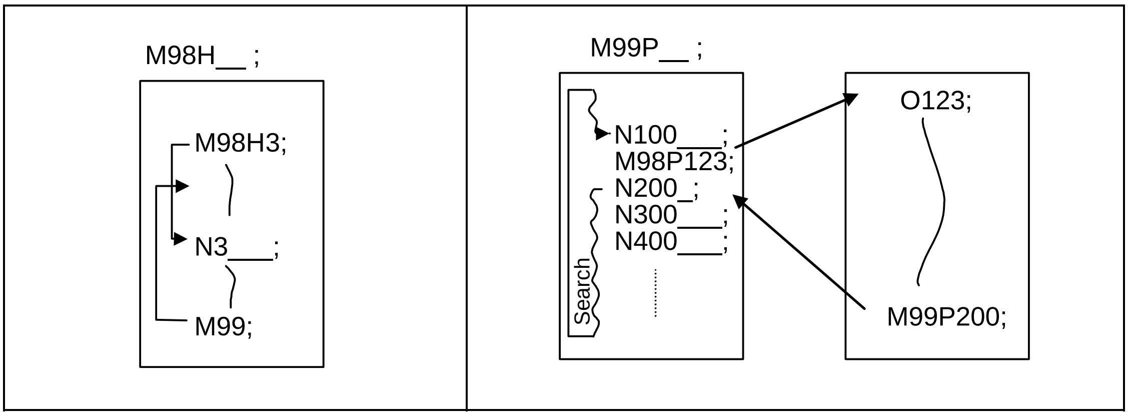


(1) For nesting, the M98 and M99 commands should always be paired off on a 1:1 basis (1)' for (1), (2)' for (2), etc.

(2) Modal information can be rewritten according to the execution sequence without distinction between main programs and subprograms. This means that after calling a subprogram, attention must be paid to the modal data status when programming.

Example of program 2

The "M98 H_ ;" and "M99 P_ ;" commands designate the sequence numbers in a program with a call instruction.



Precautions

(1) Program error (P232) results when the designated P (program number) is not located.

(2) Single block stop does not occur with the "M98 P_ ; M99 ;" block. If any address except O, N, P, L or H is used, single block stop can be executed. (With "X100. M98 P100 ;", operation branches to O100 after "X100." is executed.)

(3) When M99 is commanded by the main program, operation returns to the head. (This is same for MDI.)

(4) Branching from BTR operation to the subprogram with M98 P_ is possible, but the return destination sequence No. cannot be designated with "M99 P_ ;". (P_ is ignored).

(5) Bear in mind that the search operation will take time when the sequence number is designated by "M99 P_ ;".

13.5 Variable commands

Function and purpose

Programming can be endowed with flexibility and general-purpose capabilities by designating variables, instead of giving direct numerical values to particular addresses in a program, and by assigning the values or those variables as required when executing a program.

Command format

#ΔΔΔ = ○○○○○○○○ or #ΔΔΔ = [formula]

Detailed description

(1) Variable expressions	**Example**
(a) #m .... m = value consisting of 0~9	#100
(b) # [f] .... f = one of the following in the formula	# [– #120]
Numerical value m	123
Variable	#543
Formula Operator Formula	#110 + #119
– (minus) formula	– # 120
[Formula]	[#119]
Function [formula]	SIN [#110]

(Note 1) The 4 standard operators are +, –, ∗ and / .

(Note 2) Functions cannot be used unless the user macro specifications are available.

(Note 3) Error (P241) results when a variable number is negative.

(Note 4) Examples of incorrect variable expressions are given below.

Incorrect		Correct
#6/2	→	# [6/2] (Note that expression such as "#6/2" is regarded as "[#6]/2".)]
# – – 5	→	# [– [–5]]
# – [# 1]	→	# [– #1]

(2) Types of variables

The following table gives the types of variables.

Type of variable		Number		Function
Common variables	No. of variable sets option	Common variables 1 (Common to part systems)	Common variables 2 (Provided per part system)	• Can be used in common throughout main, sub and macro programs.
	50 + 50 × number of part systems	#500 to #549 (50 sets)	#100 to #149 (50 sets)	
	100 + 100 × number of part systems	#500 to #599 (100 sets)	#100 to #199 (100 sets)	
	200 + 100 × number of part systems	#500 to #699 (200 sets)	#100 to #199 (100 sets)	
Local variables		1 to 33		Can be used for local variables in macro programs.
System variables		1000 to		Application is fixed by system.
Fixed cycle variables		1 to 32		Local variables in fixed cycle programs.

(Note 1) All common variables are retained even when the power is turned OFF.

(Note 2) When the power is turned OFF or reset, the common variables can be set to <null> by setting the parameter (#1128 RstVC1, #1129 PwrVC1).

(Note 3) The common variables are divided into the following two types.
Common variables 1 : Used in common through all part systems
Common variables 2 : Used in common in the programs of the part system

(3) Variable quotations

Variables can be used for all addresses accept O, N and / (slash).

(a) When the variable value is used directly:
X#1................................ Value of #1 is used as the X value.

(b) When the complement of the variable value is used:
X–#2.............................. Value with the #2 sign changed is used as the X value.

(c) When defining variables:
#3 = #5........................... Variable #3 uses the equivalent value of variable #5.
#1 = 1000....................... Variable #1 uses the equivalent value 1000 (which is treated as 1000.).

(d) When defining the variable arithmetic formula:
#1 = #3 + #2 – 100......... The value of the operation result of #3 + #2 – 100. is used as the #1 value.
X [#1 + #3 + 1000] .... The value of the operation result of #1 + #3 + 1000 is used as the X value.

(Note 1) A variable cannot be defined in the same block as an address. It must be defined in a separate block.

```
  Incorrect               Correct
X #1= #3 + 100 ;  →  #1= #3 + 100 ;
                     X#1 ;
```

(Note 2) Up to five sets of square parentheses [ ] may be used.

#543 = – [[[[[#120]/2 + 15.]∗3 – #100]/#520 + #125 + #128]∗#130 + #132] ;

(Note 3) There are no restrictions on the number of characters and number of variables for variable definition.

(Note 4) The variable values should be within a range from 0 to ±99999999.
If this range is exceeded, the operations may not be conducted properly.

(Note 5) The variable definitions are valid from the moment that the variables are actually defined.
#1 = 100 ;............................ #1 = 100
#1 = 200 #2 = #1 + 200 ;...... #1 = 200, #2 = 400
#3 = #1 + 300 ;..................... #3 = 500

(Note 6) Variable quotations are always regarded as having a decimal point at the end.

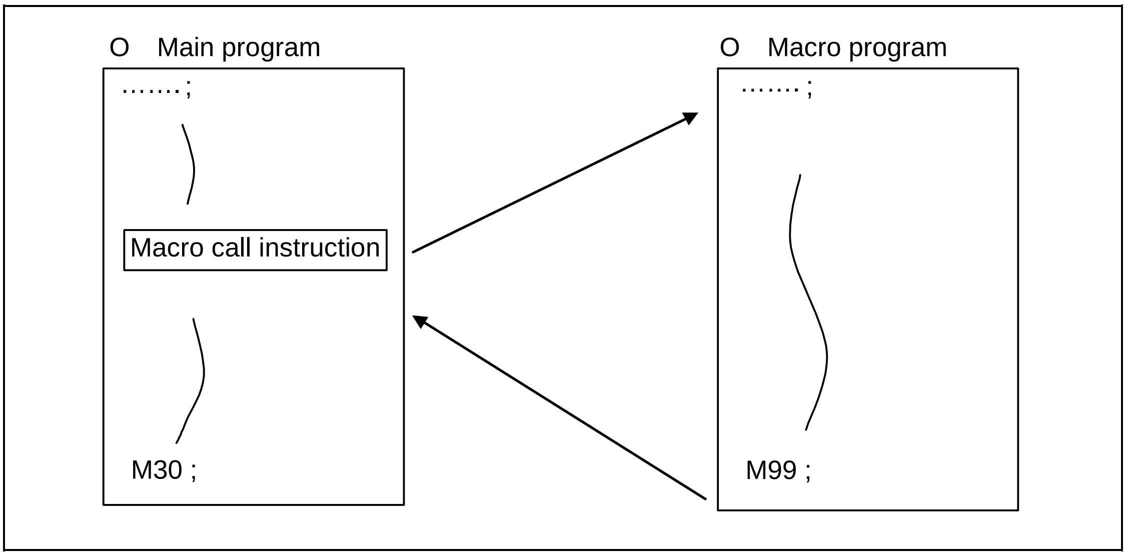
When #100 = 10,
then X#100 ; is treated as X10.

13.6 User macro

13.6.1 User macro commands; G65, G66, G66.1, G67

Function and purpose

By combining the user macros with variable commands, it is possible to use macro program call, operation, data input/output with PLC, control, decision, branch and many other instructions for measurement and other such applications.



Macro programs use variables, operation instructions and control instructions to create subprograms which function to provide dedicated control.
These dedicated control functions (macro programs) are called by the macro call instructions exactly when required from the main program.

G code	Function
G65	User macro Simple call
G66	User macro Modal call A (called after the movement command)
G66.1	User macro Modal call B (called after every block)
G67	User macro Modal call cancel

Detailed description

(1) When the G66 or G66.1 command is entered, the specified user macro program will be called after each block has been executed or after the movement command in the block with the movement commands has been executed until the G67 (cancel) command is entered.

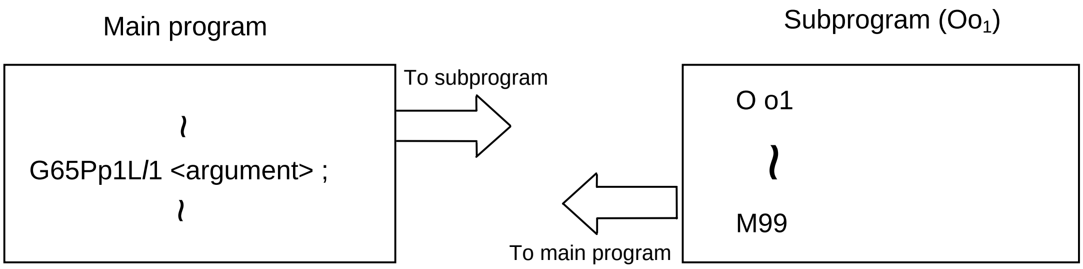
(2) The G66 (G66.1) and G67 commands must be paired in the same program.

13.6.2 Macro call instruction

Function and purpose

Included among the macro call commands are the simple calls which apply only to the instructed block and also modal calls (types A and B) which apply to each block in the call modal.

Simple macro calls



M99 is used to conclude the user macro subprogram.

Format

M98 P__ L__ <argument> ;	
P_	Program No.
L_	No. of repetitions

When the <argument> must be transferred as a local variable to a user macro subprogram, the actual value should be designated after the address.
Regardless of the address, a sign and decimal point can be used in the argument. There are 2 ways in which arguments are designated.

(1) Argument designation I

Format : A_ B_ C_ ... X_ Y_ Z_

Detailed description

(a) Arguments can be designated using any address except G, L, N, O and P.

(b) Except for I, J and K, there is no need for designation in alphabetical order.

(c) I, J and K must be designated in alphabetical order.

I_ J_ K_ ...... Correct
J_ I_ K_ ...... Incorrect

(d) Addresses which do not need to be designated can be omitted.

(e) The following table shows the correspondence between the addresses which can be designated by argument designation I and the variable numbers in the user macro main body.

Address and variable number correspondence		Call instructions and usable address	
Argument designation I address	Variable in macro	G65, G66	G66.1
A	#1	○	○
B	#2	○	○
C	#3	○	○
D	#7	○	○
E	#8	○	○
F	#9	○	○
G	#10	×	×*
H	#11	○	○
I	#4	○	○
J	#5	○	○
K	#6	○	○
L	#12	×	×*
M	#13	○	○
N	#14	×	×*
O	#15	×	×
P	#16	×	×*
Q	#17	○	○
R	#18	○	○
S	#19	○	○
T	#20	○	○
U	#21	○	○
V	#22	○	○
W	#23	○	○
X	#24	○	○
Y	#25	○	○
Z	#26	○	○

○ : Can be used.
× : Cannot be used.
* : Can be used while G66.1 command is modal.

(2) Argument designation II

Format : A_ B_ C_ I_ J_ K_ I_ J_ K_ ...

Detailed description

(a) In addition to addresses A, B and C, up to 10 groups of arguments with I, J, K serving as 1 group can be designated.

(b) When the same address is duplicated, designate the addresses in the specified order.

(c) Addresses which do not need to be designated can be omitted.

(d) The following table shows the correspondence between the addresses which can be designated by argument designation II and the variable numbers in the user macro main body.

Argument designation II **address**	**Variable within macro**
A	#1
B	#2
C	#3
I1	#4
J1	#5
K1	#6
I2	#7
J2	#8
K2	#9
I3	#10
J3	#11
K3	#12
I4	#13
J4	#14
K4	#15
I5	#16

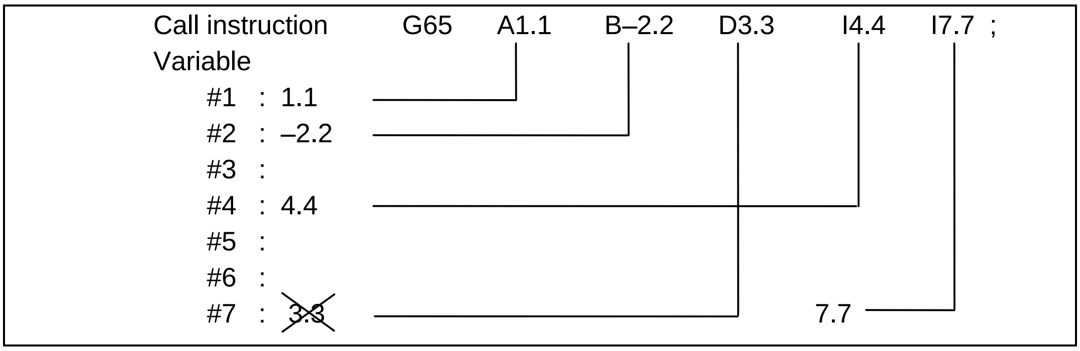
Argument designation II **address**	**Variable within macro**
J5	#17
K5	#18
I6	#19
J6	#20
K6	#21
I7	#22
J7	#23
K7	#24
I8	#25
J8	#26
K8	#27
I9	#28
J9	#29
K9	#30
I10	#31
J10	#32
K10	#33

(Note 1) The numbers 1 to 10 accompanying I, J and K denote the sequence of the commanded groups and they are not required for the actual instructions.

(3) Using arguments designations I and II together

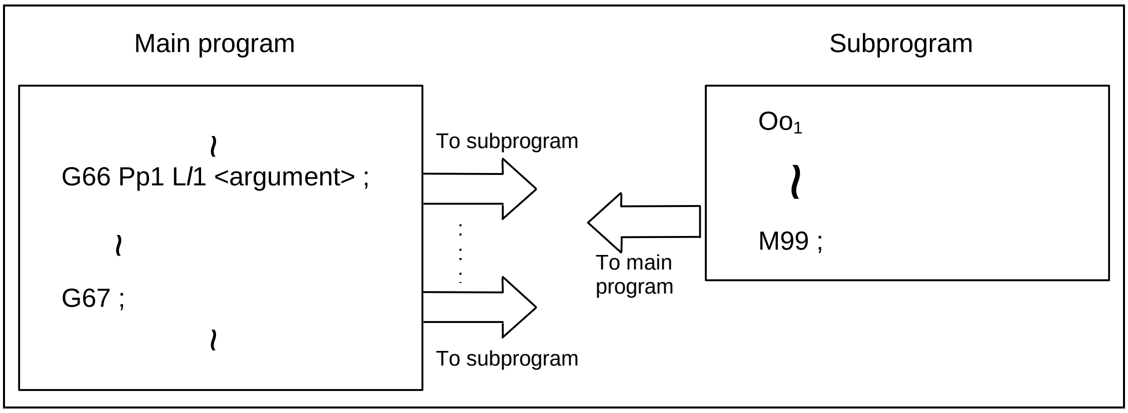
If addresses corresponding to the same variable are commanded when both types I and II are used to designate arguments, the latter address is valid.

(Example 1)



In the above example the last I7.7 argument is valid when both arguments D3.3 and I7.7 are commanded for the #7 variable.

Modal call A (called after the movement command)



When the block with a movement command is commanded between G66 and G67, the movement command is first executed and then the designated user macro subprogram is executed. The number of times the subprogram is executed is /1 times with each call.
The <argument> is the same as for a simple call.

Format

G66 P__ L__ <argument> ;	
P_	Program No.
L_	No. of repetitions

Detailed description

(1) When the G66 command is entered, the designated user macro subprogram will be called after the movement command in the block with the movement commands has been executed until the G67 (cancel) command is entered.

(2) The G66 and G67 commands must be paired in the same program.
A program error will result when G67 is issued without the G66 command.

Modal call B (called after every block)

The designated user macro subprogram is unconditionally called at each command block commanded between G66.1 and G67, and is executed the number of times designated to "L" address.
The <argument> is the same as for a simple call.

Format

G66.1 P__ L__ <argument> ;

P_	Program No.
L_	No. of repetitions

Detailed description

(1) In the G66.1 mode, everything except the O, N and G codes in the various command blocks which are read are handled as the argument without being executed. Note that the G code designated last, or the N code commanded after other than O and N is the argument.

(2) The same applies as when G65 P_ is assigned at the head of a block for all significant blocks in the G66.1 mode.

(Example 1)

N100 G01 G90 X100. Z200. F400 R1000 ;
in the G66.1 P1000 ; mode is the same as:
N100 G65 P1000 G01 G90 X100. Z200. F400 R1000 ;

(Note 1) The call is performed even in the G66.1 command block in the G66.1 mode and the correspondence between the argument address and the variable number is the same as for G65 (simple call).

(3) The range of the G and N command values which can be used new as variables in the G66.1 mode is subject to the restrictions applying to value as normal NC command values.

(4) Program No. O, sequence numbers N and modal G code are updated as modal information.

G code macro call

User macro subprograms with prescribed program numbers can be called merely by issuing the G code command.

Format

G∗∗ <argument> ;

G∗∗	G code for macro call

Detailed description

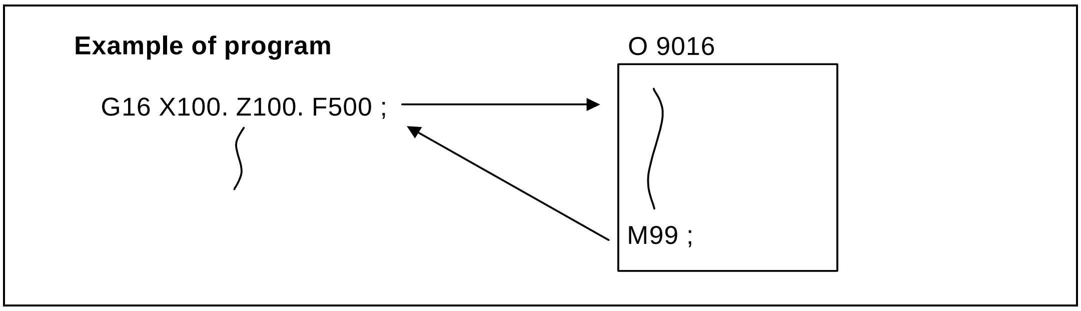
(1) The above instruction functions in the same way as the instructions below, and parameters are set for each G code to determine the correspondence with the instructions.
a: M98 PΔΔΔΔ ;
b: G65 PΔΔΔΔΔ <argument> ;
c: G66 PΔΔΔΔΔ <argument> ;
d: G66.1 PΔΔΔΔΔ <argument> ;

When the parameters corresponding to c and d above are set, issue the cancel command (G67) either in the user macro or after the call code has been commanded so as to cancel the modal call.

(2) The correspondence between the "∗∗" which conducts the macro call and the program number PΔΔΔΔ of the macro to be called is set by parameter.

(3) Up to 10 G codes from G00 to G255 can be used with this command. (G01 to G99 can also be used with parameter "#1081 Gmac_P").

(4) The commands cannot be issued during a user macro subprogram which has been called by a G code.



Example of program

```
G16 X100. Z100. F500 ;
```

```
O 9016

M99 ;
```

Miscellaneous command macro call (for M, S, T, B code macro call)

The user macro subprograms of the specified program number can be called merely by issuing an M (or S, T, B) code. (Only entered codes apply for M but all S, T and B codes apply.)

Format

M∗∗; (or S∗∗ ;, T∗∗ ;, B∗∗ ;)	
M∗∗	M code for macro call (or S, T, B code)

Detailed description

(1) The above instruction functions in the same way as the instructions below, and parameters are set for each M code to determine the correspondence with the instructions. (Same for S, T and B codes)

a: M98 PΔΔΔΔ ;
b: G65 PΔΔΔΔ M∗∗;
c: G66 PΔΔΔΔ M∗∗;
d: G66.1 PΔΔΔΔ M∗∗;

} M98, M∗∗ are not output

When the parameters corresponding to c and d above are set, issue the cancel command (G67) either in the user macro or after the call code has been commanded so as to cancel the modal call.

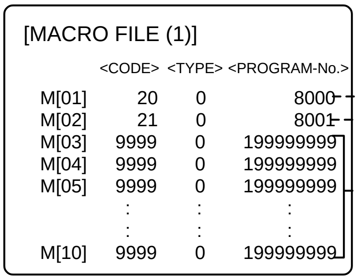
(2) The correspondence between the "M∗∗" which conducts the macro call and the program number PΔΔΔΔ of the macro to be called is set by parameter. Up to 10 M codes from M00 to M95 can be entered.
Any code except the codes basically required by the machine and the M0, M1, M2, M30 and M96 ~ M99 codes can be entered.

(3) As with M98, the display appears on the CRT screen of the setting and display unit but the M codes and MF are not output.

(4) Even if the miscellaneous command entered above is issued during a user macro subprogram called by the M code, macro call will not result and it will be handled as an ordinary miscellaneous command.

(5) All S, T and B codes call the subprograms in the prescribed program numbers of the corresponding S, T and B functions.

(6) Up to 10 M codes can be set, but set the parameter in the following manner when they will not all be used.



```
[MACRO FILE (1)]

          <CODE>  <TYPE>  <PROGRAM-No.>
 M[01]      20      0          8000
 M[02]      21      0          8001
 M[03]    9999      0     199999999
 M[04]    9999      0     199999999
 M[05]    9999      0     199999999
             :      :             :
             :      :             :
 M[10]    9999      0     199999999
```

For M20 commands, set to call O8000 in type 0 (M98 type)

For M21 commands, set to call O8001 in type 0 (M98 type)

Set parameters that will not be used as shown at the left.

Differences between M98 and G65 commands

(1) The argument can be designated for G65 but not for M98.

(2) The sequence number can be designated for M98 but not for G65, G66 and G66.1.

(3) M98 executes a subprogram after all the commands except M, P, H and L in the M98 block have been executed, but G65 branches to the subprogram without any further operation.

(4) When any address except O, N, P, H or L is included in the M98 block, single block stop results. This is not the case with G65.

(5) The level of the M98 local variables is fixed but it can be varied in accordance with the nesting depth for G65. (#1, for instance, has the same significance either before or after M98 but a different significance in each case with G65.)

(6) The M98 nesting depth extends up to 8 levels in combination with G65, G66 and G66.1. The G65 nesting depth extends up to only 4 levels in combination with G66 and G66.1.

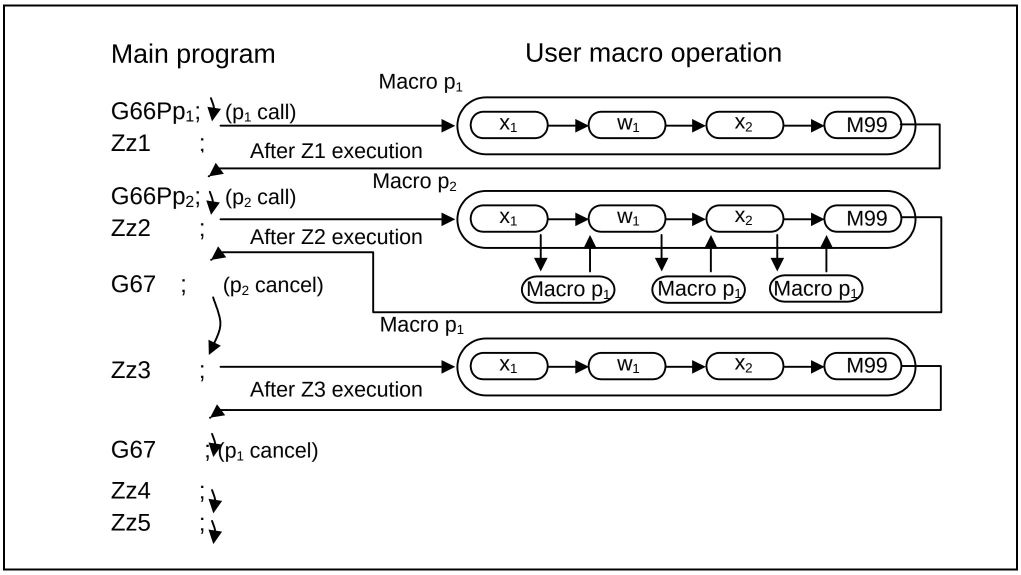
Macro call command nesting depth

Up to 4 nesting levels are available for macro subprogram calls based on simple call or modal call. The argument with a macro call instruction is valid only on the called macro level. Since the nesting depth for macro calls extends up to 4 levels, the argument can be used as a local variable for the program with each respective macro call.

(Note 1) When a G65, G66, G66.1 G code macro call or miscellaneous command macro call is conducted, this is regarded as nesting level 1 and the level of the local variables is also incremented by one.

(Note 2) The designated user macro subprogram is called every time the movement command is executed with modal call A. However, when the G66 command has been duplicated, the next user macro subprogram is called every time an axis is moved even with movement commands in the macro.
User macro subprograms are called in sequence from the subprogram commanded last.

(Example 1)



13.6.3 Variables

Function and purpose

Both the variable specifications and user macro specifications are required for the variables which are used with the user macros.
The offset amounts of the local, common and system variables among the variables for this NC unit are retained even when the unit's power is turned OFF. (Common variables can also be set to < Blank > in parameter "#1129 PwrVC1")

Use of multiple variable

When the user macro specifications apply, variable numbers can be turned into variables (multiple use of variables) or replaced by <formula>. Only one of the arithmetical (+, –, ×, ÷) operations can be conducted with <formula>.

(Example 1) Multiple use of variables

```
#1 = 10  #10 = 20  #20 = 30 ;          }  # [# [#1] ] = # [#10] from #1 = 10.
#5 = # [# [#1] ] ;                     }  # [#10] = #20 from #10 = 20.
                                          Therefore, #5 = #20 or #5 = 30.
```

```
#1 = 10  #10 = 20  #20 = 30  #5 = 1000 ;  }  # [# [#1] ] = # [#10] from #1 = 10.
# [# [#1]] = #5 ;                         }  # [#10] = #20 from #10 = 20.
                                             Therefore, #20 = #5 or #20 = 1000.
```

(Example 2) Replacing variable numbers with <formula>

```
#10 = 5 ;
# [#10 + 1] = 1000 ;        In which case, #6 = 1000.
# [#10 – 1] = –1000 ;       In which case, #4 = –1000.
# [#10∗3] = 100 ;           In which case, #15 = 100.
# [#10/2] = –100 ;          In which case, #3 = –100. (fraction rounded up)
```

Undefined variables

Variables applying with the user macro specifications such as variables which have not been used even once after the power was turned ON or local variables not quoted by the G65, G66 or G66.1 commands can be used as <Blank>. Also, variables can forcibly be set to <Blank>. Variable #0 is always used as the <Blank> variable and nothing can be defined in the left-side member.

(1) Arithmetic expressions

#1 = #0 ; .... #1 = <Blank>
#2 = #0 + 1 ; .... #2 = 1
#3 = 1 + #0 ; .... #3 = 1
#4 = #0∗10 ; .... #4 = 0
#5 = #0 + #0 ; .... #5 = 0

It should be borne in mind that <Blank> in an arithmetic expression is handled in the same way as 0.
<Blank> + <Blank> = 0
<Blank> + <Constant> = Constant
<Constant> + <Blank> = Constant

(2) Variable quotations

When undefined variable only are quoted, they are ignored up to the address.

When #1 = <Blank>
G0 X#1 Z1000 ; .... Equivalent to G0 Z1000 ;
G0 X#1 + 10 Z1000 ; .... Equivalent to G0 X10 Z1000 ;

(3) Conditional expressions

<Blank> differs from "0" only for EQ and NE. (#0 is <Blank>.)

When #101 = <Blank>	When #101 = 0
#101 EQ #0 <Blank> = <Blank> established	#101 EQ #0 0 = <Blank> not established
#101 NE 0 <Blank> ≠ 0 established	#101 NE 0 0 ≠ 0 not established
#101 GE #0 <Blank> ≥ 0 established	#101 GE #0 0 ≥ <Blank> established
#101 GT 0 <Blank> > 0 not established	#101 GT 0 0 > 0 not established
#101 LE #0 <Blank> ≤ <Blank> established	#101 LE #0 0 ≤ <Blank> established
#101 GT0 <Blank> < 0 not established	#101 LT0 0 < 0 not established

(Note 1) Only compare EQ and NE by integers. Use GE, GT, LE and LT for comparison when there are numbers below the decimal point.

13.6.4 Types of variables

Common variables

These are the variables used commonly from a random position.
The number of the common variables sets depends on the specifications.
Refer to the explanation about Variables for details.

Local variables (#1 to #33)

These can be defined as an <argument> when a macro subprogram is called or used locally within main programs and subprograms. They can be duplicated regardless of the relationship existing between macros (up to 4 levels).

G65 Pp_1 Ll_1 <argument> ;

p_1	Program number
l_1	Number of repetitions

The <argument> is assumed to be Aa1 Bb1 Cc1...... Zz1.
The following table shows the correspondences between the addresses designated by <argument> and the local variable numbers used in the user macro main body.

[Argument designation I]

Call command		Argument address	Local variable number
G65, G66	G66.1		
○	○	A	#1
○	○	B	#2
○	○	C	#3
○	○	D	#7
○	○	E	#8
○	○	F	#9
×	×*	G	#10
○	○	H	#11
○	○	I	#4
○	○	J	#5
○	○	K	#6
×	×*	L	#12
○	○	M	#13
×	×*	N	#14
×	×*	O	#15
×	×*	P	#16
○	○	Q	#17
○	○	R	#18
○	○	S	#19
○	○	T	#20
○	○	U	#21
○	○	V	#22
○	○	W	#23
○	○	X	#24
○	○	Y	#25
○	○	Z	#26
		–	#27
		–	#28
		–	#29
		–	#30
		–	#31
		–	#32
		–	#33

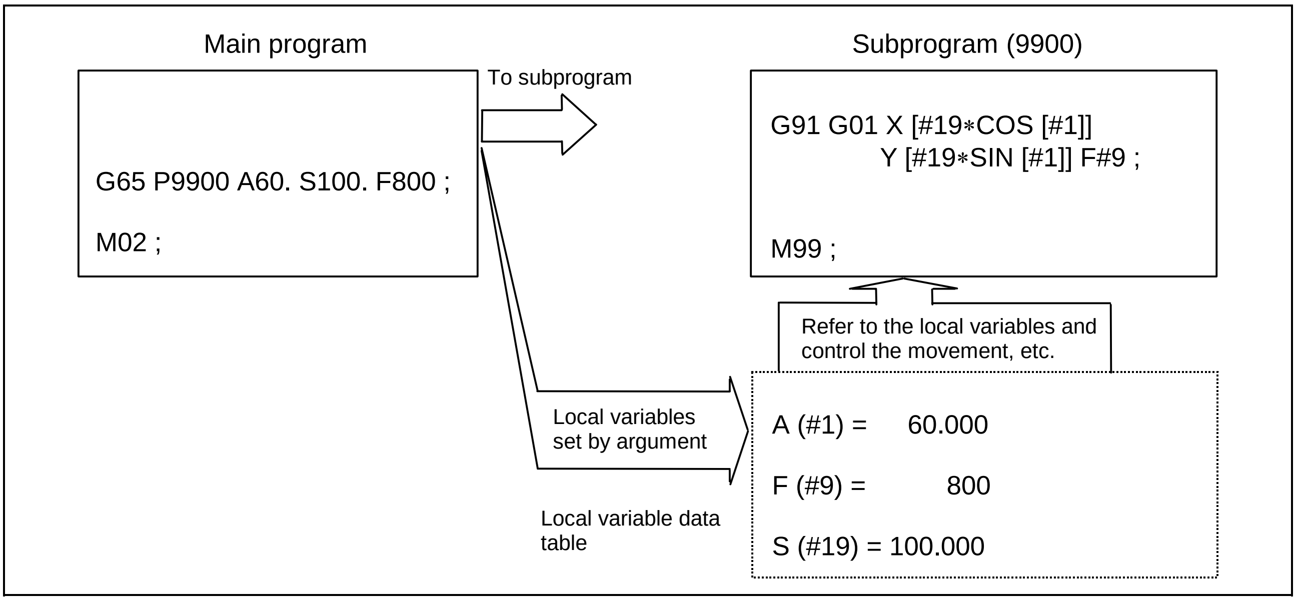
"×" in the above table denotes an argument address which cannot be used. However, provided that the G66.1 mode has been established, an argument address denoted by the asterisk can be added for use.
The hyphen (–) mark indicates that there is no corresponding address.

[Argument designation II]

Argument designation II address	Variable in macro
A	# 1
B	# 2
C	# 3
I1	# 4
J1	# 5
K1	# 6
I2	# 7
J2	# 8
K2	# 9
I3	#10
J3	#11
K3	#12
I4	#13
J4	#14
K4	#15
I5	#16
J5	#17
K5	#18
I6	#19
J6	#20
K6	#21
I7	#22
J7	#23
K7	#24
I8	#25
J8	#26
K8	#27
I9	#28
J9	#29
K9	#30
I10	#31
J10	#32
K10	#33

(Note 1) The numbers 1 to 10 added to I, J and K indicate the sequence of the commanded sets, and are not required in the actual command.

(1) Local variables in subprograms can be defined by means of the <argument> designation during macro call. (Local variables can be used freely in those subprograms.)

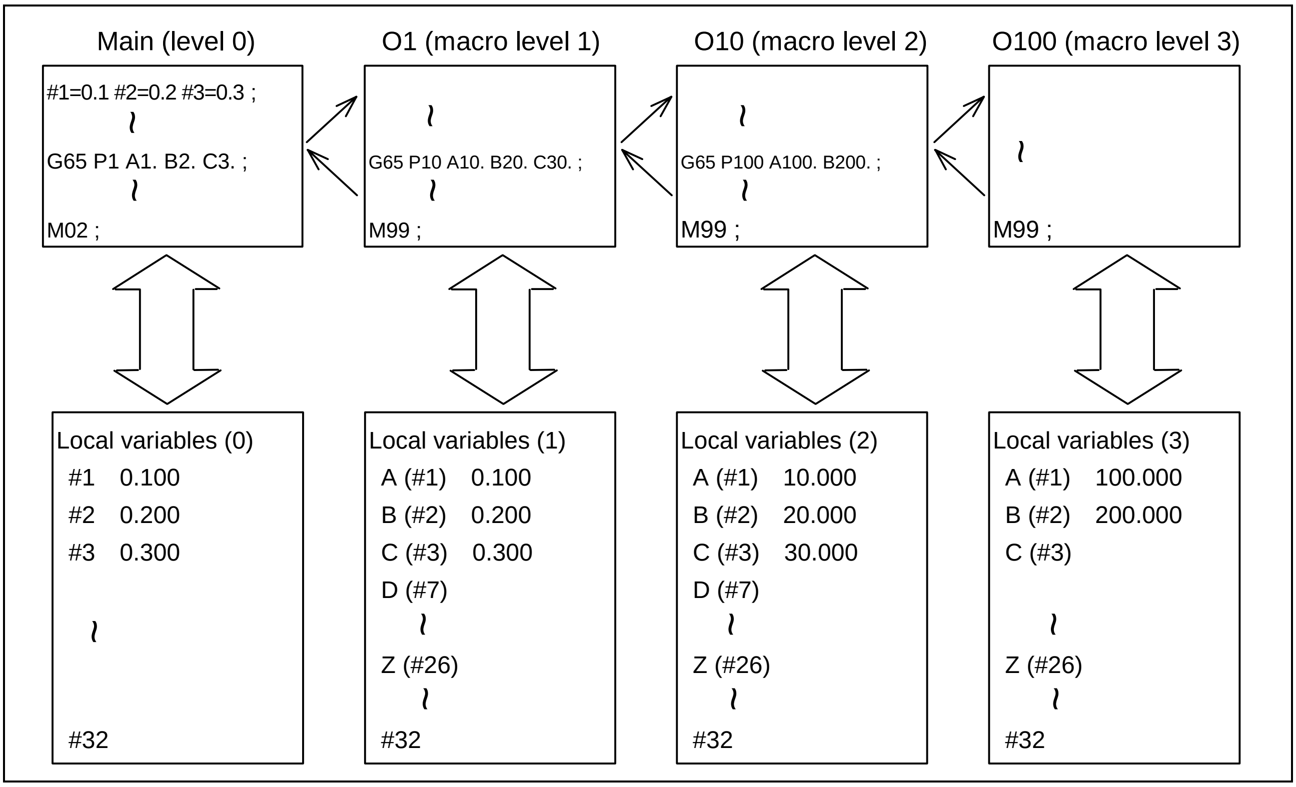

Main program
Subprogram (9900)
To subprogram
Refer to the local variables and control the movement, etc.
Local variables set by argument
Local variable data table

```
G65 P9900 A60. S100. F800 ;

M02 ;
```

```
G91 G01 X [#19∗COS [#1]]
        Y [#19∗SIN [#1]] F#9 ;

M99 ;
```

A (#1) = 60.000
F (#9) = 800
S (#19) = 100.000

(2) Local variables can be used independently on each of the macro calls levels (4 levels). Local variables are also provided independently for the main program (macro level 0). Arguments cannot be used for the level 0 local variables.



```
#1=0.1 #2=0.2 #3=0.3 ;
   ≀
G65 P1 A1. B2. C3. ;
   ≀
M02 ;
```

```
   ≀
G65 P10 A10. B20. C30. ;
   ≀
M99 ;
```

```
   ≀
G65 P100 A100. B200. ;
   ≀
M99 ;
```

```
   ≀
M99 ;
```

Local variables (0)	Local variables (1)	Local variables (2)	Local variables (3)
#1 0.100	A (#1) 0.100	A (#1) 10.000	A (#1) 100.000
#2 0.200	B (#2) 0.200	B (#2) 20.000	B (#2) 200.000
#3 0.300	C (#3) 0.300	C (#3) 30.000	C (#3)
	D (#7)	D (#7)	
≀	≀	≀	≀
	Z (#26)	Z (#26)	Z (#26)
	≀	≀	≀
#32	#32	#32	#32

The statuses of the local variables appear on the setting and display unit.
For details, refer to the Instruction Manual.

Macro interface inputs (#1000 ~ #1035, #1200 ~ #1295) : PLC → NC

The status of the interface input signals can be ascertained by reading out the values of variable numbers #1000 to #1035, #1200 to #1295. Available value which has been read out can be only one of 2 values: 1 or 0 (1: contact closed, 0: contact open). All the input signals from #1000 to #1031 can be read at once by reading out the value of variable number #1032. In the same manner, by reading the values for variable numbers #1033 to #1035, the input signals for #1200 to #1231, #1232 to #1263 and #1264 to #1295 can be read.
Variable numbers #1000 to #1035, #1200 to #1295 are for readout only, and nothing can be placed in the left side member of their operation formula.

The word "input" means input to the NC side.
To use the macro interface function by part system, set the bit selection parameter "#6454/bit0".
Refer to (2) for the signals provided for each part system.

(1) Macro interface common to part systems (input)

System variable	No. of points	Interface input signal	System variable	No. of points	Interface input signal
#1000	1	Register R24 bit 0	#1016	1	Register R25 bit 0
#1001	1	Register R24 bit 1	#1017	1	Register R25 bit 1
#1002	1	Register R24 bit 2	#1018	1	Register R25 bit 2
#1003	1	Register R24 bit 3	#1019	1	Register R25 bit 3
#1004	1	Register R24 bit 4	#1020	1	Register R25 bit 4
#1005	1	Register R24 bit 5	#1021	1	Register R25 bit 5
#1006	1	Register R24 bit 6	#1022	1	Register R25 bit 6
#1007	1	Register R24 bit 7	#1023	1	Register R25 bit 7
#1008	1	Register R24 bit 8	#1024	1	Register R25 bit 8
#1009	1	Register R24 bit 9	#1025	1	Register R25 bit 9
#1010	1	Register R24 bit 10	#1026	1	Register R25 bit 10
#1011	1	Register R24 bit 11	#1027	1	Register R25 bit 11
#1012	1	Register R24 bit 12	#1028	1	Register R25 bit 12
#1013	1	Register R24 bit 13	#1029	1	Register R25 bit 13
#1014	1	Register R24 bit 14	#1030	1	Register R25 bit 14
#1015	1	Register R24 bit 15	#1031	1	Register R25 bit 15

System variable	No. of points	Interface input signal
#1032	32	Register R24, R25
#1033	32	Register R26, R27
#1034	32	Register R28, R29
#1035	32	Register R30, R31

System variable	No. of points	Interface input signal	System variable	No. of points	Interface input signal
#1200	1	Register R26 bit 0	#1216	1	Register R27 bit 0
#1201	1	Register R26 bit 1	#1217	1	Register R27 bit 1
#1202	1	Register R26 bit 2	#1218	1	Register R27 bit 2
#1203	1	Register R26 bit 3	#1219	1	Register R27 bit 3
#1204	1	Register R26 bit 4	#1220	1	Register R27 bit 4
#1205	1	Register R26 bit 5	#1221	1	Register R27 bit 5
#1206	1	Register R26 bit 6	#1222	1	Register R27 bit 6
#1207	1	Register R26 bit 7	#1223	1	Register R27 bit 7
#1208	1	Register R26 bit 8	#1224	1	Register R27 bit 8
#1209	1	Register R26 bit 9	#1225	1	Register R27 bit 9
#1210	1	Register R26 bit 10	#1226	1	Register R27 bit 10
#1211	1	Register R26 bit 11	#1227	1	Register R27 bit 11
#1212	1	Register R26 bit 12	#1228	1	Register R27 bit 12
#1213	1	Register R26 bit 13	#1229	1	Register R27 bit 13
#1214	1	Register R26 bit 14	#1230	1	Register R27 bit 14
#1215	1	Register R26 bit 15	#1231	1	Register R27 bit 15

System variable	No. of points	Interface input signal	System variable	No. of points	Interface input signal
#1232	1	Register R28 bit 0	#1248	1	Register R29 bit 0
#1233	1	Register R28 bit 1	#1249	1	Register R29 bit 1
#1234	1	Register R28 bit 2	#1250	1	Register R29 bit 2
#1235	1	Register R28 bit 3	#1251	1	Register R29 bit 3
#1236	1	Register R28 bit 4	#1252	1	Register R29 bit 4
#1237	1	Register R28 bit 5	#1253	1	Register R29 bit 5
#1238	1	Register R28 bit 6	#1254	1	Register R29 bit 6
#1239	1	Register R28 bit 7	#1255	1	Register R29 bit 7
#1240	1	Register R28 bit 8	#1256	1	Register R29 bit 8
#1241	1	Register R28 bit 9	#1257	1	Register R29 bit 9
#1242	1	Register R28 bit 10	#1258	1	Register R29 bit 10
#1243	1	Register R28 bit 11	#1259	1	Register R29 bit 11
#1244	1	Register R28 bit 12	#1260	1	Register R29 bit 12
#1245	1	Register R28 bit 13	#1261	1	Register R29 bit 13
#1246	1	Register R28 bit 14	#1262	1	Register R29 bit 14
#1247	1	Register R28 bit 15	#1263	1	Register R29 bit 15

System variable	No. of points	Interface input signal	System variable	No. of points	Interface input signal
#1264	1	Register R30 bit 0	#1280	1	Register R31 bit 0
#1265	1	Register R30 bit 1	#1281	1	Register R31 bit 1
#1266	1	Register R30 bit 2	#1282	1	Register R31 bit 2
#1267	1	Register R30 bit 3	#1283	1	Register R31 bit 3
#1268	1	Register R30 bit 4	#1284	1	Register R31 bit 4
#1269	1	Register R30 bit 5	#1285	1	Register R31 bit 5
#1270	1	Register R30 bit 6	#1286	1	Register R31 bit 6
#1271	1	Register R30 bit 7	#1287	1	Register R31 bit 7
#1272	1	Register R30 bit 8	#1288	1	Register R31 bit 8
#1273	1	Register R30 bit 9	#1289	1	Register R31 bit 9
#1274	1	Register R30 bit 10	#1290	1	Register R31 bit 10
#1275	1	Register R30 bit 11	#1291	1	Register R31 bit 11
#1276	1	Register R30 bit 12	#1292	1	Register R31 bit 12
#1277	1	Register R30 bit 13	#1293	1	Register R31 bit 13
#1278	1	Register R30 bit 14	#1294	1	Register R31 bit 14
#1279	1	Register R30 bit 15	#1295	1	Register R31 bit 15

(2) Macro interface by part system (input)

(Note) As for the C64T system, the input/output signals used for this function are valid up to 3rd part system.

System variable	**No. of points**	**Interface input signal**						
		$1	**$2**	**$3**	**$4**	**$5**	**$6**	**$7**
		R970	R1070	R1170	R1270	R1370	R1470	R1570
#1000	1	bit0	bit0	bit0	bit0	bit0	bit0	bit0
#1001	1	bit1	bit1	bit1	bit1	bit1	bit1	bit1
#1002	1	bit2	bit2	bit2	bit2	bit2	bit2	bit2
#1003	1	bit3	bit3	bit3	bit3	bit3	bit3	bit3
#1004	1	bit4	bit4	bit4	bit4	bit4	bit4	bit4
#1005	1	bit5	bit5	bit5	bit5	bit5	bit5	bit5
#1006	1	bit6	bit6	bit6	bit6	bit6	bit6	bit6
#1007	1	bit7	bit7	bit7	bit7	bit7	bit7	bit7
#1008	1	bit8	bit8	bit8	bit8	bit8	bit8	bit8
#1009	1	bit9	bit9	bit9	bit9	bit9	bit9	bit9
#1010	1	bit10	bit10	bit10	bit10	bit10	bit10	bit10
#1011	1	bit11	bit11	bit11	bit11	bit11	bit11	bit11
#1012	1	bit12	bit12	bit12	bit12	bit12	bit12	bit12
#1013	1	bit13	bit13	bit13	bit13	bit13	bit13	bit13
#1014	1	bit14	bit14	bit14	bit14	bit14	bit14	bit14
#1015	1	bit15	bit15	bit15	bit15	bit15	bit15	bit15

System variable	**No. of points**	**Interface input signal**						
		$1	**$2**	**$3**	**$4**	**$5**	**$6**	**$7**
		R971	R1071	R1171	R1271	R1371	R1471	R1571
#1016	1	bit0	bit0	bit0	bit0	bit0	bit0	bit0
#1017	1	bit1	bit1	bit1	bit1	bit1	bit1	bit1
#1018	1	bit2	bit2	bit2	bit2	bit2	bit2	bit2
#1019	1	bit3	bit3	bit3	bit3	bit3	bit3	bit3
#1020	1	bit4	bit4	bit4	bit4	bit4	bit4	bit4
#1021	1	bit5	bit5	bit5	bit5	bit5	bit5	bit5
#1022	1	bit6	bit6	bit6	bit6	bit6	bit6	bit6
#1023	1	bit7	bit7	bit7	bit7	bit7	bit7	bit7
#1024	1	bit8	bit8	bit8	bit8	bit8	bit8	bit8
#1025	1	bit9	bit9	bit9	bit9	bit9	bit9	bit9
#1026	1	bit10	bit10	bit10	bit10	bit10	bit10	bit10
#1027	1	bit11	bit11	bit11	bit11	bit11	bit11	bit11
#1028	1	bit12	bit12	bit12	bit12	bit12	bit12	bit12
#1029	1	bit13	bit13	bit13	bit13	bit13	bit13	bit13
#1030	1	bit14	bit14	bit14	bit14	bit14	bit14	bit14
#1031	1	bit15	bit15	bit15	bit15	bit15	bit15	bit15

System variable	**No. of points**	**Interface input signal**						
		$1	**$2**	**$3**	**$4**	**$5**	**$6**	**$7**
#1032	32	R970, R971	R1070, R1071	R1170, R1171	R1270, R1271	R1370, R1371	R1470, R1471	R1570, R1571
#1033	32	R972, R973	R1072, R1073	R1172, R1173	R1272, R1273	R1372, R1373	R1472, R1473	R1572, R1573
#1034	32	R974, R975	R1074, R1075	R1174, R1175	R1274, R1275	R1374, R1375	R1474, R1475	R1574, R1575
#1035	32	R976, R977	R1076, R1077	R1176, R1177	R1276, R1277	R1376, R1377	R1476, R1477	R1576, R1577

Macro interface outputs (#1100 ~ #1135, #1300 ~ #1395) : NC → PLC

The interface output signals can be sent by substituting values in variable numbers #1100 to #1135, #1300 to #1395. An output signal can be only 0 or 1.
All the output signals from #1100 to #1131 can be sent at once by substituting a value in variable number #1132. In the same manner, by reading the values for variable numbers #1133 to #1135, the output signals for #1300 to #1331, #1332 to #1363 and #1364 to #1395 can be read. (2^0 ~ 2^{31})
The status of the writing and output signals can be read in order to offset the #1100 to #1135, #1300 to #1395 output signals. Output here refers to the output from the NC.

The word "output" means output from the NC side.
To use the macro interface function by part system, set the bit selection parameter "#6454/bit0".
Refer to (2) for the signals provided for each part system.

(1) Macro interface common to part systems (output)

System variable	No. of points	Interface input signal	System variable	No. of points	Interface input signal
#1100	1	Register R124 bit 0	#1116	1	Register R125 bit 0
#1101	1	Register R124 bit 1	#1117	1	Register R125 bit 1
#1102	1	Register R124 bit 2	#1118	1	Register R125 bit 2
#1103	1	Register R124 bit 3	#1119	1	Register R125 bit 3
#1104	1	Register R124 bit 4	#1120	1	Register R125 bit 4
#1105	1	Register R124 bit 5	#1121	1	Register R125 bit 5
#1106	1	Register R124 bit 6	#1122	1	Register R125 bit 6
#1107	1	Register R124 bit 7	#1123	1	Register R125 bit 7
#1108	1	Register R124 bit 8	#1124	1	Register R125 bit 8
#1109	1	Register R124 bit 9	#1125	1	Register R125 bit 9
#1110	1	Register R124 bit 10	#1126	1	Register R125 bit 10
#1111	1	Register R124 bit 11	#1127	1	Register R125 bit 11
#1112	1	Register R124 bit 12	#1128	1	Register R125 bit 12
#1113	1	Register R124 bit 13	#1129	1	Register R125 bit 13
#1114	1	Register R124 bit 14	#1130	1	Register R125 bit 14
#1115	1	Register R124 bit 15	#1131	1	Register R125 bit 15

System variable	No. of points	Interface input signal
#1132	32	Register R124, R125
#1133	32	Register R126, R127
#1134	32	Register R128, R129
#1135	32	Register R130, R131

(Note 1) The last values of the system variables #1100 to #1135, #1300 to #1395 sent are retained as 1 or 0.
(They are not cleared even with resetting.)

(Note 2) The following applies when any number except 1 or 0 is substituted into #1100 to #1131, #1300 to #1395.
<Blank> is treated as 0.
Any number except 0 and <Blank> is treated as 1.
Any value less than 0.00000001 is indefinite.

System variable	No. of points	Interface input signal	System variable	No. of points	Interface input signal
#1300	1	Register R126 bit 0	#1316	1	Register R127 bit 0
#1301	1	Register R126 bit 1	#1317	1	Register R127 bit 1
#1302	1	Register R126 bit 2	#1318	1	Register R127 bit 2
#1303	1	Register R126 bit 3	#1319	1	Register R127 bit 3
#1304	1	Register R126 bit 4	#1320	1	Register R127 bit 4
#1305	1	Register R126 bit 5	#1321	1	Register R127 bit 5
#1306	1	Register R126 bit 6	#1322	1	Register R127 bit 6
#1307	1	Register R126 bit 7	#1323	1	Register R127 bit 7
#1308	1	Register R126 bit 8	#1324	1	Register R127 bit 8
#1309	1	Register R126 bit 9	#1325	1	Register R127 bit 9
#1310	1	Register R126 bit 10	#1326	1	Register R127 bit 10
#1311	1	Register R126 bit 11	#1327	1	Register R127 bit 11
#1312	1	Register R126 bit 12	#1328	1	Register R127 bit 12
#1313	1	Register R126 bit 13	#1329	1	Register R127 bit 13
#1314	1	Register R126 bit 14	#1330	1	Register R127 bit 14
#1315	1	Register R126 bit 15	#1331	1	Register R127 bit 15

System variable	No. of points	Interface input signal	System variable	No. of points	Interface input signal
#1332	1	Register R128 bit 0	#1348	1	Register R129 bit 0
#1333	1	Register R128 bit 1	#1349	1	Register R129 bit 1
#1334	1	Register R128 bit 2	#1350	1	Register R129 bit 2
#1335	1	Register R128 bit 3	#1351	1	Register R129 bit 3
#1336	1	Register R128 bit 4	#1352	1	Register R129 bit 4
#1337	1	Register R128 bit 5	#1353	1	Register R129 bit 5
#1338	1	Register R128 bit 6	#1354	1	Register R129 bit 6
#1339	1	Register R128 bit 7	#1355	1	Register R129 bit 7
#1340	1	Register R128 bit 8	#1356	1	Register R129 bit 8
#1341	1	Register R128 bit 9	#1357	1	Register R129 bit 9
#1342	1	Register R128 bit 10	#1358	1	Register R129 bit 10
#1343	1	Register R128 bit 11	#1359	1	Register R129 bit 11
#1344	1	Register R128 bit 12	#1360	1	Register R129 bit 12
#1345	1	Register R128 bit 13	#1361	1	Register R129 bit 13
#1346	1	Register R128 bit 14	#1362	1	Register R129 bit 14
#1347	1	Register R128 bit 15	#1363	1	Register R129 bit 15

System variable	No. of points	Interface input signal	System variable	No. of points	Interface input signal
#1364	1	Register R130 bit 0	#1380	1	Register R131 bit 0
#1365	1	Register R130 bit 1	#1381	1	Register R131 bit 1
#1366	1	Register R130 bit 2	#1382	1	Register R131 bit 2
#1367	1	Register R130 bit 3	#1383	1	Register R131 bit 3
#1368	1	Register R130 bit 4	#1384	1	Register R131 bit 4
#1369	1	Register R130 bit 5	#1385	1	Register R131 bit 5
#1370	1	Register R130 bit 6	#1386	1	Register R131 bit 6
#1371	1	Register R130 bit 7	#1387	1	Register R131 bit 7
#1372	1	Register R130 bit 8	#1388	1	Register R131 bit 8
#1373	1	Register R130 bit 9	#1389	1	Register R131 bit 9
#1374	1	Register R130 bit 10	#1390	1	Register R131 bit 10
#1375	1	Register R130 bit 11	#1391	1	Register R131 bit 11
#1376	1	Register R130 bit 12	#1392	1	Register R131 bit 12
#1377	1	Register R130 bit 13	#1393	1	Register R131 bit 13
#1378	1	Register R130 bit 14	#1394	1	Register R131 bit 14
#1379	1	Register R130 bit 15	#1395	1	Register R131 bit 15

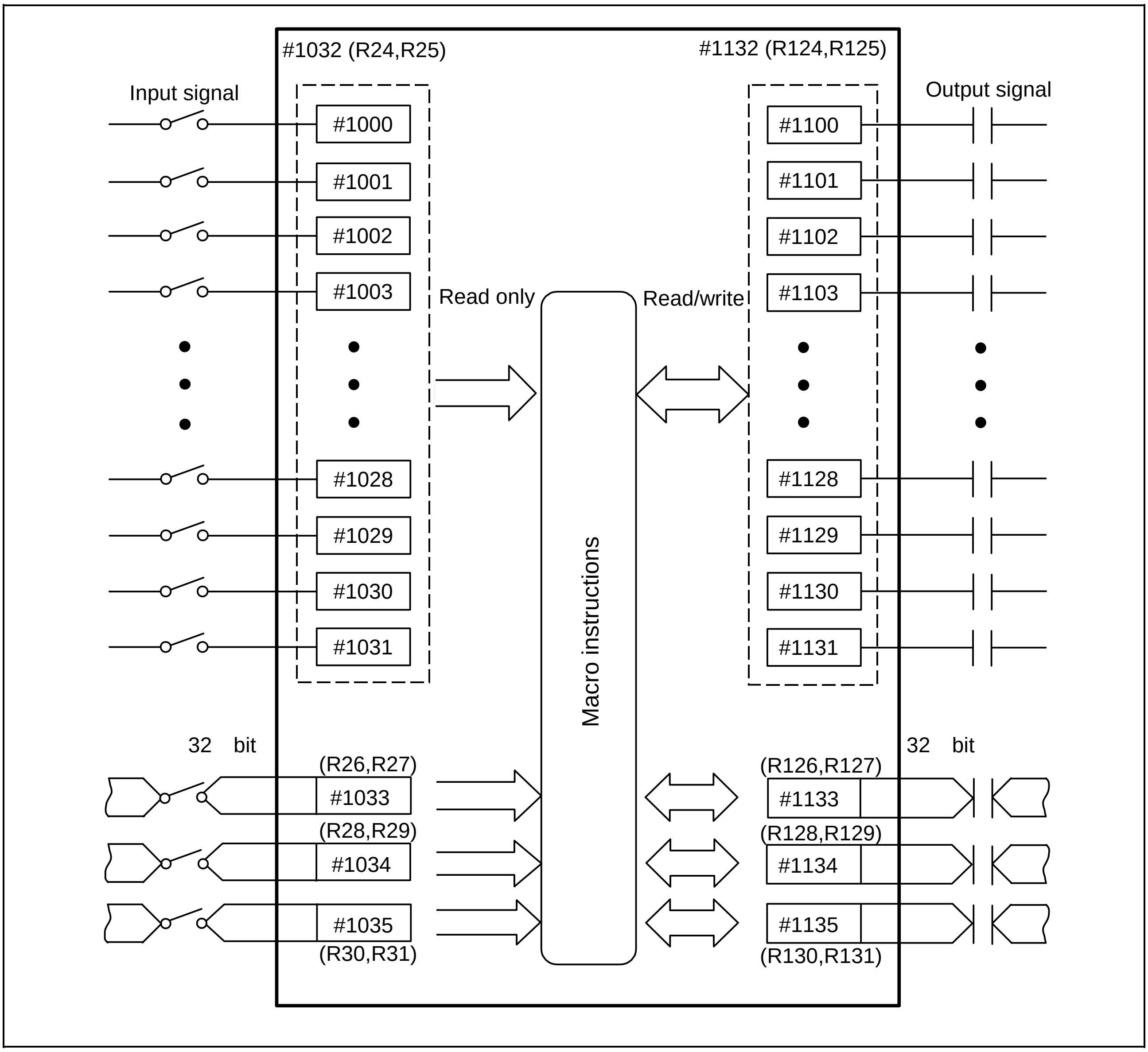
(2) Macro interface by part system (output)

(Note) As for the C64T system, the input/output signals used for this function are valid up to 3rd part system.

System variable	No. of points	Interface output signal						
		$1	$2	$3	$4	$5	$6	$7
		R270	R370	R470	R570	R670	R770	R870
#1100	1	bit0	bit0	bit0	bit0	bit0	bit0	bit0
#1101	1	bit1	bit1	bit1	bit1	bit1	bit1	bit1
#1102	1	bit2	bit2	bit2	bit2	bit2	bit2	bit2
#1103	1	bit3	bit3	bit3	bit3	bit3	bit3	bit3
#1104	1	bit4	bit4	bit4	bit4	bit4	bit4	bit4
#1105	1	bit5	bit5	bit5	bit5	bit5	bit5	bit5
#1106	1	bit6	bit6	bit6	bit6	bit6	bit6	bit6
#1107	1	bit7	bit7	bit7	bit7	bit7	bit7	bit7
#1108	1	bit8	bit8	bit8	bit8	bit8	bit8	bit8
#1109	1	bit9	bit9	bit9	bit9	bit9	bit9	bit9
#1110	1	bit10	bit10	bit10	bit10	bit10	bit10	bit10
#1111	1	bit11	bit11	bit11	bit11	bit11	bit11	bit11
#1112	1	bit12	bit12	bit12	bit12	bit12	bit12	bit12
#1113	1	bit13	bit13	bit13	bit13	bit13	bit13	bit13
#1114	1	bit14	bit14	bit14	bit14	bit14	bit14	bit14
#1115	1	bit15	bit15	bit15	bit15	bit15	bit15	bit15

System variable	No. of points	Interface output signal						
		$1	$2	$3	$4	$5	$6	$7
		R271	R371	R471	R571	R671	R771	R871
#1116	1	bit0	bit0	bit0	bit0	bit0	bit0	bit0
#1117	1	bit1	bit1	bit1	bit1	bit1	bit1	bit1
#1118	1	bit2	bit2	bit2	bit2	bit2	bit2	bit2
#1119	1	bit3	bit3	bit3	bit3	bit3	bit3	bit3
#1120	1	bit4	bit4	bit4	bit4	bit4	bit4	bit4
#1121	1	bit5	bit5	bit5	bit5	bit5	bit5	bit5
#1122	1	bit6	bit6	bit6	bit6	bit6	bit6	bit6
#1123	1	bit7	bit7	bit7	bit7	bit7	bit7	bit7
#1124	1	bit8	bit8	bit8	bit8	bit8	bit8	bit8
#1125	1	bit9	bit9	bit9	bit9	bit9	bit9	bit9
#1126	1	bit10	bit10	bit10	bit10	bit10	bit10	bit10
#1127	1	bit11	bit11	bit11	bit11	bit11	bit11	bit11
#1128	1	bit12	bit12	bit12	bit12	bit12	bit12	bit12
#1129	1	bit13	bit13	bit13	bit13	bit13	bit13	bit13
#1130	1	bit14	bit14	bit14	bit14	bit14	bit14	bit14
#1131	1	bit15	bit15	bit15	bit15	bit15	bit15	bit15

System variable	No. of points	Interface output signal						
		$1	$2	$3	$4	$5	$6	$7
#1132	32	R270, R271	R370, R371	R470, R471	R570, R571	R670, R671	R770, R771	R870, R871
#1133	32	R272, R273	R372, R373	R472, R473	R572, R573	R672, R673	R772, R773	R872, R873
#1134	32	R274, R275	R374, R375	R474, R475	R574, R575	R674, R675	R774, R775	R874, R875
#1135	32	R276, R277	R376, R377	R476, R477	R576, R577	R676, R677	R776, R777	R876, R877


#1032 (R24,R25)
#1132 (R124,R125)
Input signal
Output signal
#1000
#1001
#1002
#1003
#1028
#1029
#1030
#1031
#1100
#1101
#1102
#1103
#1128
#1129
#1130
#1131
Read only
Read/write
Macro instructions
32 bit
32 bit
(R26,R27)
#1033
(R28,R29)
#1034
#1035
(R30,R31)
(R126,R127)
#1133
(R128,R129)
#1134
#1135
(R130,R131)

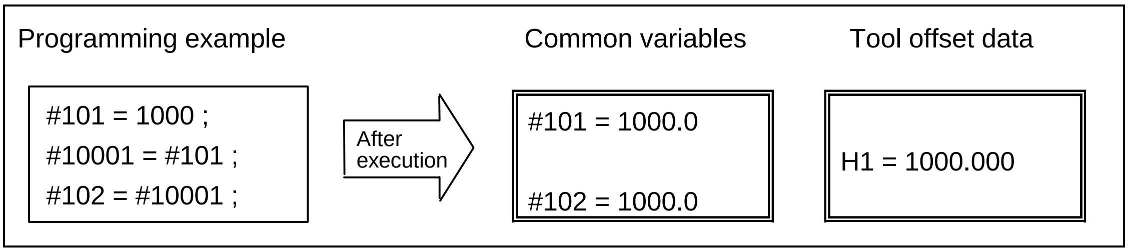
Tool offset

This is used to change the variable number of the user macro variable's tool offset shape compensation and wear compensation.

The variable No. of the address #2000 X, Z and R compensation amounts is changed according to the value set in the "#1120 TofVal (change macro variable)" parameter.

Variable number range			Details
#1120 TofVal=0,1	**#1120 TofVal=0**	**#1120 TofVal=1**	
#10001 to #10000+n	#2001 to #2000+n	#2701 to #2700+n	X shape compensation amount
#11001 to #11000+n	#2701 to #2700+n	#2001 to #2000+n	X wear compensation amount
#12001 to #12000+n	–		3rd axis shape compensation amount
#13001 to #13000+n	–		3rd axis wear compensation amount
#14001 to #14000+n	#2101 to #2100+n	#2801 to #2800+n	Z shape compensation amount
#15001 to #15000+n	#2801 to #2800+n	#2101 to #2100+n	Z wear compensation amount
#16001 to #16000+n	#2201 to #2200+n	#2901 to #2900+n	R shape compensation amount
#17001 to #17000+n	#2901 to #2900+n	#2201 to #2200+n	R wear compensation amount
#18001 to #18000+n	#2301 to #2300+n		Nose compensation amount

Tool data can be read and values substituted using the variable numbers.
Either the numbers in the #10000 order or #2000 order can be used.
The last 3 digits of the variable numbers correspond to the tool offset number.
The tool offset data are configured as data with a decimal point in the same way as for other variables.
Consequently, this decimal point must be commanded when data below the decimal point is to be entered.


Programming example

```
#101 = 1000 ;
#10001 = #101 ;
#102 = #10001 ;
```

Common variables

```
#101 = 1000.0

#102 = 1000.0
```

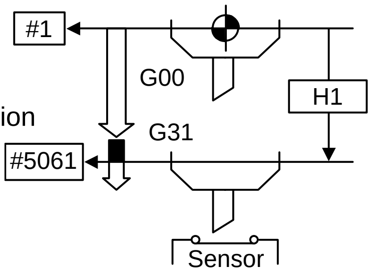
Tool offset data

```
H1 = 1000.000
```

(Example 1) Calculation and tool offset data setting

```
G28 X0 T0101 ;
M06 ;
#1 = #5001 ;
G00 X–200. ;
G31 X–50. F100 ;
#10001 = #5061 – #1 ;

       ≀
```

Zero point return
Tool change (T0101)
Start point storage
Rapid traverse to safe position
Skip measuring
Measurement distance calculation and tool offset data setting



(Note 1) In (Example 1) no consideration is given to the delay in the skip sensor signal.
#5001 is the X-axis start point position and #5061 is the X-axis skip coordinates, and indicated is the position at which the skip signal is input while G31 is being executed.

Workpiece coordinate system offset

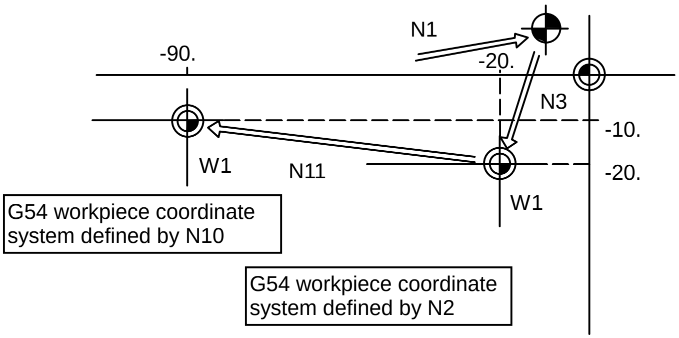
By using variable numbers #5201 to #532n, it is possible to read out the workpiece coordinate system offset data or to substitute values.

(Note) The number of axes which can be controlled differs according to the specifications. The last digit in the variable number corresponds to the control axis number.

Axis No. Coordinate name	1st axis	2nd axis	3rd axis	4th axis	• •	nth axis	Remarks
External workpiece offset	#5201	#5202	#5203	#5204	• •	#520n	External workpiece offset specifications are required.
G54	#5221	#5222	#5223	#5224	• •	#522n	Workpiece coordinate system offset specifications are required.
G55	#5241	#5242	#5243	#5244	• •	#524n	
G56	#5261	#5262	#5263	#5264	• •	#526n	
G57	#5281	#5282	#5283	#5284	• •	#528n	
G58	#5301	#5302	#5303	#5304	• •	#530n	
G59	#5321	#5322	#5323	#5324	• •	#532n	

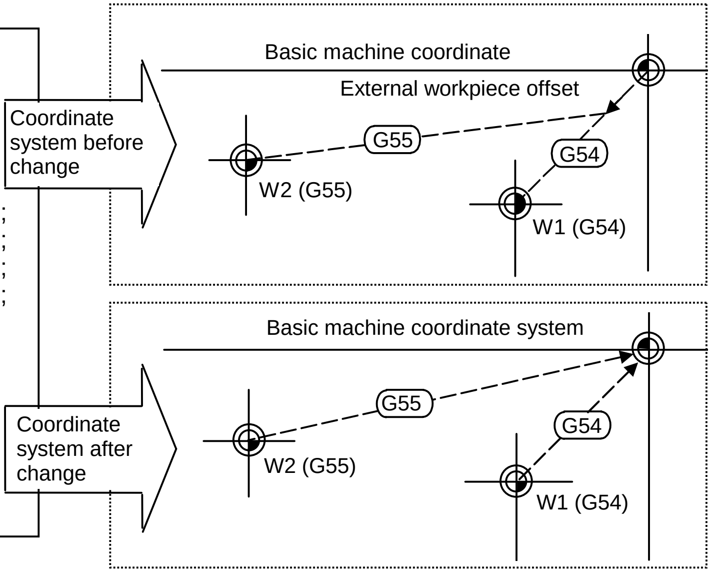
(Example 1)

```
N1 G28 X0 Z0 ;
N2 #5221 = –20. #5223 = –20. ;
N3 G00 G54 X0 Z0 ;
      ≀
N10 #5221 = –10. #5223 = –90. ;
N11 G00 G54 X020 ;
      ≀
M02 ;
```


N1
-90.
-20.
N3
-10.
-20.
W1
N11
W1
G54 workpiece coordinate system defined by N10
G54 workpiece coordinate system defined by N2

(Example 2)

```
          ≀
N100   #5221 = #5221 + #5201 ;
       #5222 = #5222 + #5202 ;
       #5241 = #5241 + #5201 ;
       #5242 = #5242 + #5202 ;
       #5201 = 0  #5202 = 0 ;
          ≀
```


Coordinate system before change
Basic machine coordinate
External workpiece offset
G55
G54
W2 (G55)
W1 (G54)
Coordinate system after change
Basic machine coordinate system
G55
G54
W2 (G55)
W1 (G54)

This is an example where the eternal workpiece offset values are added to the workpiece coordinate (G54, G55) system offset values without changing the position of the workpiece coordinate systems.

NC alarm (#3000)

The NC unit can be forcibly set to the alarm state by using variable number #3000.

Format

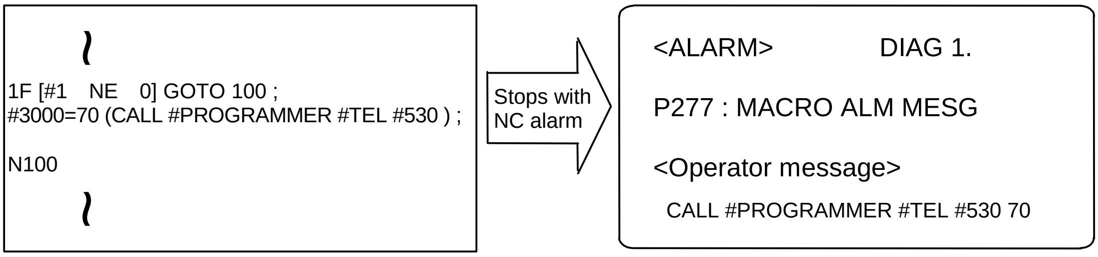
#3000 = 70 (CALL #PROGRAMMER #TEL #530) ;

70	Alarm number
CALL #PROGRAMMER #TEL #530	Alarm message

Any alarm number from 1 to 9999 can be specified.
The alarm message must be less than 31 characters long.

The "P277: MACRO ALM MESG" appears in the <ALARM> column on "DIAG 1." screen while the alarm number and alarm message "70: (CALL #PROGRAMMER #TEL #530)" is indicated in the <Operator massage>.

Example of program (alarm when #1 = 0)



```
        ≀
1F [#1    NE    0] GOTO 100 ;
#3000=70 (CALL #PROGRAMMER #TEL #530 ) ;

N100
        ≀
```

```
<ALARM>              DIAG 1.

P277 : MACRO ALM MESG

<Operator message>
  CALL #PROGRAMMER #TEL #530 70
```

(Note 1) Alarm number 0 is not displayed and any number exceeding 9999 cannot be indicated.

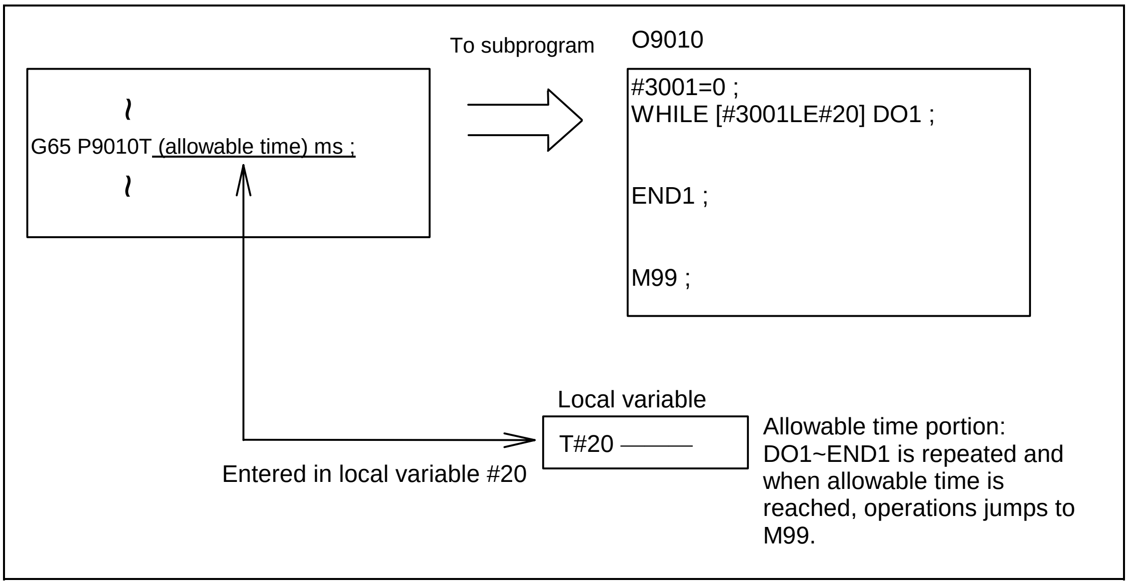
(Note 2) The characters following the first alphabet letter in the right member is treated as the alarm message. Therefore, a number cannot be designated as the first character of an alarm manage. It is recommended that the alarm messages be enclosed in round parentheses.

Integrating time (#3001, #3002)

The integrating time can be read when the power is turned ON or automatic start or values can be substituted by using variable numbers #3001 and #3002.

Type	Variable number	Unit	Contents when power is switched on	Initialization of contents	Count conditions
Power ON	3001	1ms	Same as when power is turned OFF	Value substituted for variable	At all times while power is ON
Automatic start	3002				In-automatic start

The integrating time returns to zero in about 2.44×10^{11} ms (approximately 7.7 years).



```
G65 P9010T (allowable time) ms ;
```

```
#3001=0 ;
WHILE [#3001LE#20] DO1 ;

END1 ;

M99 ;
```

```
T#20
```

Allowable time portion: DO1~END1 is repeated and when allowable time is reached, operations jumps to M99.

Suppression of single block stop and miscellaneous function finish signal waiting

By substituting the values below in variable number #3003, it is possible to suppress single block stop in the subsequent blocks or to advance to the next block without waiting for the miscellaneous function (M, S, T, B) finish (FIN) signal.

#3003	Single block stop	Miscellaneous function finish signal
0	Not suppressed	Wait
1	Suppressed	Wait
2	Not suppressed	No wait
3	Suppressed	No wait

(Note 1) #3003 is cleared to zero by resetting.

Feed hold, feedrate override, G09 valid/invalid

By substituting the values below in variable number #3004, it is possible to make the feed hold, feedrate override and G09 functions either valid or invalid in the subsequent blocks.

#3004 contents (value)	**Bit 0**	**Bit 1**	**Bit 2**
	Feed hold	**Feedrate override**	**G09 check**
0	Valid	Valid	Valid
1	Invalid	Valid	Valid
2	Valid	Invalid	Valid
3	Invalid	Invalid	Valid
4	Valid	Valid	Invalid
5	Invalid	Valid	Invalid
6	Valid	Invalid	Invalid
7	Invalid	Invalid	Invalid

(Note 1) #3004 is cleared to zero by resetting.

(Note 2) The functions are valid when the above bits are 0 and invalid when they are 1.

Message display and stop

By using variable number #3006, the execution is stopped after the previous block has been executed and, if message display data have been commanded, then the corresponding message will be indicated on the operator message area.

Format

```
#3006=1 (TAKE FIVE) ;

TAKE FIVE                Message
```

The message should not be longer than 31 characters and it should be enclosed within round parentheses.

Mirror image

By reading variable number #3007, it is possible to ascertain the status of mirror image at a particular point in time for each axis.
The axes correspond to the bits of #3007. When the bits are 0, it means that the mirror image function is invalid; when they are 1, it means that it is valid.

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
nth axis													4	3	2	1

G command modals

Using variable numbers #4001 to #4021, it is possible to read the G modal commands which have been issued up to the block immediately before.
Similarly, it is possible to read the medals in the block being executed with variable numbers #4201 to #4221.

Variable number		Function
Pre-read block	Execution block	
#4001	#4201	Interpolation mode: G00:0, G01:1, G02:2, G03:3, G33:33, G34:34
#4002	#4202	Plane selection: G17:17, G18:18, G19:19
#4003	#4203	Absolute/incremental: G90:90, G91:91
#4004	#4204	Barrier check: G22:22, G23:23
#4005	#4205	Feed designation: G94:94, G95:95
#4006	#4206	Inch/metric: G20:20, G21:21
#4007	#4207	Tool nose R compensation: G40:40, G41:41, G42:42, G46:46
#4008	#4208	No variable No.
#4009	#4209	Fixed cycle: G80:80, G70~79:70~79, G83~G85:83~85, G83.2:83.2, G87~G89:87~89
#4010	#4210	Return level: G98:98, G99:99
#4011	#4211	
#4012	#4212	Workpiece coordinate system: G54~G59:54~59
#4013	#4213	Acceleration/deceleration:G61~G64:61~64, G61.1:61.1
#4014	#4214	Macro modal call: G66:66, G66.1:66.1, G67:67
#4015	#4215	
#4016	#4216	No variable No.
#4017	#4217	Constant surface speed control: G96:96, G97:97
#4018	#4218	Balance cut: G14:14, G15:15
#4019	#4219	
#4020	#4220	
#4021	#4221	

(Example)

```
G29 X0 Z0 ;
G00 X150. Z200 ;
G65 P300 G02 W–30. K–15. F1000 ;
M02 ;
O300
#1 = #4001 ; → Group 01 G modal (pre-read) #1 = 2.0
#2 = #4201 ; → Group 01 G modal (now being executed) #2 = 0.0
G#1 W#24 ;
M99 ;
%
```

Other modals

Using variable numbers #4101 to #4120, it is possible to read the modal commands assigned up to the block immediately before.
Similarly, it is possible to read the medals in the block being executed with variable numbers #4301 to #4320.

Variable number		Modal information
Pre-read	Execution	
#4101	#4301	
#4102	#4302	
#4103	#4303	
#4104	#4304	
#4105	#4305	
#4106	#4306	
#4107	#4307	
#4108	#4308	
#4109	#4309	Feedrate F
#4110	#4310	

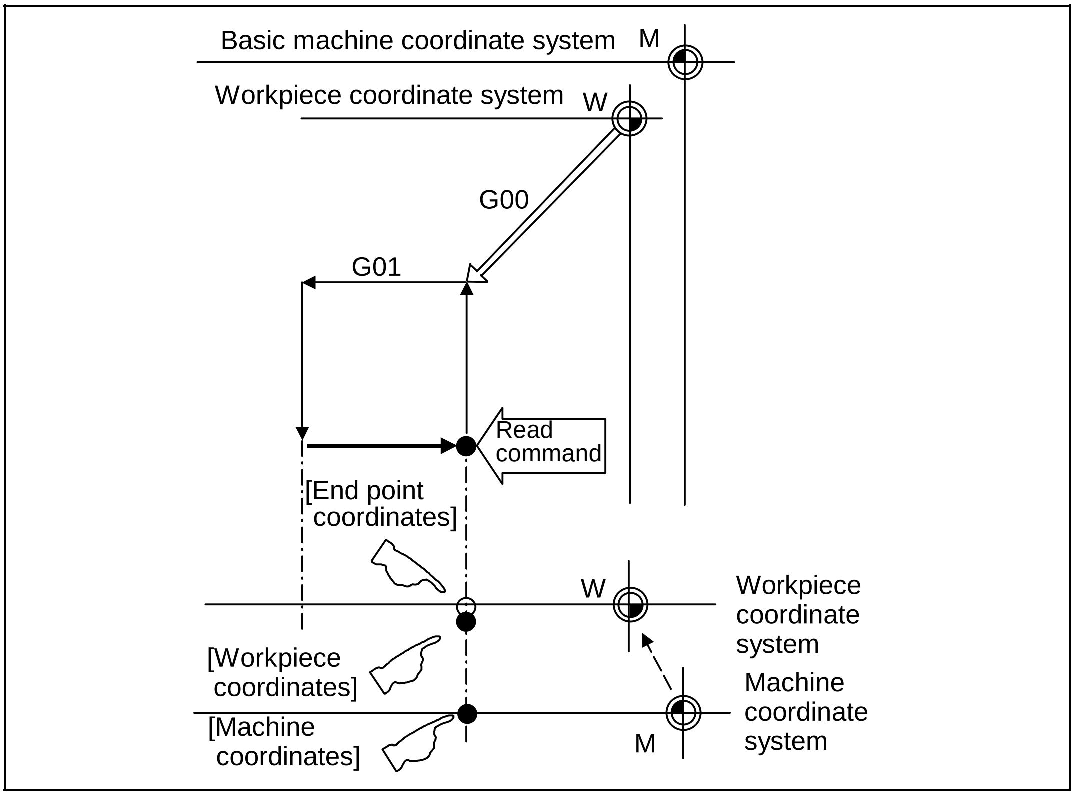
Variable number		Modal information
Pre-read	Execution	
#4111	#4311	
#4112	#4312	
#4113	#4313	Miscellaneous function M
#4114	#4314	Sequence number N
#4115	#4315	Program number O
#4116	#4316	
#4117	#4317	
#4118	#4318	
#4119	#4319	Spindle function S
#4120	#4320	Tool function T

Position information

Using variable numbers #5001 to #5104, it is possible to read the servo deviation amounts, tool position offset amount, skip coordinates, work coordinates, machine coordinates and end point coordinates in the block immediately before.

Position information Axis No.	End point coordinate of block immediately before	Machine coordinate	Workpiece coordinate	Skip coordinate	Tool position offset amount	Servo deviation amount
1	#5001	#5021	#5041	#5061	#5081	#5101
2	#5002	#5022	#5042	#5062	#5082	#5102
3	#5003	#5023	#5043	#5063	#5083	#5203
4	#5004	#5024	#5044	#5064	#5084	#5104
:	:	:	:	:	:	:
n	#5000+n	#5020+n	#5040+n	#5060+n	#5080+n	#5100+n
Remarks (reading during movement)	Yes	No	No	Yes	No	Yes

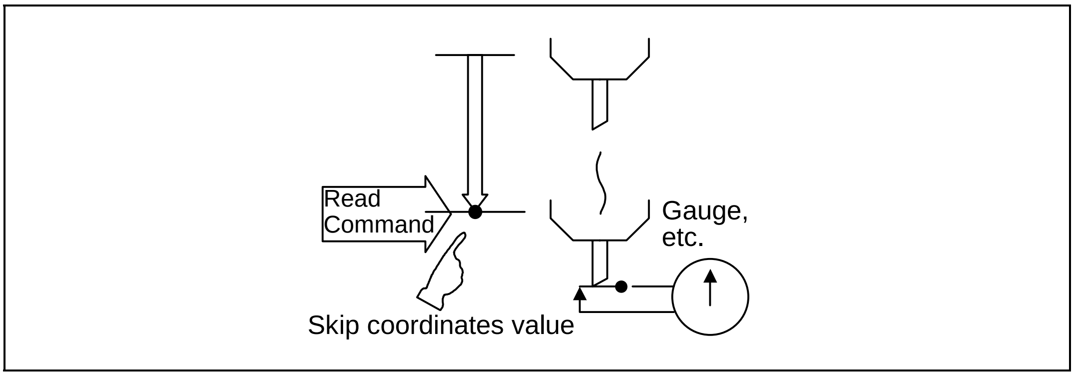
(Note) The number of axes which can be controlled differs according to the NC specifications.
The last digit of the variable number corresponds to the control axis number.


Basic machine coordinate system
M
Workpiece coordinate system
W
G00
G01
Read command
[End point coordinates]
W
Workpiece coordinate system
[Workpiece coordinates]
Machine coordinate system
[Machine coordinates]
M

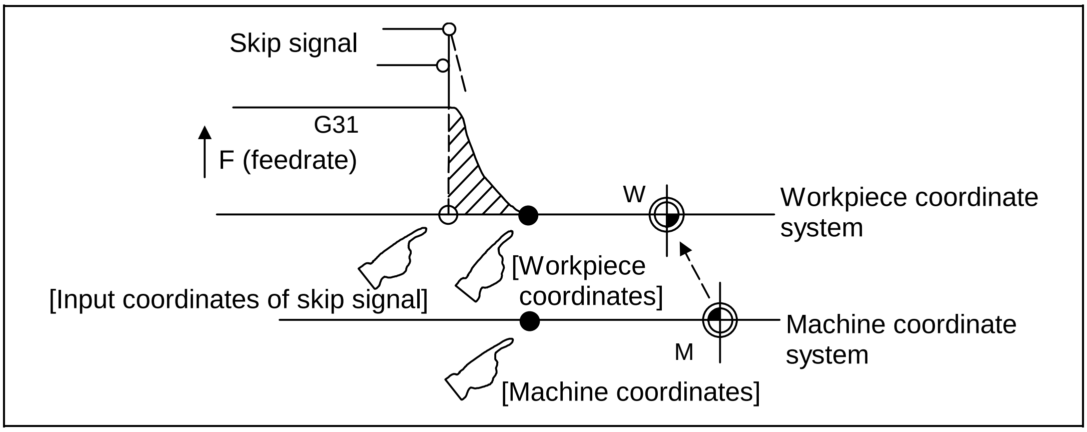
(1) The positions of the end point coordinates and skip coordinates are positions in the workpiece coordinate system.

(2) The end point coordinates, skip coordinates and servo deviation amounts can be read even during movement. However, it must first be checked that movement has stopped before reading the machine coordinates and workpiece coordinates.

(3) The position where the skip signal is turned ON in the G31 block is indicated for the skip coordinates. The end point position is indicated when the skip signal has not been turned ON. (For further details, refer to the section on tool length measurement.)



(4) The tool nose position where the tool offset and other such factors are not considered is indicated as the end point position. The tool reference point position with consideration given to tool offset is indicated for the machine coordinates, workpiece coordinates and skip coordinates.


Skip signal
G31
F (feedrate)
W
Workpiece coordinate system
[Workpiece coordinates]
[Input coordinates of skip signal]
Machine coordinate system
M
[Machine coordinates]

For "●", check stop and then proceed to read.
For "○", reading is possible during movement.

The position of the skip signal input coordinate value is the position in the workpiece coordinate system. The coordinate value in variable numbers #5061 to #5064 memorize the moments when the skip input signal during movement was input and so they can be read at any subsequent time.
For further details, reference should be made to the section on the skip function.

Variable name setting and quotation

Any name (variable name) can be given to common variables #500 to #519. It must be composed of not more than 7 alphanumerics and it must begin with a letter. Do not use "#" in the variable name. An alarm will result at execution when this sign is used.

Format

SETVNn [NAME1, NAME2,…….] ;

n	Head number of variable which assigns name
NAME1	#n name (variable name)
NAME2	#n + 1 name (variable name)

Variable names are separated by a comma (,).

Detailed description

(1) Once variable names have been set, they will not be cleared even when the power is turned OFF.

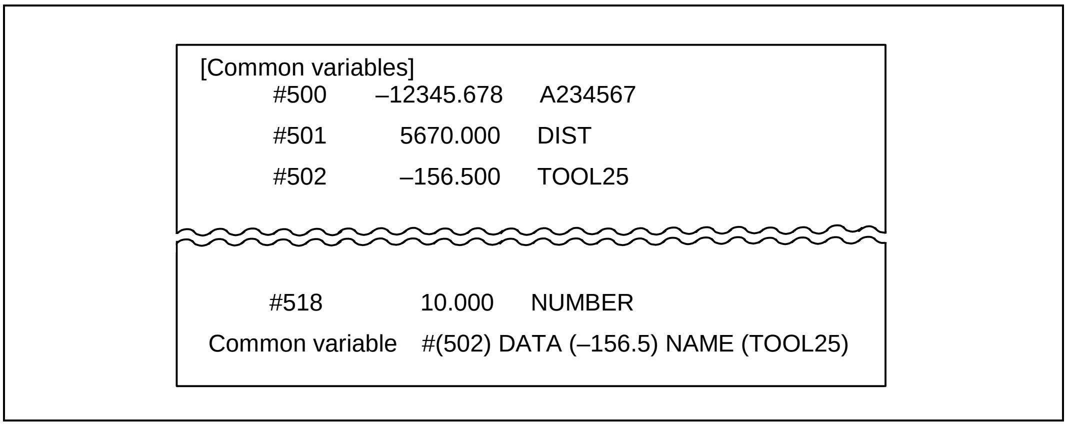
(2) The variables in the program are quoted as variable names. In cases like this, the variables should be enclosed in square parentheses.

(Example 1) G01X [#POINT1] ;

(3) The variable numbers, data and variable names appear on the CRT screen of the setting and display unit.

(Example 2)

Program... SETVN500 [A234567, DIST, TOOL25] ;



```
[Common variables]
      #500    –12345.678    A234567
      #501       5670.000   DIST
      #502       –156.500   TOOL25

      #518         10.000   NUMBER
 Common variable   #(502) DATA (–156.5) NAME (TOOL25)
```

(Note) Do not use characters (SIN, COS, etc.) predetermined by the NC for use as operation commands at the head of the variable name.

Workpiece coordinate shift amount

The workpiece coordinate system shift amount can be read using variables #2501 and #2601.
By substituting a value in these variables, the workpiece coordinate system shift amount can be changed.

Axis No.	Workpiece coordinate system shift amount
1	#2501
2	#2601

Number of workpiece machining times

The number of workpiece machining times can be read using variables #3901 and #3902.
By substituting a value in these variables, the number of workpiece machining times can be changed.

Type	Variable No.	Data setting range
Number of workpiece machining times	#3901	0 to 999999
Maximum workpiece value	#3902	

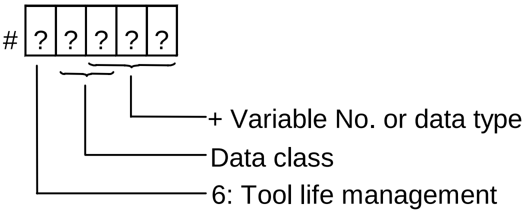
(Note) Always input the number of workpiece machining times as a positive value.

Tool life management

(1) Definition of variable numbers

(a) Designation of group No.
#60000
The tool life management data group No. to be read with #60001 to #64700 is designated by substituting a value in this variable. If a group No. is not designated, the data of the group registered first is read. This is valid until reset.

(b) Tool life management system variable No. (Read)
#60001 to #64700



(c) Details of data classification

Data class	M System	L System	Remarks
00	For control	For control	Refer to following types
05	Group No.	Group No.	Refer to registration No.
10	Tool No.	Tool No.	Refer to registration No.
15	Tool data flag	Method	Refer to registration No.
20	Tool status	Status	Refer to registration No.
25	Life data	Life time/No. of times	Refer to registration No.
30	Usage data	Usage time/No. of times	Refer to registration No.
35	Tool length compensation data	–	Refer to registration No.
40	Tool radius compensation data	–	Refer to registration No.
45	Auxiliary data	–	Refer to registration No.

The group No., L System method, and life data are common for the group.

(d) Registration No.

M System	1 to 200
L System	1 to 16

(e) Data type

Type	M System	L System	Remarks
1	Number of registered tools	Number of registered tools	
2	Life current value	Life current value	
3	Tool selected No.	Tool selected No.	
4	Number of remaining registered tools	Number of remaining registered tools	
5	Signal being executed	Signal being executed	
6	Cutting time cumulative value (minute)	Cutting time cumulative value (minute)	
7	Life end signal	Life end signal	
8	Life prediction signal	Life prediction signal	

Variable No.	Item	Type	Details	Data range
60001	Number of registered tools	System common	Total number of tools registered in each group.	0 to 80
60002	Life current value	For each group (Desig-nate group No. #60000)	Usage time/No. of uses of tool being used. Usage data of tool being used (If tool uses several compensation numbers, the total of the usage data for each compensation No.).	0 to 999999 min 0 to 999999 times
60003	Tool selected No.		Registration No. of tool being used. Designated group's selection tool registration No. (If tool is not selected, the first tool of ST:1, or if ST:1 is not used, the first tool of ST:0. When all tools have reached their lives, the last tool).	0 to 16
60004	Remaining number of registered tools		Total number of "usable" tools in the group. Number of tools registered in designated group for which ST is 0: Not used.	0 to 16
60005	Signal being executed		"1" when this group is used in program being executed. "1" when tool in designated group is selected.	0/1
60006	Cutting time cumulative value (minute)		Indicates the time that this group is used in the program being executed.	
60007	Life end signal		"1" when lives of all tools in this group have been reached. "1" when all tools registered in designated group reach lives.	0/1
60008	Life prediction signal		"1" when new tool is selected with next command in this group. "1" when there is a tool for which ST is 0: Not used in the tools registered the designated group, and there are no tools for which ST is 1: Tools in use.	0/1

Variable No.	Item	Type	Details	Data range
60500 +***	Group No.	Each group/ registration No. (Group No. #60000/ registration No. *** is designated.) Note the group No., method and life are common for the groups.	This group's No.	1 to 9999
61000 +***	Tool No.		Tool's No. and compensation No. Tool No. + compensation No. (When tool No. = 22 and compensation No. = 01, 2201=899H)	0 to 9999
61500 +***	Method		Whether to management this group's life as time or No. of uses. 0: Time, 1: No. of uses	0/1
62000 +***	Status		Tool usage state 0: Not used tool 1: Tool being used 2: Normal life tool 3: Tool skip tool	0 to 3
62500 +***	Life time/No. of uses		This group's tool life value	0 to 999999 min 0 to 999999 times
63000 +***	Usage time/No. of uses			0 to 999999 min 0 to 999999 times
63500 +***	–			
64000 +***	–			
64500 +***	–			

Example of program

(1) **Normal commands**

```
#101 = #60001 ; ...... Reads the number of registered tools.
#102 = #60002 ; ...... Reads the life current value.
#103 = #60003 ; ...... Reads the tool selection No.
#60000 = 10 ; .......... Designates the group No. of the life data to be
                          read.
#104 = #60004 ; ...... Reads the remaining number of registered   ⎫
                          tools in group 10.                        ⎪
#105 = #60005 ; ...... Reads the signal being executed in group 10. ⎬ Designated
#111 = #61001 ; ...... Reads the group 10, #1 tool No.              ⎪ program No. is
#112 = #62001 ; ...... Reads the group 10, #1 status.               ⎪ valid until reset.
#113 = #61002 ; ...... Reads the group 10, #2 tool No.              ⎭
%
```

(2) **When group No. is not designated**

```
#104 = #60004 ; ...... Reads the remaining number of registered tools in the group registered
                          first.
#111 = #61001 ; ...... Reads the #1 tool No. in the group registered first.
%
```

(3) **When non-registered group No. is designated (Group 9999 does not exist.)**

```
#60000 = 9999 ; ...... Designates the group No.
#104 = #60004 ; ...... #104 = –1.
```

(4) **When registration No. not used is designated (Group 10 has 15 tools)**

```
#60000 = 10 ; .......... Designates the group No.
#111 = #61016 ; ...... #101 = –1.
```

(5) **When registration No. out of the specifications is designated**

```
#6000 = 10 ;
#111 = #61017 ; ...... Program error (P241)
```

(6) **When tool life management data is registered with G10 command after group No. is designated**

```
#60000 = 10 ; .......... Designates the group No.
G10 L3 ; ................... Starts the life management data registration.  ⎫
P10 LLn NNn ; ........ 10 is the group No., Ln is the life per tool,          ⎪
                          Nn is the method.                                   ⎪
TTn ; ........................ Tn is the tool No.                             ⎬ The group 10 life data
    :                                                                         ⎪ is registered.
G11 ; ....................... Registers the group 10 data with the G10        ⎪
 ................................. command.                                   ⎭
#111 = #61001 ; ...... Reads the group 10, #1 tool No.
G10 L3 ; ................... Starts the life management data registration.  ⎫
P1 LLn NNn ; .......... 1 is the group No., Ln is the life per tool,          ⎪
 ................................. Nn is the method.                          ⎪
TTn ; ........................ Tn is the tool No.                             ⎪
    :                                                                         ⎬ The life data other than
G11 ; ........................ Registers the life data with the G10 command.  ⎪ group 10 is registered.
 ................................. (The registered data is deleted.)          ⎪
#111 = 61001 ; ........ Group 10 does not exist. #111 = –1.                   ⎭
```

Precautions

(1) If the tool life management system variable is commanded without designating a group No., the data of the group registered at the head of the registered data will be read.

(2) If a non-registered group No. is designated and the tool life management system variable is commanded, "–1" will be read as the data.

(3) If an unused registration No. tool life management system variable is commanded, "–1" will be read as the data.

(4) Once commanded, the group No. is valid until NC reset.

13.6.5 Operation commands

A variety of operations can be performed between variables.

Command format

#i = <formula> ;

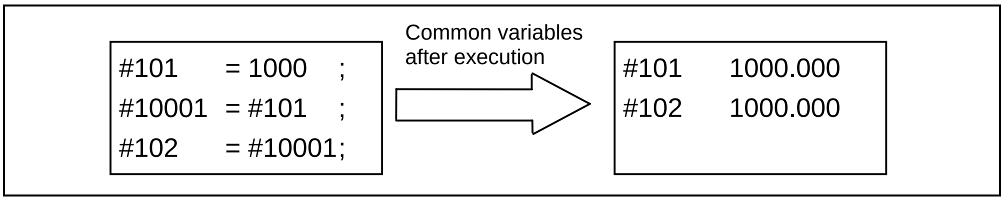
<Formula> is a combination of constants, variables, functions and operators.
Constants can be used instead of #j and #k below.

(1) Definition and substitution of variables	#i = #j	Definition, substitution
(2) Addition operation	#i = #j + #k	Addition
	#i = #j – #k	Subtraction
	#i = #j OR #k	Logical sum (at every bit of 32 bits)
	#i = #j XOR #k	Exclusive OR (at every bit of 32 bits)
(3) Multiplication operation	#i = #j ∗ #k	Multiplication
	#i = #j / #k	Division
	#i = #j MOD #k	Remainder
	#i = #j AND #k	Logical product (at every bit of 32 bits)
(4) Functions	#i = SIN [#k]	Sine
	#i = COS [#k]	Cosine
	#i = TAN [#k]	Tangent tan θ uses sinθ/cosθ.
	#i = ATAN [#k]	Arctangent (ATAN or ATN may be used)
	#i = ACOS [#k]	Arccosine
	#i = SQRT [#k]	Square root (SQRT or SQR may be used)
	#i = ABS [#k]	Absolute value
	#i = BIN [#k]	Conversion from BCD to BIN
	#i = BCD [#k]	Conversion from BIN to BCD
	#i = ROUND [#k]	Rounding off (ROUND or RND may be used)
	#i = FIX [#k]	Discard fractions less than 1
	#i = FUP [#k]	Add for fractions less than 1
	#i = LN [#k]	Natural logarithm
	#i = EXP [#k]	Exponent with e (=2.718...) as bottom

(Note 1) A value without a decimal point is basically treats as a value with a decimal point at the end (1 = 1.000).

(Note 2) Offset amounts from #10001 and workpiece coordinate system offset values from #5201 are handled as data with a decimal point. Consequently, data with a decimal point will be produced even when data without a decimal point have been defined in the variable numbers.

(Example)



```
#101     = 1000    ;
#10001   = #101    ;
#102     = #10001;
```

Common variables after execution

```
#101     1000.000
#102     1000.000
```

(Note 3) The <formula> after a function must be enclosed in the square parentheses.

Sequence of operations

(1) The sequence of the operations (1) to (3) is, respectively, the functions followed by the multiplication operation followed in turn by the addition operation.

$$\#101 = \underbrace{\#111 + \underbrace{\#112 * \underbrace{\text{SIN } [\#113]}_{\text{(1) Function}}}_{\text{(2) Multiplication operation}}}_{\text{(3) Addition operation}}$$

(2) The part to be given priority in the operation sequence should be enclosed in brackets. Up to 5 pairs of such brackets including those for the functions may be used.

$$\#101=\text{SQRT } \underbrace{[\ \underbrace{[\ \underbrace{[\#111 - \#112]}_{\text{First pair of brackets}} * \text{SIN } [\#113] + [\#114]}_{\text{Second pair of brackets}} * \#115]}_{\text{Third pair of brackets}}\ ;$$

Examples of operation commands

(1)	Main program and argument designation	G65 P100 A10 B20. ; #101=100.000 #102=200.000 ;	#1 10.000 #2 20.000 #101 100.000 #102 200.000
(2)	Definition and substitution (=)	#1=1000 #2=1000. #3=#101 #4=#102 #5=#5041	#1 1000.000 #2 1000.000 #3 100.000 From common variables #4 200.000 #5 –10.000 From offset amount
(3)	Addition and subtraction (+, –)	#11=#1+1000 #12=#2–50. #13=#101+#1 #14=#5041–3. #15=#5041+#102	#11 2000.000 #12 950.000 #13 1100.000 #14 –13.000 #15 190.000
(4)	Logical sum (OR)	#3=100 #4=#3 OR 14	#3 = 01100100 14 = 00001110 #4 = 01101110 = 110
(5)	Exclusive OR (XOR)	#3=100 #4=#3 XOR 14	#3 = 01100100 14 = 00001110 #4 = 01101010 = 106
(6)	Multiplication and division (∗, /)	#21=100∗100 #22=100.∗100 #23=100∗100 #24=100.∗100. #25=100/100 #26=100./100 #27=100/100. #28=100./100. #29=5041∗#101 #30=5041/#102	#21 10000.000 #22 10000.000 #23 10000.000 #24 10000.000 #25 1.000 #26 1.000 #27 1.000 #28 1.000 #29 –1000.000 #30 –0.050
(7)	Remainder (MOD)	#31=#19 MOD #20	#19/#20 = 48/9 = 5 with 3 over
(8)	Logical product (AND)	#9=100 #10=#9 AND 15	#9 = 01100100 15 = 00001111 #10 = 00000100 = 4

(9) Sin (SIN)	#501 = SIN [60] #502 = SIN [60.] #503 = 1000∗SIN [60] #504 = 1000∗SIN [60.] #505 = 1000.∗SIN [60] #506 = 1000.∗SIN [60.] **(Note)** SIN [60] is equivalent to SIN [60.]	#501 0.860 #502 0.860 #503 866.025 #504 866.025 #505 866.025 #506 866.025
(10) Cosine (COS)	#541 = COS [45] #542 = COS [45.] #543 = 1000∗COS [45] #544 = 1000∗COS [45.] #545 = 1000.∗COS [45] #546 = 1000.∗COS [45.] **(Note)** COS [45] is equivalent to COS [45.]	#541 0.707 #542 0.707 #543 707.107 #544 707.107 #545 707.107 #546 707.107
(11) Tangent (TAN)	#551 = TAN [60] #552 = TAN [60.] #553 = 1000∗TAN [60] #554 = 1000∗TAN [60.] #555 = 1000.∗TAN [60] #556 = 1000.∗TAN [60.] **(Note)** TAN [60] is equivalent to TAN [60.]	#551 1.732 #552 1.732 #553 1732.051 #554 1732.051 #555 1732.051 #556 1732.051
(12) Arctangent (ATAN or ATN)	#561 = ATAN [173205/100000] #562 = ATAN [173205/100.] #563 = ATAN [173.205/100000] #564 = ATAN [173.205/100.] #565 = ATAN [1.732]	#561 60.000 #562 60.000 #563 60.000 #564 60.000 #565 59.999
(13) Arccosine (ACOS)	#521 = ACOS [100./141.421] #522 = ACOS [100./141.421] #523 = ACOS [1000./1414.213] #524 = ACOS [10./14.142] #525 = ACOS [0.707]	#521 45.000 #522 45.000 #523 45.000 #524 44.999 #525 45.009
(14) Square root (SQR or SQRT)	#571 = SQRT [1000] #572 = SQRT [1000.] #573 = SQRT [10. ∗10. +20. ∗20.] #574 = SQRT [#14∗#14 + #15∗#15] **(Note)** In order to increase the accuracy, proceed with the operation inside parentheses.	#571 31.623 #572 31.623 #573 22.361 #574 190.444
(15) Absolute value (ABS)	#576 = –1000 #577 = ABS [#576] #3 = 70. #4 = –50. #580 = ABS [#4 – #3]	#576 –1000.000 #577 1000.000 #580 120.000
(16) BIN, BCD	#1 = 100 #11 = BIN [#1] #12 = BCD [#1]	 #11 64 #12 256

(17)	Rounding off (ROUND or RND)	#21 = ROUND [14/3] #22 = ROUND [14./3] #23 = ROUND [14/3.] #24 = ROUND [14./3.] #25 = ROUND [–14/3] #26 = ROUND [–14./3] #27 = ROUND [–14/3.] #28 = ROUND [–14./3.]	#21 5 #22 5 #23 5 #24 5 #25 –5 #26 –5 #27 –5 #28 –5
(18)	Discarding fractions below decimal point (FIX)	#21 = FIX [14/3] #22 = FIX [14./3] #23 = FIX [14/3.] #24 = FIX [14./3.] #25 = FIX [–14/3] #26 = FIX [–14./3] #27 = FIX [–14/3.] #28 = FIX [–14./3.]	#21 4.000 #22 4.000 #23 4.000 #24 4.000 #25 –4.000 #26 –4.000 #27 –4.000 #28 –4.000
(19)	Adding fractions less than 1 (FUP)	#21 = FUP [14/3] #22 = FUP [14./3] #23 = FUP [14/3.] #24 = FUP [14./3.] #25 = FUP [–14/3] #26 = FUP [–14./3] #27 = FUP [–14/3.] #28 = FUP [–14./3.]	#21 5.000 #22 5.000 #23 5.000 #24 5.000 #25 –5.000 #26 –5.000 #27 –5.000 #28 –5.000
(20)	Natural logarithms (LN)	#101 = LN [5] #102 = LN [0.5] #103 = LN [–5]	#101 1.609 #102 –0.693 Error "P282"
(21)	Exponents (EXP)	#104 = EXP [2] #105 = EXP [1] #106 = EXP [–2]	#104 7.389 #105 2.718 #106 0.135

Operation accuracy

As shown in the following table errors will be generated when performing operations once and these errors will be accumulated by repeating the operations.

Operation format	Average error	Maximum error	Type of error

a = b + c
a = b – c
	2.33×10^{-10}	5.32×10^{-10}	Min. $\left\|\frac{\varepsilon}{b}\right\|$, $\left\|\frac{\varepsilon}{c}\right\|$

a = b∗c	1.55×10^{-10}	4.66×10^{-10}	Relative error $\left\|\frac{\varepsilon}{a}\right\|$
a = b/c	4.66×10^{-10}	1.86×10^{-9}	
a = b	1.24×10^{-9}	3.73×10^{-9}	

a = SIN [b]
a = COS [b]
	5.0×10^{-9}	1.0×10^{-8}	Absolute error
			$\|\varepsilon\|$°

a = ATAN [b/c]	1.8×10^{-6}	3.6×10^{-6}	

(Note) SIN/COS is calculated for the function TAN.

Notes on reduced accuracy

(1) Addition and subtraction

It should be noted that when absolute values are used subtractively in addition or subtraction, the relative error cannot be kept below 10.
For instance, it is assumed that the real value produced as the operation calculation result of #10 and #20 are as follows (these value cannot be substituted directly):

```
#10 = 2345678988888.888
#20 = 2345678901234.567
```

Performing #10 – #20 will not produce #10 – #20 = 87654.321. There are 8 decimal digits in the variables and so the values of #10 and #20 will be as follows (strictly speaking, the internal values will differ somewhat from the value below because they are binary numbers):

```
#10 = 2345679000000.000
#20 = 2345678900000.000
```

Consequently, #10 – #20 = 100000.000 will generate a large error.

(2) Logical relation

EQ, NE, GT, LT, GE and LE are basically the same as addition and subtraction and so care should be taken with errors. For instance, to determine whether or not #10 and #20 are equal in the above example:

```
IF [#10 EQ #20]
```

It is not always possible to provide proper evaluation because of the above-mentioned error.
Therefore when the error is evaluated as in the following expression:

```
IF [ABS [#10 – #20] LT 200000]
```

and the difference between #10 and #20 falls within the designated range error, both values should be considered equal.

(3) Trigonometric functions

Absolute errors are guaranteed with trigonometric functions but since the relative error is not under 10, care should be taken when dividing or multiplying after having used a trigonometric function.

13.6.6 Control commands

The flow of programs can be controlled by IF ~ GOTO ~ and WHILE ~ DO ~.

Branching

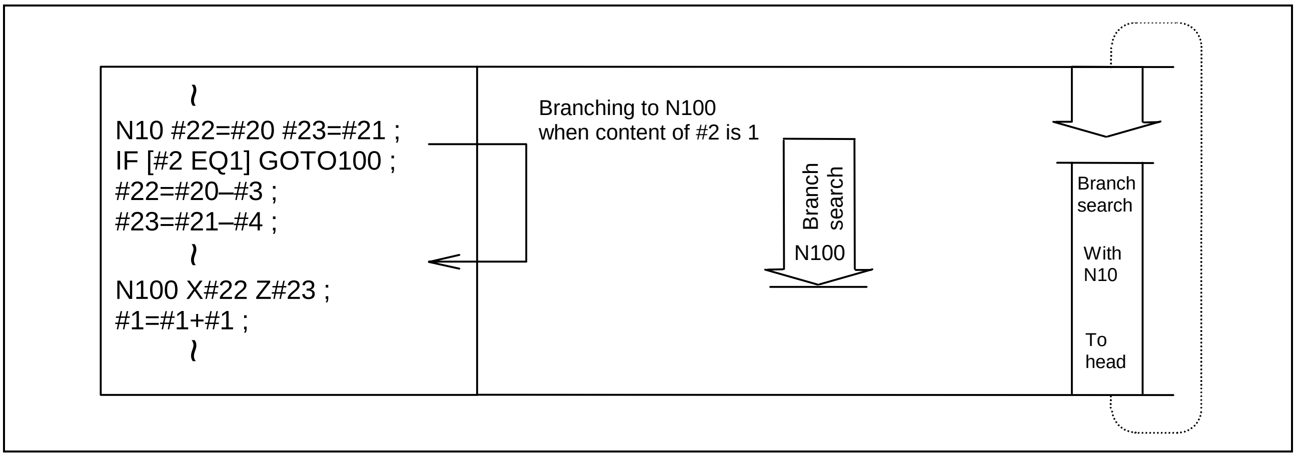
Format

IF [conditional expression] GOTO n ; (where n = sequence number in the program)

When the condition is satisfied, control branches to "n" and when it is not satisfied, the next block is executed.
IF [conditional expression] can be omitted and, when it is, control passes to "n" unconditionally.
The following types of [conditional expressions] are available.

#i EQ #j	= When #i and #j are equal
#i NE #j	≠ When #i and #j are not equal
#i GT #j	> When #i is greater than #j
#i LT #j	< When #i is less than #j
#i GE #j	≥ When #i is #j or more
#i LE #j	≤ When #i is #j or less

"n" of "GOTO n" must always be in the same program. Program error (P231) will result if it is not. A formula or variable can be used instead of #i, #j and "n".
In the block with sequence number "n" which will be executed after a "GOTO n" command, the sequence number Nn must always be at the head of the block. Otherwise, program error (P231) will result.
If "/" is at the head of the block and Nn follows, control can be branched to the sequence number.



```
        ≀
N10 #22=#20 #23=#21 ;
IF [#2 EQ1] GOTO100 ;
#22=#20–#3 ;
#23=#21–#4 ;
        ≀
N100 X#22 Z#23 ;
#1=#1+#1 ;
        ≀
```

(Note 1) When the sequence number of the branch destination is searched, the search is conducted up to the end of the program (% code) from the block following "IF….. ;" and if it is not found, it is conducted up to the block before "IF ..... ;". Therefore, branch searches in the opposite direction to the program flow will take longer to execute compared with branch searches in the forward direction.

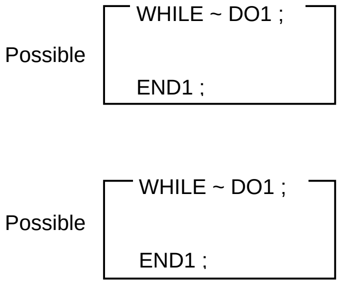
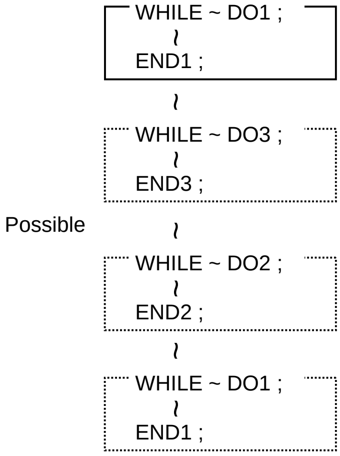
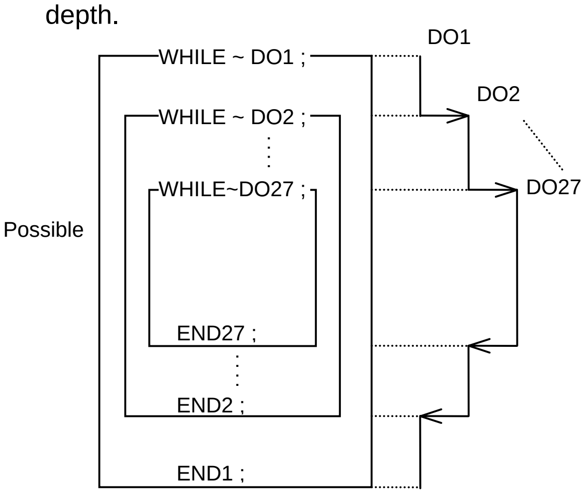
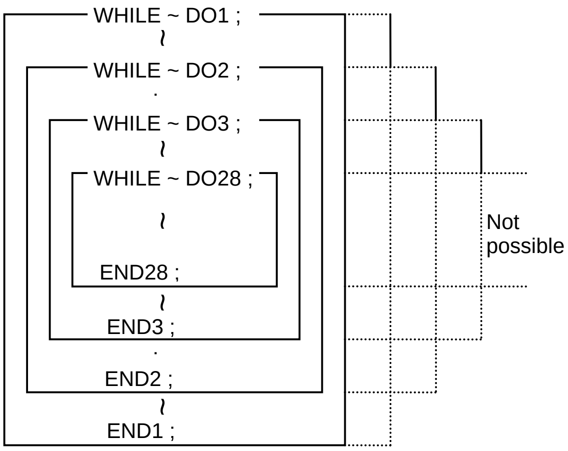
(Note 2) Only compare EQ and NE by integers. Use GE, GT, LE and LT for comparison when there are numbers below the decimal point.

Repetition

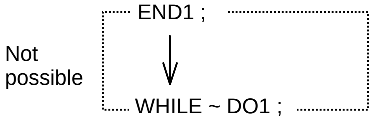
Format

```
WHILE [conditional expression] DOm ; (m =1, 2, 3 ..... 127)
   ~
ENDm ;
```

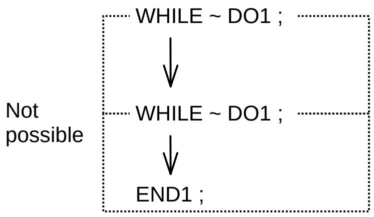
While the conditional expression is established, the blocks from the following block to ENDm are repeatedly executed; when it is not established, execution moves to the block after ENDm. DOm may come before WHILE.
"WHILE [conditional expression] DOm" and "ENDm" must be used as a pair. If "WHILE [conditional expression]" is omitted, these blocks will be repeatedly ad infinitum. The repeating identification numbers range from 1 to 127 (DO1, DO2, DO3, ... DO127). Up to 27 nesting levels can be used.

(1) Same identification number can be used any number of times.  Possible WHILE ~ DO1 ; END1 ; Possible WHILE ~ DO1 ; END1 ;	(2) Any number may be used for the WHILE~ DOm identification number.  WHILE ~ DO1 ; END1 ; WHILE ~ DO3 ; END3 ; Possible WHILE ~ DO2 ; END2 ; WHILE ~ DO1 ; END1 ;
(3) Up to 27 nesting levels for WHILE~DOm. "m" is any number form 1 to 127 for the nesting depth.  DO1 DO2 DO27 WHILE ~ DO1 ; WHILE ~ DO2 ; WHILE~DO27 ; Possible END27 ; END2 ; END1 ; **(Note)** With nesting, "m" which has been used once cannot be used.	(4) The number of WHILE~DOm nesting levels cannot exceed 27.  WHILE ~ DO1 ; WHILE ~ DO2 ; WHILE ~ DO3 ; WHILE ~ DO28 ; END28 ; END3 ; END2 ; END1 ; Not possible

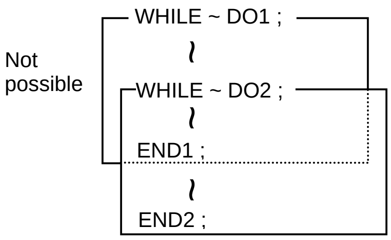
(5) WHILE ~ DOm must be designated first and ENDm last.



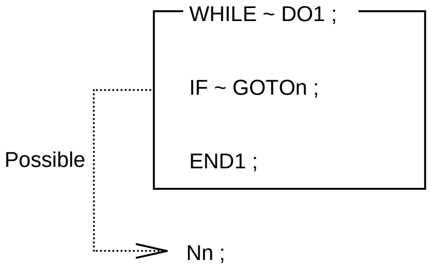
(6) WHILE ~ DOm and ENDm must correspond on a 1:1 (pairing) basis in the same program.



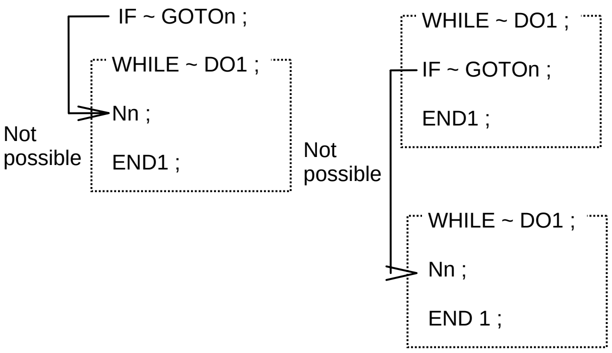
(7) Two WHILE ~ DOm's must not overlap.



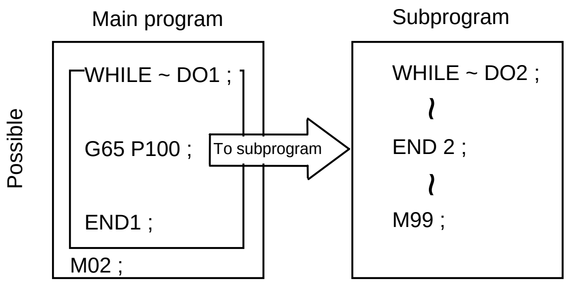
(8) Branching externally is possible from the WHILE ~ DOm range.



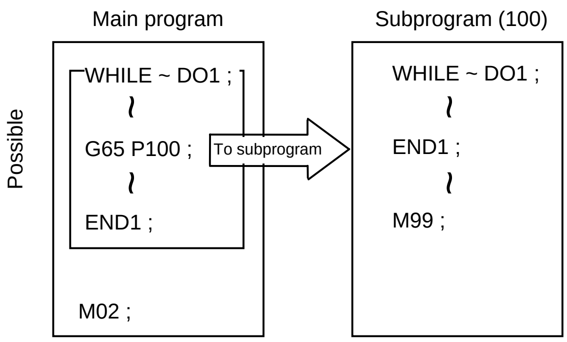
(9) No branching is possible inside WHILE ~ DOm.



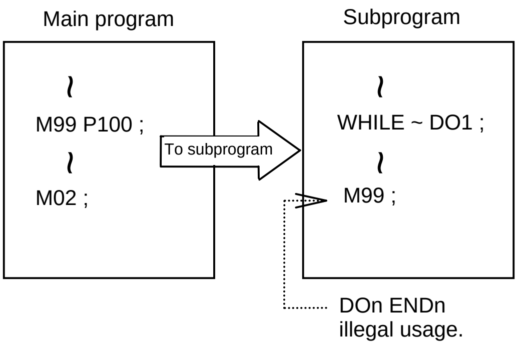
(10) Subprograms can be called by M98, G65 or G66 between WHILE ~ DOm's.



(11) Calls can be initiated by G65 or G66 between WHILE ~ DOm's and commands can be issued again from 1. Up to 27 nesting levels are possible for the main program and subprograms.



(12) A program error results with M99 unless WHILE and END are paired within the subprograms (including macro programs).



(Note) Even if a fixed cycle containing WHILE is called, the nesting level will be counted up.

13.6.7 External output commands

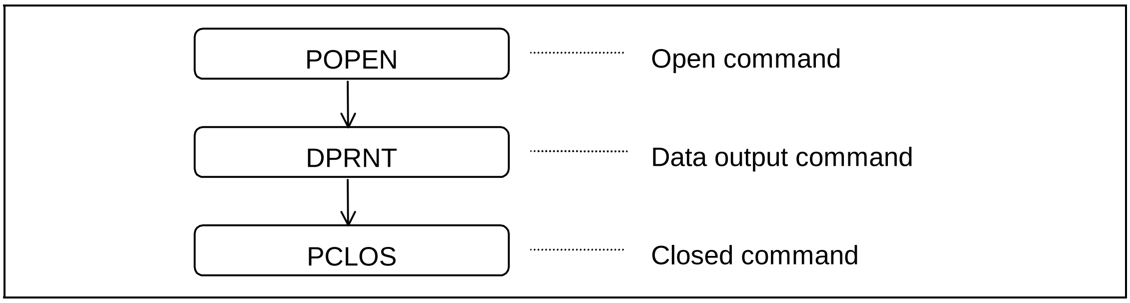
Function and purpose

Besides the standard user macro commands, the following macro instructions are also available as external output commands. They are designed to output the variable values or characters via the RS-232C interface.

Command format

POPEN	**For preparing the processing of data outputs**
PCLOS	**For terminating the processing of data outputs**
DPRNT	**For character output and digit-by-digit variable numerical output**

Command sequence



Open command : POPEN

(1) The command is issued before the series of data output commands.

(2) The DC2 control code and % code are output from the NC system to the external output device.

(3) Once POPEN ; has been issued, it will remain valid until PCLOS ; is issued.

Close command : PCLOS

(1) This command is issued when all the data outputs are completed.

(2) The DC4 control code and % code are output from the NC unit to the external output device.

(3) This command is used together with the open command and it should not be issued unless the open mode has been established.

(4) Issue the close command at the end of the program even when operation has been suspended by resetting or some other operation during data output.

Data output command : DPRNT

DPRNT [/1 # v1 [d1 c1] /2 # v2 [d2 c2] ……………..]

/1	Character string	
v1	Variable number	
d1	Significant digits above decimal point	c + d ≤ 8
c1	Significant digits below decimal point	

(1) The character output and decimal output of the variable values are done with ISO codes.

(2) The commanded character string is output as is by the ISO code.
Alphanumerics (A ~ Z, 0 ~ 9) and special characters (+, –, ∗, /) can be used.

(3) The required significant digits above and below the decimal point in the variable values are commanded within square parentheses. As a result, the variable values equivalent to the commanded number of digits including the decimal point are output in ISO code in decimal notation from the high-order digits. Trailing zeroes are not omitted.

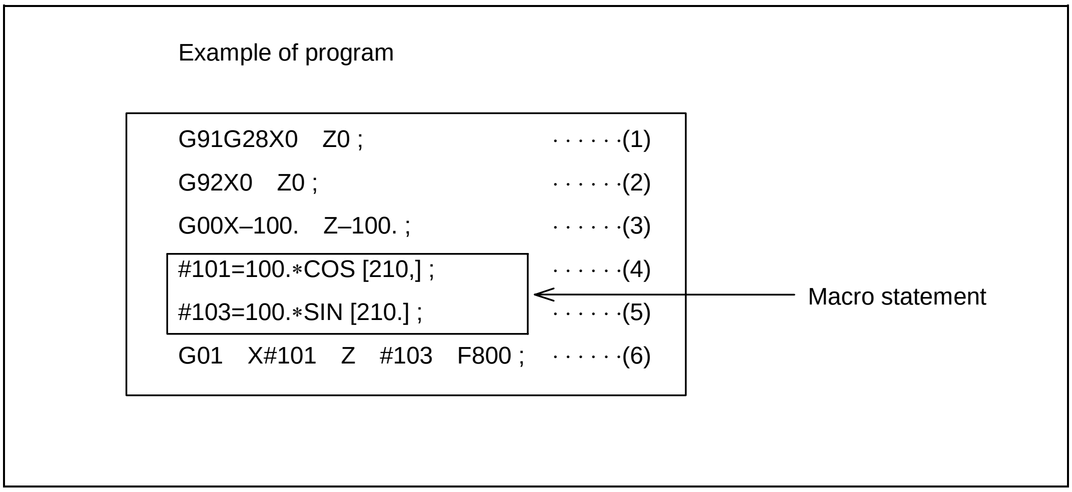
(4) Leading zeroes are omitted.
The leading zeroes can also be replaced by blank if so specified with a parameter. This can justify printed data on the last column.

(Note) A data output command can be issued even in dual-system mode. In this case, however, note that the output channel is shared for both systems. So, take care not to execute data output in both systems simultaneously.

13.6.8 Precautions

Precautions

(1) When the user macro commands are employed, it is possible to use the M, S, T and other control commands together with the operation, decision, branching and other macro commands for creating the machining programs. When the former commands are made into executable statements and the latter commands into macro statements, the macro statement processing should be accomplished as quickly as possible in order to minimize the machining time, because such processing is not directly related to machine control.
As a result, the parameter (#8101 MACRO SINGLE on the parameter screen) can be decided upon and the macro statements can be processed in parallel with the execution of the executable statement.
(The parameter can be set OFF during normal machining to process all the macro statements together or set ON during a program check to execute the macro statements block by block. This enables the setting to be made in accordance with the intended objective in mind.)



Example of program

```
G91G28X0    Z0 ;                      ······(1)
G92X0    Z0 ;                         ······(2)
G00X–100.    Z–100. ;                 ······(3)
#101=100.∗COS [210,] ;                ······(4)
#103=100.∗SIN [210.] ;                ······(5)
G01    X#101    Z    #103    F800 ;   ······(6)
```

Macro statements are:

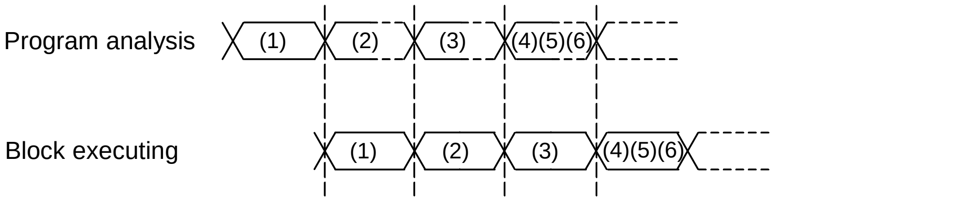
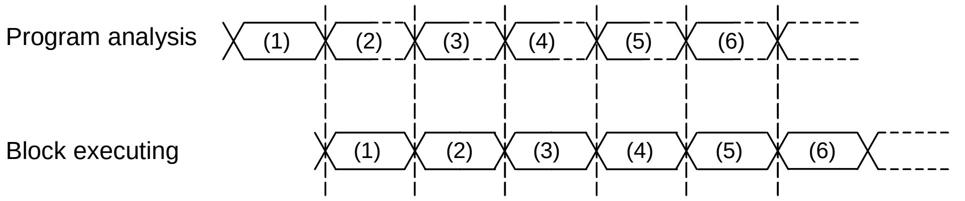
(a) Operation commands (blocks including "=")

(b) Control commands (blocks including GOTO, DO~END, etc.)

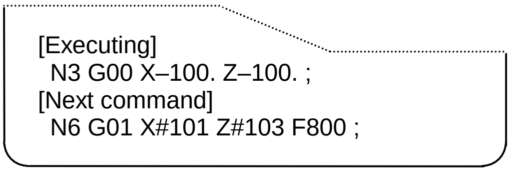
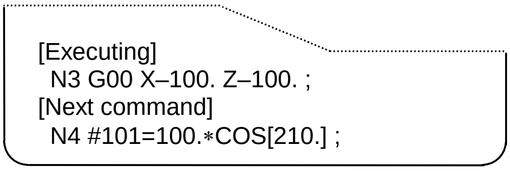
(c) Macro call commands (including macro calls based on G codes and cancel command (G65. G66. G66.1, G67))

NC statements are all those statements which are not executable statements.

Flow of processing

MACRO SINGLE OFF	 Program analysis (1) (2) (3) (4)(5)(6) Block executing (1) (2) (3) (4)(5)(6)
MACRO SINGLE ON	 Program analysis (1) (2) (3) (4) (5) (6) Block executing (1) (2) (3) (4) (5) (6)

Machining program display

MACRO SINGLE OFF	 [Executing] N3 G00 X–100. Z–100. ; [Next command] N6 G01 X#101 Z#103 F800 ;	N4, N5 and N6 are processed in parallel with the control of the executable statement of N3. N6 is an executable statement and so it is displayed as the next command. If the N4, N5 and N6 analysis is in time during N3 control, the machine movement will be continuously controlled.
MACRO SINGLE ON	 [Executing] N3 G00 X–100. Z–100. ; [Next command] N4 #101=100.∗COS[210.] ;	N4 is processed in parallel with the control of the executable statement of N3, and it is displayed as the next command. N5 and N6 are analyzed and N6 is executed after N3 has finished, and so the machine control is held on standby during the N5 and N6 analysis time.

13.7 Corner chamfering/corner rounding I

Chamfering at any angle or corner rounding is performed automatically by adding ",C_" or ",R_" to the end of the block to be commanded first among those command blocks which shape the corner with lines only.

13.7.1 Corner chamfering ",C"

Function and purpose

The corner is chamfered in such a way that the positions produced by subtracting the lengths commanded by ",C_" (or "I_", "K_", "C_") from the hypothetical starting and final corners which would apply if no chamfering were to be performed, are connected.

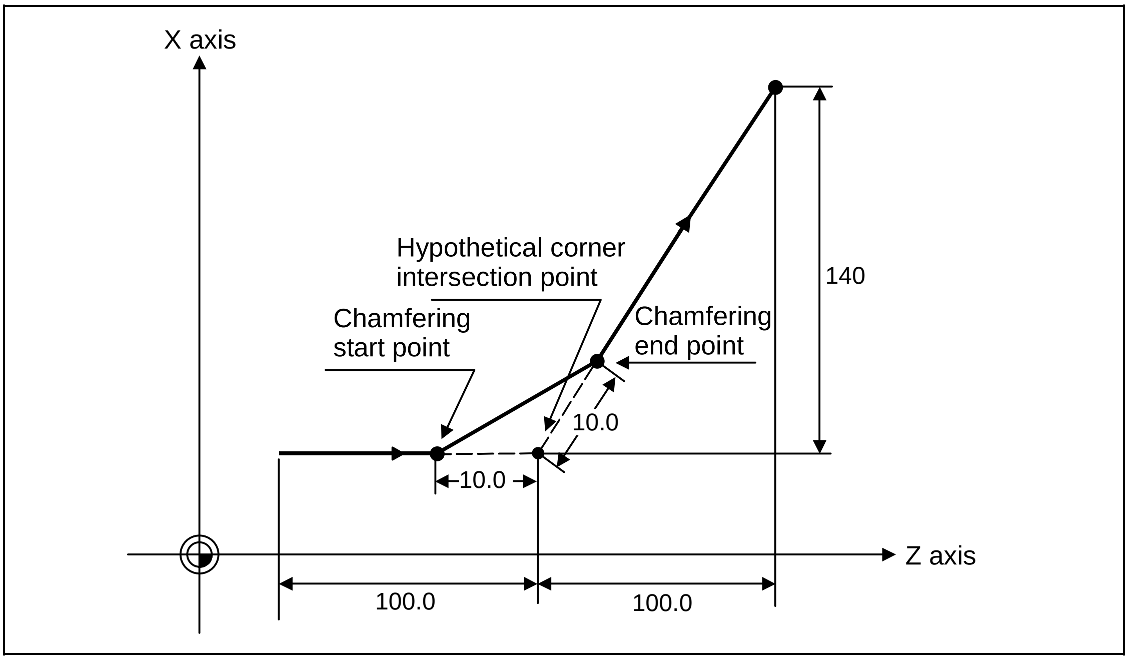
Command format

N100 G01 X__ Z__ ,C__ ;	
N200 G01 X__ Z__ ;	
,C_	Length up to chamfering starting point or end point from hypothetical corner

Chamfering is performed at the point where N100 and N200 intersect.

Example of program

G01 W100. ,C10. F100 ;
U280. W100. ;



Detailed description

(1) The start point of the block following the corner chamfering serves as the hypothetical corner intersection point.

(2) When the comma in ",C" is not present, it is handled as a C command.

(3) When both corner chamfering and corner rounding are commanded in the same block, the latter command is valid.

(4) Tool offset is calculated for the shape which has already been subjected to corner chamfering.

(5) When the block following a command with corner chamfering does not contain a linear command, a corner chamfering/corner rounding II function results.

(6) Program error (P383) results when the movement amount in the block commanding corner chamfering is less than the chamfering amount.

(7) Program error (P384) results when the movement amount in the block following the block commanding corner chamfering is less than the chamfering amount.

(8) A program error (P382) results when a movement command is not issued in the block following the corner chamfering I command.

13.7.2 Corner rounding ",R_"

Function and purpose

Corner rounding of the hypothetical starting and final corners when corner is assumed as not rounded is performed at the radius of the arc commanded in ",R_" .

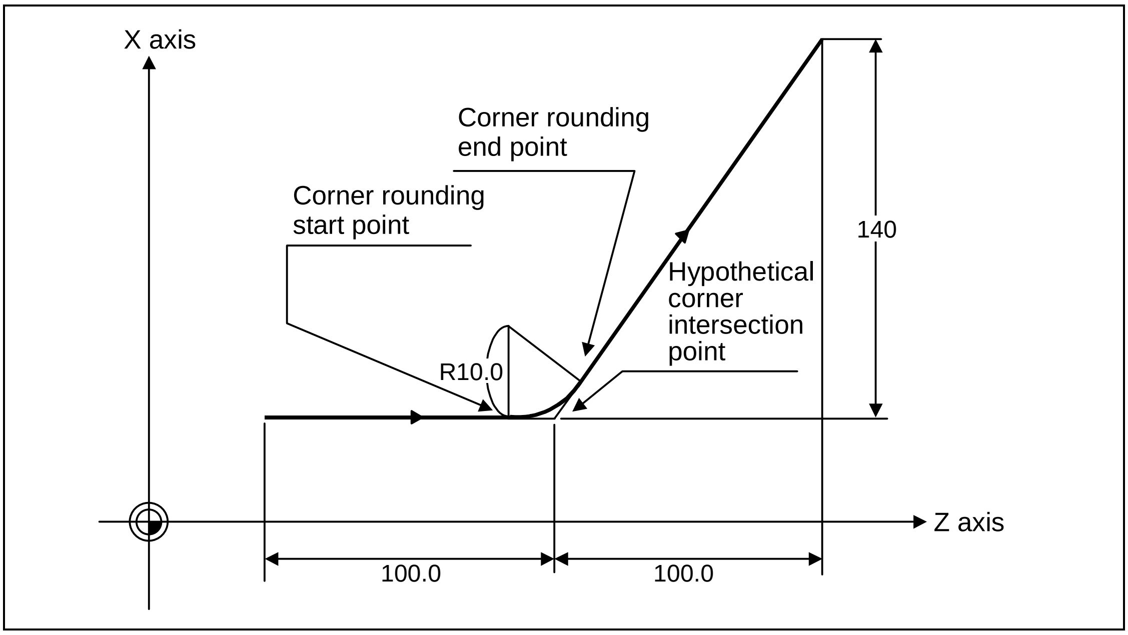
Command format

```
N100 G01 X__ Z__ ,R__ ;
N200 G01 X__ Z__ ;
,R_                Arc radius of corner rounding
```

Corner rounding is performed at the point where N100 and N200 intersect.

Example of program

```
G01 W100. ,R10. F100 ;
U280. W100. ;
```


X axis
Corner rounding end point
Corner rounding start point
140
Hypothetical corner intersection point
R10.0
Z axis
100.0
100.0

Detailed description

(1) The start point of the block following the corner rounding serves as the hypothetical corner intersection point.

(2) When the comma in ",R" is not present, it is handled as an R command.

(3) When both corner chamfering and corner rounding are commanded in the same block the latter command is valid.

(4) Tool offset is calculated for the shape which has already been subjected to corner rounding.

(5) When the block following a command with corner rounding does not contain a linear command, a corner chamfering/corner rounding II function results.

(6) Program error (P383) results when the movement amount in the block commanding corner rounding is less than the R value.

(7) Program error (P384) results when the movement amount in the block following corner rounding is less than the R value.

(8) A program error (P382) will occur if a movement command is not issued in the block following corner rounding.

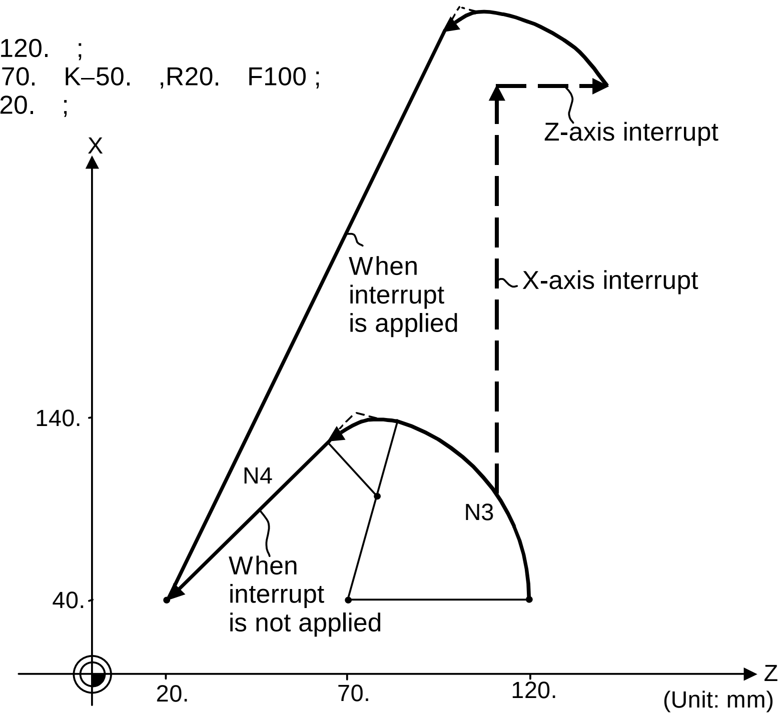
13.7.3 Interrupt during corner chamfering/corner rounding

Detailed description

(1) The operations are shown below for manual interrupt during corner chamfering or corner rounding.

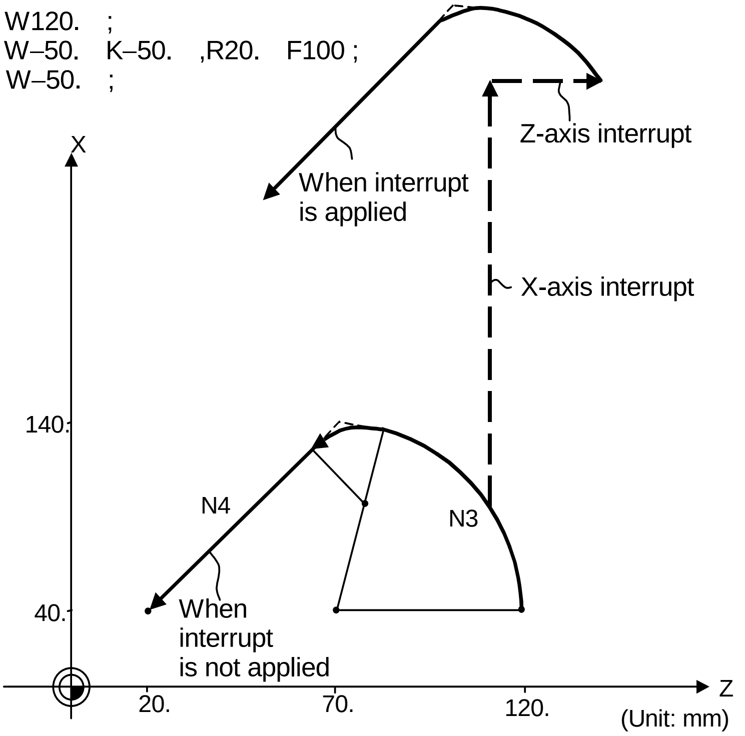
With an absolute value command and manual absolute switch ON.

```
N1   G28   XZ ;
N2   G00   X40.   Z120.   ;
N3   G03   X140.  Z70.   K–50.   ,R20.   F100 ;
N4   G01   X40.   Z20.   ;
            :
```



With an incremental value command and manual absolute switch OFF

```
N1   G28   XZ ;
N2   G00   U40.      W120.   ;
N3   G03   U100.   W–50.   K–50.   ,R20.   F100 ;
N4   G01   U–100.  W–50.   ;
              :
```



(2) With a single block during corner chamfering or corner rounding, the tool stops after corner chamfering or corner rounding is executed.

13.8 Corner chamfering/corner rounding II

In a block that forms a corner with continuous random angle lines or arcs, corner chamfering and corner rounding can be performed by adding ",C" or ",R" to the end of the block commanded first. Corner chamfering and corner rounding can both be commanded as an absolute value or incremental value.

13.8.1 Corner chamfering ",C_"

Function and purpose

The corner is chamfered by commanding ",C" in the 1st block of two blocks having continuous arcs. For an arc, this will be the chord length.

Command format

N100 G03 X__ Z__ K__ ,C__ ;
N200 G01 X__ Z__ ;

,C_	Length up to chamfering starting point or end point from hypothetical corner

Corner chamfering is performed at the point where N100 and N200 intersect.

Example of program

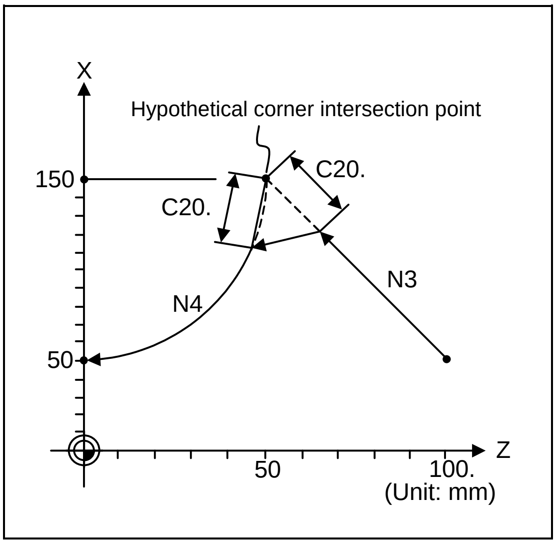
(1) Linear – arc

Absolute value command

```
N1 G28 X Z ;
N2 G00 X50. Z100. ;
N3 G01 X150. Z50. ,C20. F100 ;
N4 G02 X50. Z0 I0 K–50. ;
          :
```

Relative value command

```
N1 G28 X Z ;
N2 G00 U25. W100. ;
N3 G01 U50. W–50. ,C20. F100 ;
N4 G02 U–50. W–50. I0 K–50. ;
          :
```



Detailed description

(1) The corner chamfering and corner rounding options are required to use this function.

(2) The start point of the block following the corner chamfering serves as the hypothetical corner intersection point.

(3) When the comma in ",C" is not present, it is handled as a C command.

(4) If there are multiple or duplicate corner chamfering commands in the same block, the command issued last will be valid.

(5) When both corner chamfering and corner rounding are commanded in the same block, the latter command is valid.

(6) Tool offset is calculated for the shape which has already been subjected to corner chamfering.

(7) A program error (P385) results when positioning or thread cutting is commanded in the corner chamfering command block or next block.

(8) A program error (P382) results when the block following corner chamfering contains a G command other than group 01 or another command.

(9) Program error (P383) results when the movement amount in the block commanding corner chamfering is less than the chamfering amount.

(10) Program error (P384) results when the movement amount in the block following the block commanding corner chamfering is less than the chamfering amount.

(11) Even if a diameter is commanded, it will be handled as a radius value during corner chamfering.

(12) A program error (P382) results when a movement command is not issued in the block following the corner chamfering II command.

13.8.2 Corner rounding ",R_"

Function and purpose

The corner is rounded by commanding ",R_" in the 1st block of two blocks containing continuous arcs.

Command format

```
N100 G03 X__ Z__ I__ K__ ,R__ ;
N200 G01 X__ Z__ ;
,R_                Arc radius of corner rounding
```

Corner rounding is performed at the point where N100 and N200 intersect.

Example of program

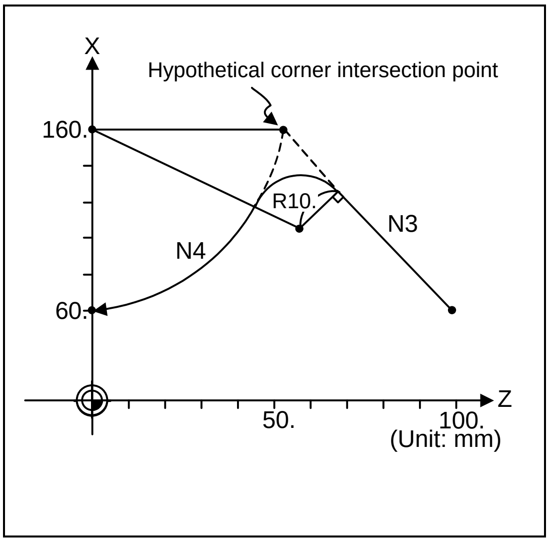
(1) Linear – arc

Absolute value command

```
N1 G28 X Z ;
N2 G00 X60.  Z100. ;
N3 G01 X160. Z50. ,R10. F100 ;
N4 G02 X60.  Z0 I0 K–50. ;
          :
```

Relative value command

```
N1 G28 X Z ;
N2 G00 U30. W100. ;
N3 G01 U50. W–50. ,R10. F100 ;
N4 G02 U–50. W–50. I0 K–50. ;
          :
```



Detailed description

(1) The corner chamfering and corner rounding options are required to use this function.

(2) The start point of the block following the corner rounding serves as the hypothetical corner intersection point.

(3) When the comma in ",R" is not present, it is handled as an R command.

(4) When both corner chamfering and corner rounding are commanded in the same block the latter command is valid.

(5) Tool offset is calculated for the shape which has already been subjected to corner rounding.

(6) A program error (P385) results when positioning or thread cutting is commanded in the corner rounding command block or next block.

(7) A program error (P382) results when the block following corner rounding contains a G command other than group 01 or another command.

(8) Program error (P383) results when the movement amount in the block commanding corner rounding is less than the R value.

(9) Program error (P384) results when the movement amount in the block following the block commanding corner rounding is less than the R value.

(10) Even if a diameter is commanded, it will be handled as a radius value during corner rounding.

(11) A program error (P382) results when a movement command is not issued in the block following corner rounding II.

13.8.3 Interrupt during corner chamfering/corner rounding

Refer to section "13.7.3 Interrupt during corner chamfering/corner rounding" for details.

13.9 Geometric

13.9.1 Geometric I

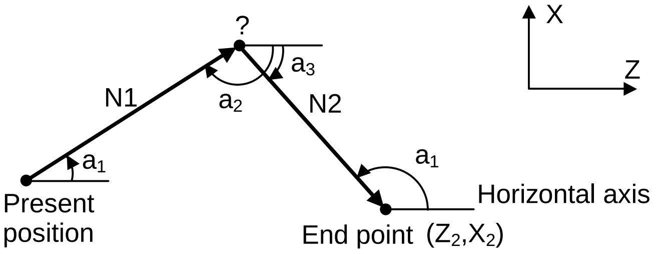
Function and purpose

When it is difficult to determine the point at which the two straight lines intersect with a continuous linear interpolation command, the end point of the first straight line will be automatically calculated inside the CNC and the movement command will be controlled provided that the slope of the first straight line as well as the end point coordinates and slope of the second straight line are commanded.

(Note) If the parameter (#1082 Geomet) is set to 0, geometric I will not function.

Command format

N1 G01 Aa_1 (A–a_2) Ff_1 ;	**This designates the angle and feedrate.**
N2 Xx_2 Zz_2 A–a_2 (Aa_3) Ff_2 ;	**This designates the next block end point coordinates, angle and feedrate.**
Aa_1, A–a_2, Aa_3	Angle
Ff_1, Ff_2	Feedrate
Xx_2, Zz_2	Next block end point coordinates



Detailed description

(1) Program error (P396) results when the geometric command is not on the selected plane.

(2) The slope is expressed as the angle that is formed with the horizontal axis + direction on the selected plane. The counterclockwise (CCW) direction is considered to be + and the clockwise direction (CW) –.

(3) Slope "a" ranges from –360.000 ≤ a ≤ 360.000.
When a value outside this range is commanded, it will be divided by 360 (degrees) and the remainder will be commanded.

(Example) If 400. is commanded, 40° (remainder of 400/360) will become the command angle.

(4) The slope of the line can be commanded on the start or end point side. The start or end point side of the commanded slope is identified automatically inside the NC unit.

(5) The end point coordinates of the second block should be commanded with absolute values. When incremental values are used, program error (P393) will result.

(6) The feedrate can be commanded for each block.

(7) When the angle where the two straight lines intersect is less than 1°, program error (P392) will result.

(8) Program error (P396) results when the plane is selected in the 1st block and 2nd block.

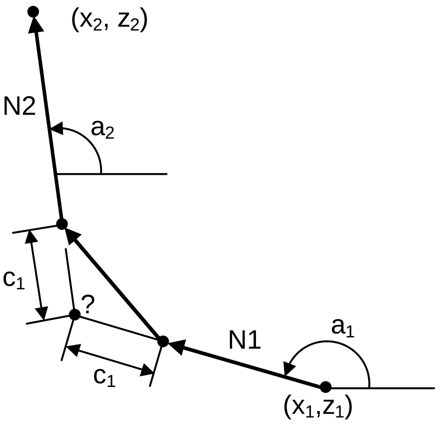
(9) This function is ignored when address A is used for the axis name or as the 2nd miscellaneous function.

(10) Single block stop is possible at the end point of the 1st block.

(11) Program error (P394) results when the 1st and 2nd blocks do not contain the G01 or G33 command.

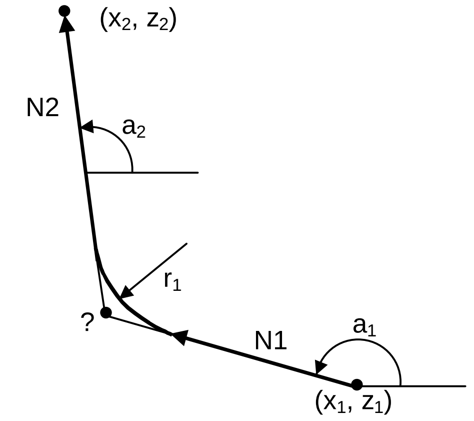
Relationship with other functions

(1) Corner chamfering or corner rounding can be commanded after the angle command in the 1st block.

(Example 1) N1 Aa$_1$, Cc$_1$; N2 Xx$_2$ Zz$_2$ Aa$_2$;	 (x$_2$, z$_2$) N2 a$_2$ c$_1$? c$_1$ N1 a$_1$ (x$_1$,z$_1$)

(Example 2)

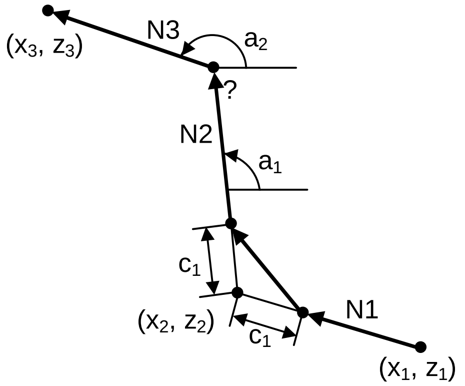
N1 Aa_1, Rr_1 ;
N2 Xx_2 Zz_2 Aa_2 ;



(2) The geometric command I can be issued after the corner chamfering or corner rounding command.

(Example 3)

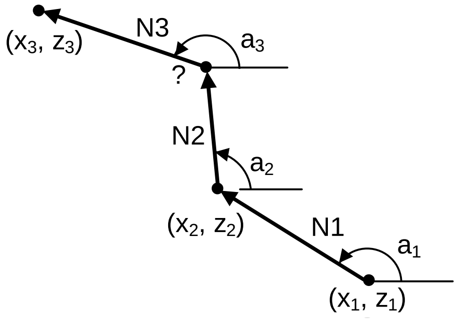
N1 Xx_2 Zz_2 ,Cc_1 ;
N2 Aa_1 ;
N3 Xx_3 Zz_3 Aa_2 ;



(3) The geometric command I can be issued after the linear angle command.

(Example 4)

N1 Xx_2 Aa_1 ;
N2 Aa_2 ;
N3 Xx_3 Zz_3 Aa_3 ;



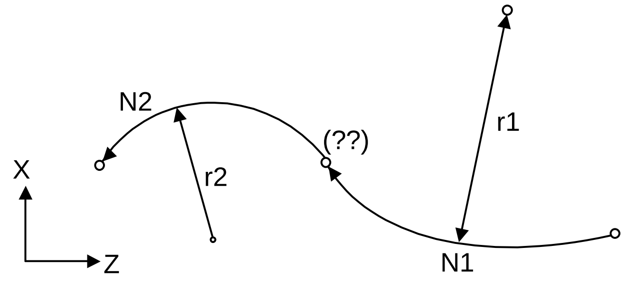
13.9.2 Geometric IB

Function and purpose

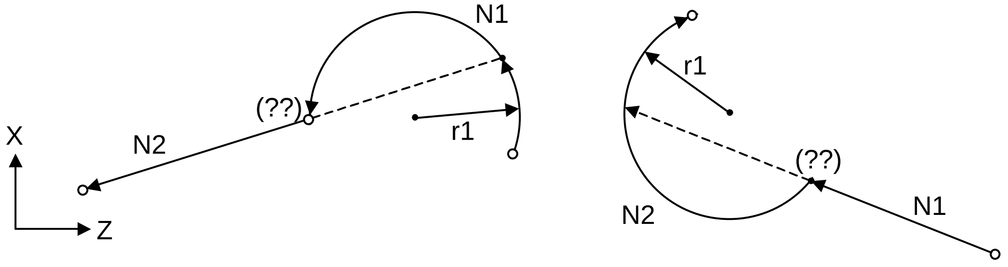
With the geometric IB function, the contact and intersection are obtained by commanding an arc center point or linear angle in the movement commands of two continuous blocks (only for blocks having arc commands), instead of commanding the first block end point.

Control target block

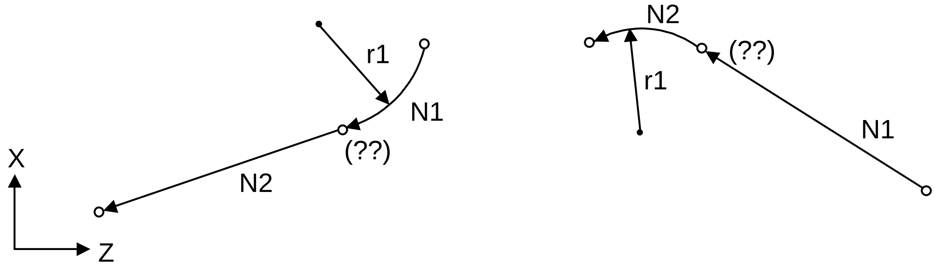
(1) Two-arc contact



(2) Linear - arc (arc - linear) intersection



(3) Linear - arc (arc - linear) contact



(Note) If the parameter (#1082 Geomet) is set to a value other than 2, geometric IB will not function.

Function and purpose 1 (Automatic calculation of two-arc contact)

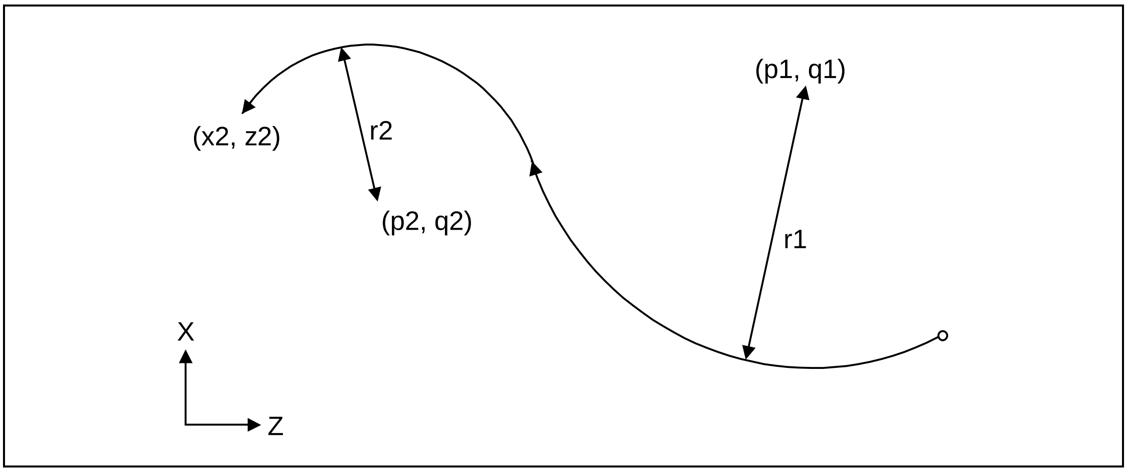
When the contact of two continuous contacting arcs is not indicated in the drawings, it can be automatically calculated by commanding the 1st arc center coordinate value or radius, and the 2nd arc end point absolute value and center coordinate value or radius.

Command format 1 (Automatic calculation of two-arc contact)

N1	**G02 (G03)**	**Pp_1 Qq_1 Ff_1 ;**
N2	**G03 (G02)**	**Xx_2 Zz_2 Pp_2 Qq_2 Ff_2 ;**
N1	**G02 (G03)**	**Pp_1 Qq_1 Ff_1 ;**
N2	**G03 (G02)**	**Xx_2 Zz_2 Rr_2 Ff_2 ;**
N1	**G02 (G03)**	**Rr_1 Ff_1 ;**
N2	**G03 (G02)**	**Xx_2 Zz_2 Pp_2 Qq_2 Ff_2 ;**
P, Q	X and Z axes arc center coordinate absolute value (diameter/radius value command) The center address for the 3rd axis is commanded with A.	
R	Arc radius (when a (–) sign is attached, the arc is judged to be 180° or more)	

* I and K (X and Z axes arc center coordinate incremental value) commands can be issued instead of P and Q.

1st block arc : Radius command incremental amount from the start point to the center
2nd block arc : Radius command incremental amount from the end point to the center



Detailed description 1 (Automatic calculation of two-arc contact)

(1) A program error (P393) will result before the 1st block if the 2nd block does not contain a coordinate absolute value command.

(2) A program error (P398) will result before the 1st block if there are no geometric IB specifications.

(3) A program error (P395) will result before the 1st block if there is no R (here, the 1st block is designated with P and Q (I, K)) or P and Q (I, K) designation.

(4) A program error (P396) will result before the 1st block if another plane selection command (G17 to G19) is issued in the 2nd block.

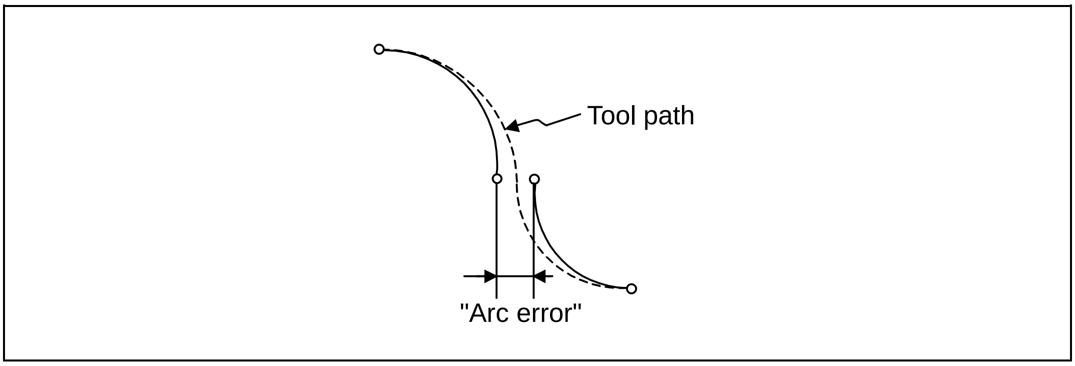
(5) A program error (P397) will result before the 1st block if two arcs that do not contact are commanded.

(6) The contact calculation accuracy is ±1μm (fractions rounded up).

(7) Single block operation stops at the 1st block.

(8) When I or K is omitted, the values are regarded as I0 and K0. P and Q cannot be omitted.

(9) The error range in which the contact is obtained is set in parameter "#1084 RadErr".

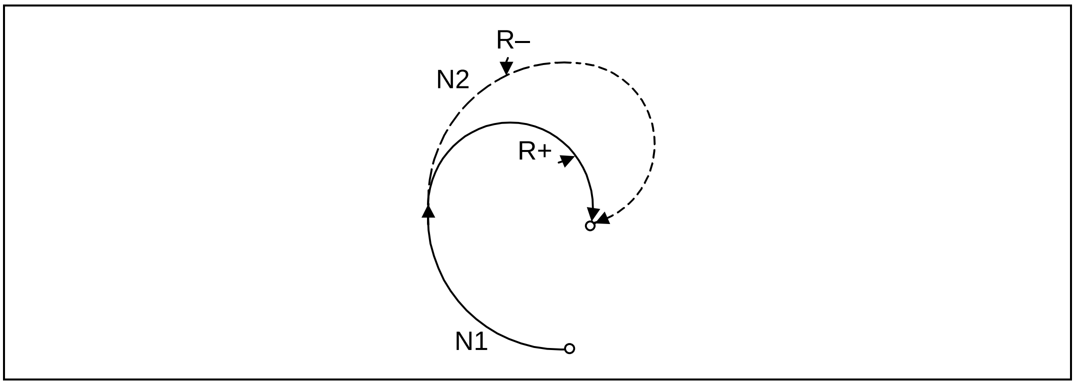


(10) For an arc block perfect circle command (arc block start point = arc block end point), the R designation arc command finishes immediately, and there is no operation. Thus, use a PQ (IK) designation arc command.

(11) G codes of the G modal group 1 in the 1st/2nd block can be omitted.

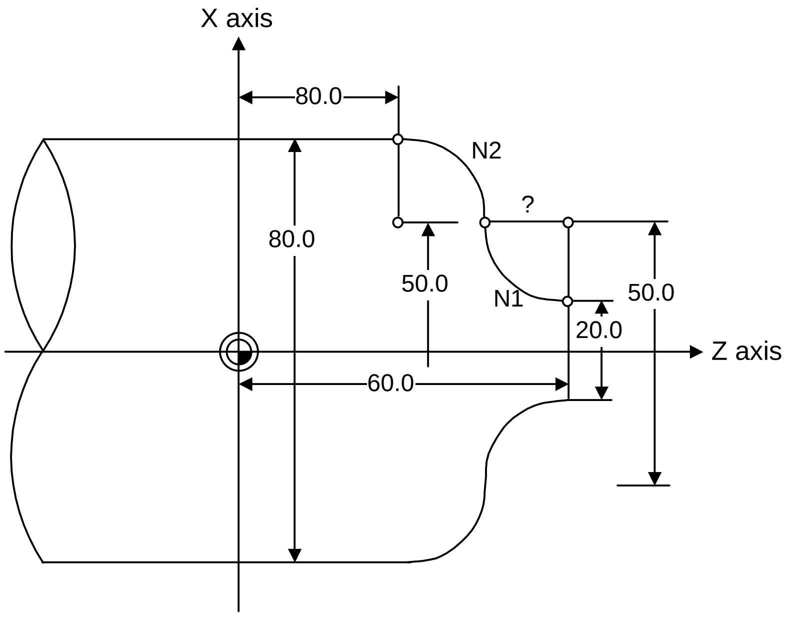
(12) Addresses being used as axis names cannot be used as command addresses for arc center coordinates or arc radii.

(13) If the 2nd block arc inscribes the 1st arc block when the 2nd block is an R designation arc, the R+ sign becomes the inward turning arc command, and the R– sign becomes the outward turning arc command.



Example of program 1 (Automatic calculation of two-arc contact)

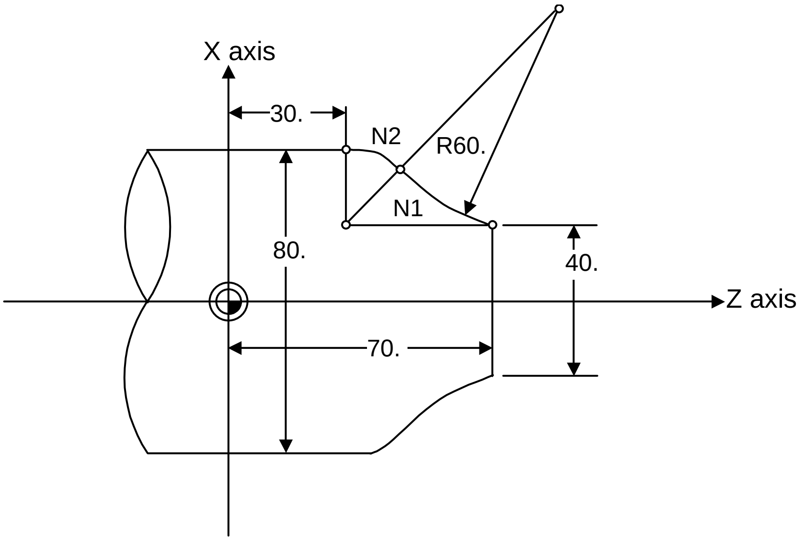
(1) PQ, PQ command



```
     G01  X20.0  Z60.0 ;
N1   G02  P50.0  Q60.0  F100 ;
N2   G03  X80.0  Z30.0  P50.0  Q30.0 ;
```

(Unit: mm)

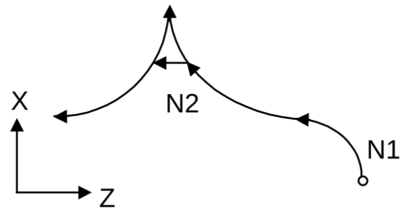
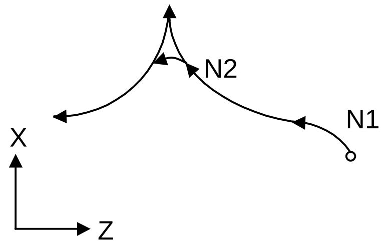
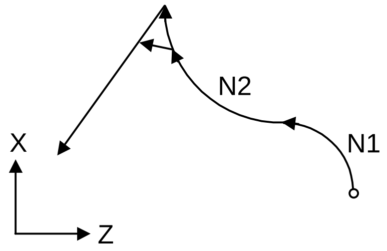
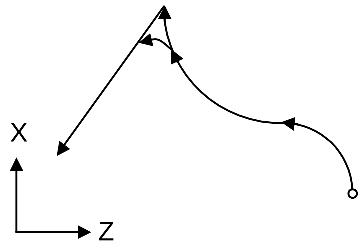
(2) PQ, R command



```
     G01  X40.0  Z70.0  F100 ;
N1   G02  R60.0 ;
N2   G03  X80.0  Z30.0  P40.0  Q30.0 ;
```

(Unit: mm)

Relation with other functions 1 (Automatic calculation of two-arc contact)

Command	Tool path
Geometric IB + corner chamfering II N1 G03 P__ Q__ ; N2 G02 X__ Z__ R__ ,C__ ; G02 X__ Z__ R__ ;	
Geometric IB + corner rounding II N1 G03 P__ Q__ ; N2 G02 X__ Z__ R__ ,R__ ; G02 X__ Z__ R__ ;	
Geometric IB + corner chamfering II N1 G03 P__ Q__ ; N2 G02 X__ Z__ R__ ,C__ ; G01 X__ Z__ ;	
Geometric IB + corner rounding II N1 G03 P__ Q__ ; N2 G02 X__ Z__ R__ ,R__ ; G02 X__ Z__ ;	

Function and purpose 2 (Automatic calculation of linear - arc intersection)

When the intersection of a shape in which a line and arc intersect is not indicated in the drawings, it can be automatically calculated by commanding the following program.

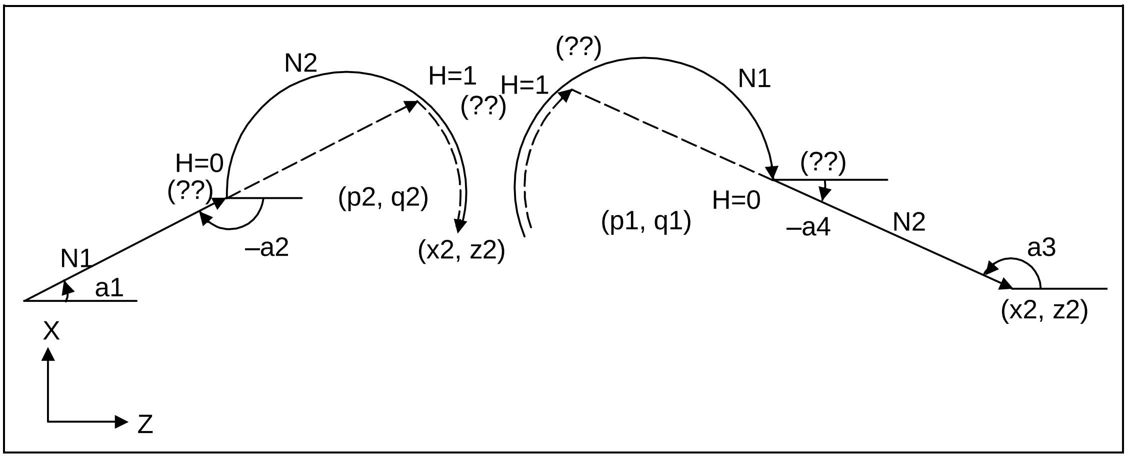
Command format 2 (Automatic calculation of linear - arc intersection: For G18 plane)

N1	**G01**	**Aa_1 (A–a_2) Ff_1 ;**
N2	**G02 (G03)**	**Xx_2 Zz_2 Pp_2 Qq_2 Hh_2 Ff_2 ;**
N1	**G02 (G03)**	**Pp_1 Qq_1 Hh_1 Ff_1 ;**
N2	**G01**	**Xx_2 Zz_2 Aa_3 (A–a_4) Ff_2 ;**

A	Linear angle (–360.000° to 360.000°)
P, Q	X and Z axes arc center coordinate absolute value (diameter/radius value command) The center address for the 3rd axis is commanded with A.
H	Linear - arc intersection selection: 0 : Intersection of the shorter line 1 : Intersection of the longer line

* I and K (X and Z axes arc center coordinate incremental value) commands can be issued instead of P and Q.

1st block arc : Radius command incremental amount from the start point to the center
2nd block arc : Radius command incremental amount from the end point to the center



Detailed description 2 (Automatic calculation of linear - arc intersection)

(1) When the 2nd miscellaneous function address is A, the 2nd miscellaneous function is validated and this function is invalidated.

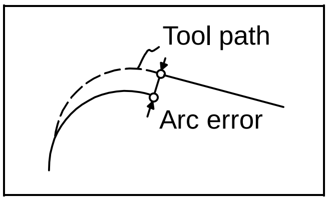
(2) A program error (P393) will result before the 1st block if the 2nd block does not contain a coordinate absolute value command.

(3) A program error (P398) will result before the 1st block if there are no geometric IB specifications.

(4) A program error (P395) will result before the 1st block if there is no P and Q (I, K) designation. A program error (P395) will also result if there is no A designation for the line.

(5) A program error (P396) will result before the 1st block if another plane selection command (G17 to G19) is issued in the 2nd block.

(6) A program error (P397) will result before the 1st block if a straight line and arc that do not contact or intersect are commanded.



(7) Single block operation stops at the 1st block.

(8) When I or K is omitted, the values are regarded as I0 and K0. P and Q cannot be omitted.

(9) When H is omitted, the value is regarded as H0.

(10) The linear - arc contact is automatically calculated by designating R instead of P and Q (I, K).

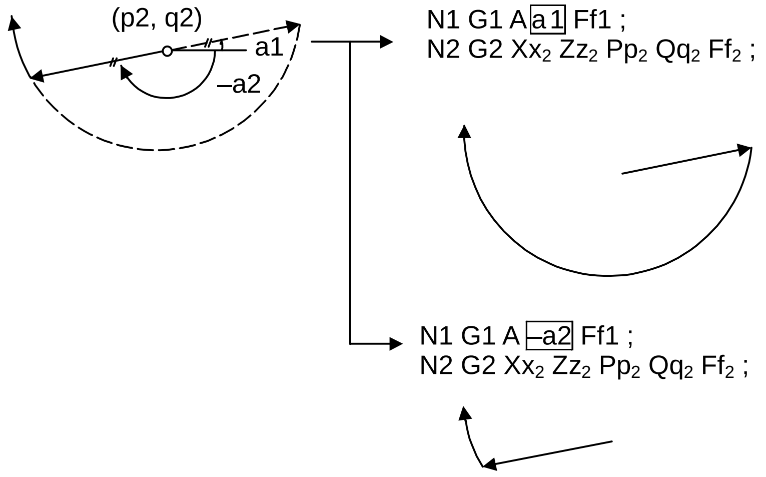
(11) The error range in which the intersection is obtained is set in parameter "#1084 RadErr".

(12) The line slope is rotated at the angle regarded as its horizontal axis. Counterclockwise (CCW) is positive (+). Clockwise (CW) is negative (–).

(13) The line slope can be commanded from either the start point side or the end point side. The judgment whether the designated slope is start point side or end point side is carried out automatically.

(14) When the distance to the intersection of the line and arc is the same (as in the drawing below), the control by address H (short/long distance selection) is invalidated. In this case the judgment is carried out based on the angle of the line.

Linear - arc



N1 G1 A$\boxed{a1}$ Ff1 ;
N2 G2 Xx_2 Zz_2 Pp_2 Qq_2 Ff_2 ;

N1 G1 A $\boxed{-a2}$ Ff1 ;
N2 G2 Xx_2 Zz_2 Pp_2 Qq_2 Ff_2 ;

(15) The intersection calculation accuracy is ±1μm (fractions rounded up).

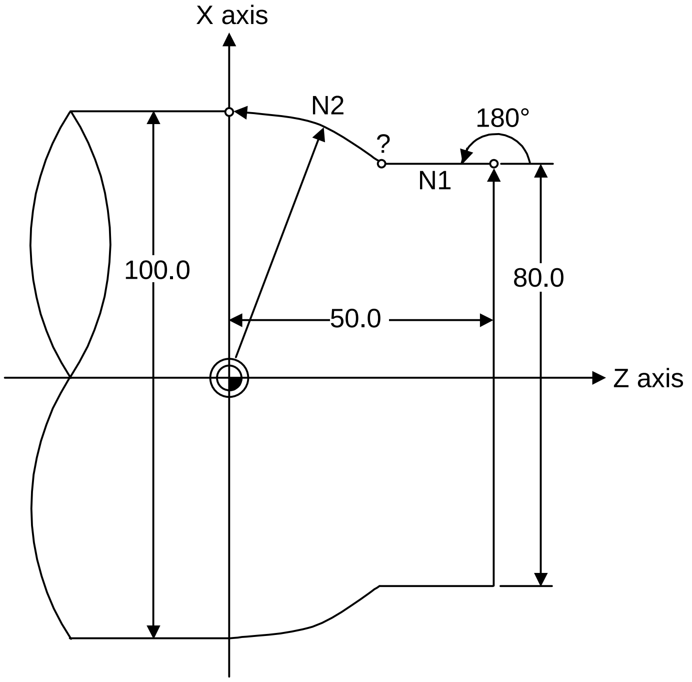
(16) In linear - arc intersections, the arc command can only be a PQ (IK) command. When the arc block start point = arc block end point, the arc is a perfect circle.

(17) G codes of the G modal group in the 1st block can be omitted.

(18) Addresses being used as axis names cannot be used as command addresses for angles, arc center coordinates or intersection selections.

(19) When geometric IB is commanded, two blocks are pre-read.

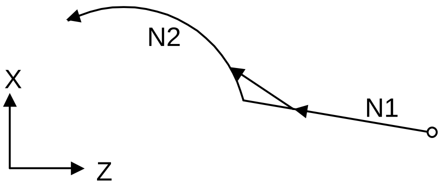
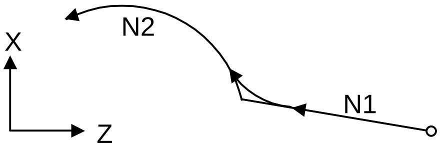
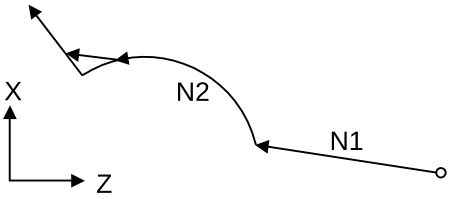
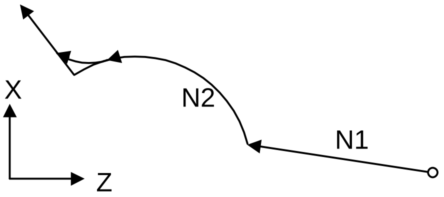
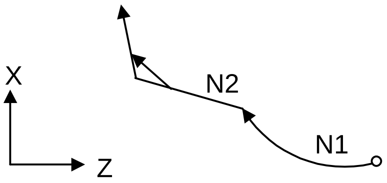
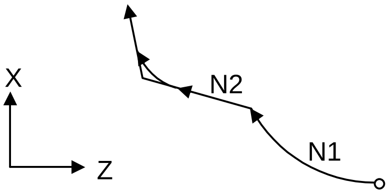
Example of program 2 (Automatic calculation of linear - arc intersection)



```
    G01 X80.0 Z50.0 F100 ;
N1 G01 A180.0 ;
N2 G03 X100.0 Z0 P0 Q0 ;
```

(Unit: mm)

Relation with other functions 2 (Automatic calculation of linear - arc intersection)

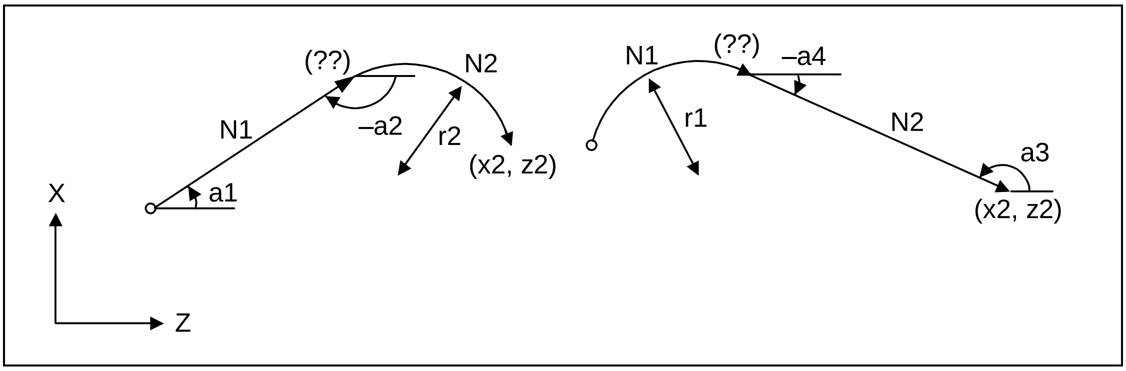
Command	Tool path
Geometric IB + corner chamfering II N1 G01 A__ ,C__ ; N2 G03 X__ Z__ P__ Q__ H__ ;	
Geometric IB + corner rounding II N1 G01 A__ ,R__ ; N2 G03 X__ Z__ P__ Q__ H__ ;	
Geometric IB + corner chamfering II N1 G01 A__ ; N2 G03 X__ Z__ P__ Q__ H__ ,C__ ; G01 X__ Z__ ;	
Geometric IB + corner rounding II N1 G01 A__ ; N2 G03 X__ Z__ P__ Q__ H__ ,R__ ; G01 X__ Z__ ;	
Geometric IB + corner chamfering II N1 G02 P__ Q__ H__ ; N2 G01 X__ Z__ A__ ,C__ ; G01 X__ Z__ ;	
Geometric IB + corner rounding II N1 G02 P__ Q__ H__ ; N2 G01 X__ Z__ A__ ,R__ ; G01 X__ Z__ ;	

Function and purpose 3 (Automatic calculation of linear - arc intersection)

When the contact of a shape in which a line and arc contact is not indicated in the drawings, it can be automatically calculated by commanding the following program.

Command format 3 (Automatic calculation of linear - arc intersection: For G18 plane)

N1	**G0**	**Aa$_1$ (A–a$_2$) Ff$_1$;**
N2	**G03 (G02)**	**Xx$_2$ Zz$_2$ Rr$_2$;**
N1	**G03 (G02)**	**Rr$_2$ Ff$_1$;**
N2	**G01**	**Xx$_2$ Zz$_2$ Aa$_3$ (A–a$_4$) Ff$_2$;**
A		Linear angle (–360.000° to 360.000°)
R		Arc radius



Detailed description 3 (Automatic calculation of linear - arc intersection)

(1) When the 2nd miscellaneous function address is A, the 2nd miscellaneous function is validated and this function is invalidated.

(2) A program error (P393) will result before the 1st block if the 2nd block does not contain a coordinate absolute value command.

(3) A program error (P398) will result before the 1st block if there are no geometric IB specifications.

(4) A program error (P396) will result before the 1st block if another plane selection command (G17 to G19) is issued in the 2nd block.

(5) A program error (P397) will result before the 1st block if a straight line and arc that do not contact are commanded.

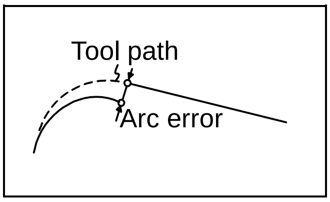
(6) A program error (P395) will result before the 1st block if there is no R designation for the 2nd block. A program error (P395) will also result if there is no A designation for the line.

(7) Single block operation stops at the 1st block.

(8) The linear - arc intersection is automatically calculated by designating R instead of P and Q (I, K).

(9) The error range in which the contact is obtained is set in parameter "#1084 RadErr".

(10) The line slope is rotated at the angle regarded as the positive (+) direction of its horizontal axis. Counterclockwise (CCW) is positive (+). Clockwise (CW) is negative (–).



(11) The line slope can be commanded from either the start point side or the end point side. The judgment whether the designated slope is start point side or end point side is carried out automatically.

(12) The intersection calculation accuracy is ± 1μm (fractions rounded up).

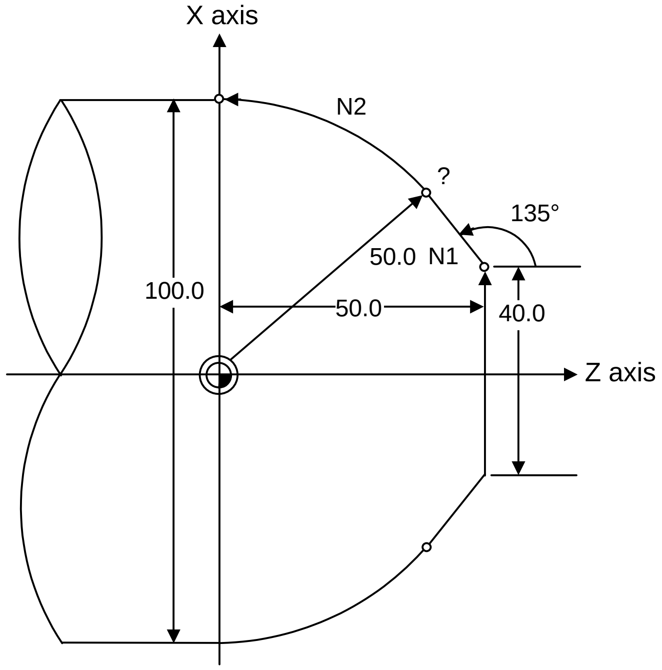
(13) In linear - arc contact, the arc command can only be an R command. Thus, when the arc block start point = arc block end point, the arc command finishes immediately, and there is no operation. (Perfect circle commands are not possible.)

(14) G codes of the G modal group 1 in the 1st block can be omitted.

(15) Addresses being used as axis names cannot be used as command addresses for angles or arc radii.

(16) When geometric IB is commanded, two blocks are pre-read.

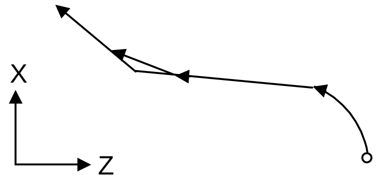
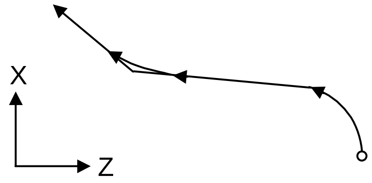
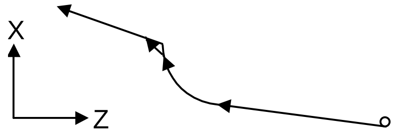
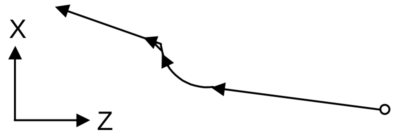
Example of program 3 (Automatic calculation of linear - arc intersection)



```
    G01 X40.0 Z50.0 F100 ;
N1 G01 A135.0 ;
N2 G03 X100.0 Z0.0 R50.0 ;
```

(Unit: mm)

Relation with other functions 3 (Automatic calculation of linear - arc intersection)

Command	Tool path
Geometric IB + corner chamfering N1 G03 R__ ; N2 G01 X__ Z__ A__ ,C__ ; G01 X__ Z__ R__ ;	
Geometric IB + corner rounding N1 G03 R__ ; N2 G01 X__ Z__ A__ ,R__ ; G01 X__ Z__ ;	
Geometric IB + corner chamfering II N1 G01 A__ ; N2 G02 X__ Z__ R__ ,C__ ; G01 X__ Z__ ;	
Geometric IB + corner rounding II N1 G01 A__ ; N2 G02 X__ Z__ R__ ,R__ ; G01 X__ Z__ ;	

13.10 Program parameter input; G10, G11

Function and purpose

The parameters set from the setting and display unit can be changed in the machining programs. The data format used for the data setting is as follows.

Command format

G10 L50 ; Data setting command

P major classification number N data number H bit type data ;
P major classification number A axis number N data number D byte type data ;
P major classification number A axis number N data number S word type data ;
P major classification number A axis number N data number L 2 word type data ;

G11 ; Data setting mode cancel (data setting completed)

There are 8 types of data formats according to the type of parameter (axis-common and axis-independent) and data type, as listed below.

With axis-common data	
Axis-common bit-type parameter	P___ N___ H____ ;
Axis-common byte-type parameter	P___ N___ D____ ;
Axis-common word-type parameter	P___ N___ S____ ;
Axis-common 2-word-type parameter	P___ N___ L____ ;
With axis-independent data	
Axis-independent bit-type parameter	P__ A__ N__ H___ ;
Axis-independent byte-type parameter	P__ A__ N__ D___ ;
Axis-independent word-type parameter	P__ A__ N__ S___ ;
Axis-independent 2-word-type parameter	P__ A__ N__ L___ ;

(Note 1) The sequence of addresses in a block must be as shown above.

(Note 2) Whether the parameter value is replaced or added depends on the modal state of G90/G91 when G10 is commanded.

(Note 3) Refer to Appendix Table 1 for the P, N number correspondence table.

(Note 4) For a bit type parameter, the data type will be H□ (□ is a value between 0 and 7).

(Note 5) The axis number is set in the following manner: 1st axis is 1, 2nd axis is 2, and so forth. When using multiple part system, the 1st axis in each part system is set as 1, the second axis is set as 2, and so forth.

(Note 6) Command G10L50, L11 in independent blocks. A program error (P33, P421) will occur if not commanded in independent blocks.

Example of program

(Example) To turn ON bit 2 of bit selection #6401

```
G10  L50  ;
P8  N1  H21  ;
G11  ;
```

13.11 Macro interrupt ; M96, M97

Function and purpose

A user macro interrupt signal (UIT) is input from the machine to interrupt the program being currently executed and instead call another program and execute it. This is called the user macro interrupt function.
Use of this function allows the program to operate flexibly enough to meet varying conditions.
For setting the parameters of this function, refer to the Operating Manual.

Command format

M96 P__ H__ ;	**User macro interrupt enable**
M97 ;	**User macro interrupt disable**
P	Interrupt program number
H	Interrupt sequence number

The user macro interrupt function is enabled and disabled by the M96 and M97 commands programmed to make the user macro interrupt signal (UIT) valid or invalid. That is, if an interrupt signal (UIT) is input from the machine side in a user macro interrupt enable period from when M96 is issued to when M97 is issued or the NC is reset, a user macro interrupt is caused to execute the program specified by P__ instead of the one being executed currently.
Another interrupt signal (UIT) is ignored while one user macro interrupt is being in service. It is also ignored in a user macro interrupt disable state such as after an M97 command is issued or the system is reset.
M96 and M97 are processed internally as user macro interrupt control M codes.

Interrupt enable conditions

A user macro interrupt is enabled only during execution of a program. The requirements for the user macro interrupt are as follows:

(1) A memory operation mode or MDI has been selected.

(2) The system is running in automatic mode.

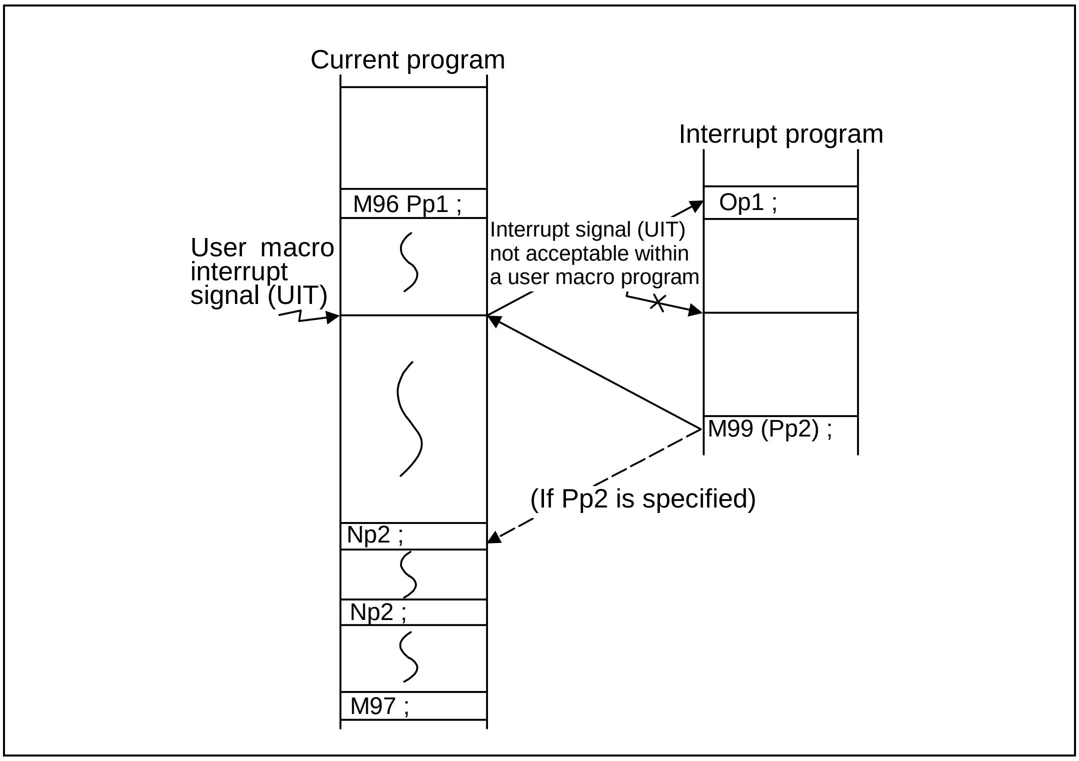
(3) No user macro interrupt is being processed.

(Note 1) A macro interrupt is disabled in manual operation mode (JOG, STEP, HANDLE, etc.)

Outline of operation

(1) When a user macro interrupt signal (UIT) is input after an M96 Pp1 ; command is issued by the current program, interrupt program Op1 is executed. When an M99 ; command is issued by the interrupt program, control returns to the main program.

(2) If M99 Pp2 ; is specified, the blocks from the one next to the interrupted block to the last one are searched for the block with sequence number Np2 ;. Control thus returns to the block with sequence number Np2 ; that is found first in the above search.


Current program
Interrupt program
M96 Pp1 ;
Op1 ;
User macro interrupt signal (UIT)
Interrupt signal (UIT) not acceptable within a user macro program
M99 (Pp2) ;
(If Pp2 is specified)
Np2 ;
Np2 ;
M97 ;

Interrupt type

Interrupt types 1 and 2 can be selected by the parameter "#1113 INT_2".

[Type 1]

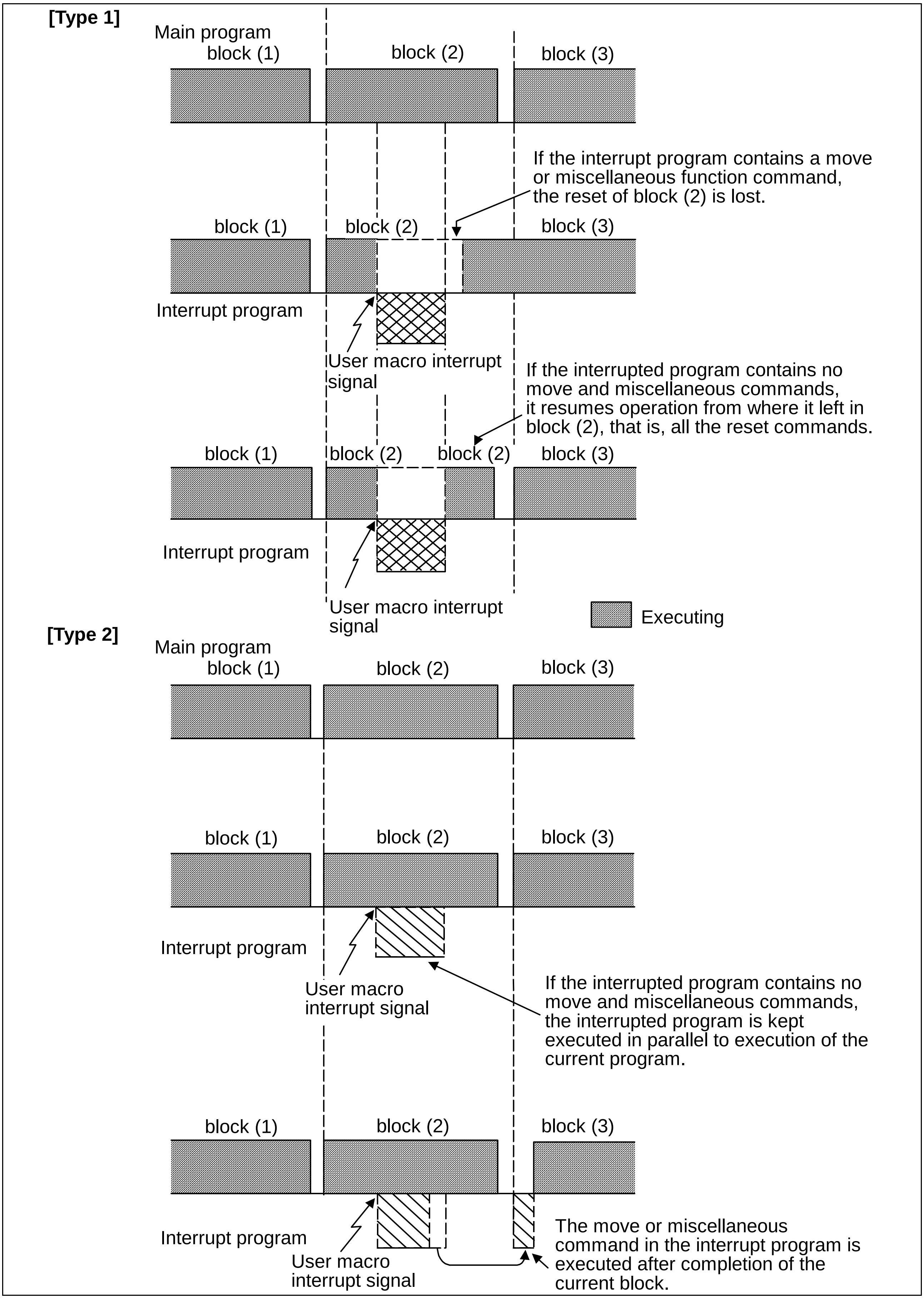
- When an interrupt signal (UIT) is input, the system immediately stops moving the tool and interrupts dwell, then permits the interrupt program to run.
- If the interrupt program contains a move or miscellaneous function (MSTB) command, the commands in the interrupted block are lost. After the interrupt program completes, the main program resumes operation from the block next to the interrupted one.
- If the interrupted program contains no move and miscellaneous (MSTB) commands, it resumes operation, after completion of the interrupt program, from the point in the block where the interrupt was caused.

If an interrupt signal (UIT) is input during execution of a miscellaneous function (MSTB) command, the NC system waits for a completion signal (FIN). The system thus executes a move or miscellaneous function (MSTB) command in the interrupt program only after input of FIN.

[Type 2]

- When an interrupt signal (UIT) is input, the program completes the commands in the current block, then transfers control to the interrupt program.
- If the interrupt program contains no move and miscellaneous function (MSTB) commands, the interrupt program is executed without interrupting execution of the current program.

However, if the interrupt program has not ended even after the execution of the original block is completed, the system may stop machining temporarily.


[Type 1]
Main program
block (1)
block (2)
block (3)
If the interrupt program contains a move or miscellaneous function command, the reset of block (2) is lost.
block (1)
block (2)
block (3)
Interrupt program
User macro interrupt signal
If the interrupted program contains no move and miscellaneous commands, it resumes operation from where it left in block (2), that is, all the reset commands.
block (1)
block (2)
block (2)
block (3)
Interrupt program
User macro interrupt signal
Executing
[Type 2]
Main program
block (1)
block (2)
block (3)
block (1)
block (2)
block (3)
Interrupt program
User macro interrupt signal
If the interrupted program contains no move and miscellaneous commands, the interrupted program is kept executed in parallel to execution of the current program.
block (1)
block (2)
block (3)
Interrupt program
User macro interrupt signal
The move or miscellaneous command in the interrupt program is executed after completion of the current block.

Calling method

User macro interrupt is classified into the following two types depending on the way an interrupt program is called. These two types of interrupt are selected by parameter "#1229 set01/bit0".

a. Subprogram type interrupt
b. Macro type interrupt

Both types of interrupt are included in calculation of the nest level. The subprograms and user macros called in the interrupt program are also included in calculation of the nest level.

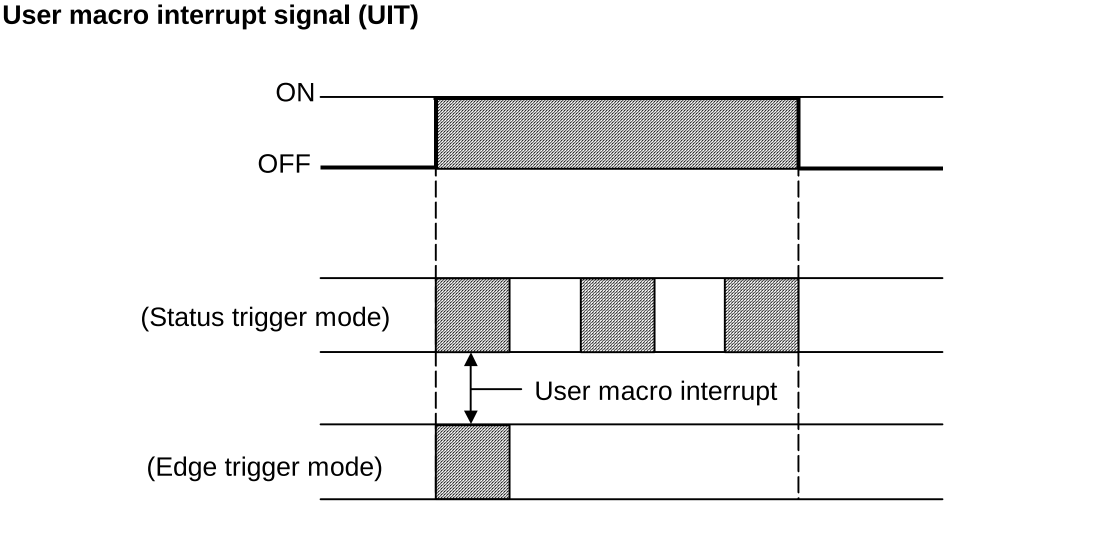
Subprogram type interrupt	The user macro interrupt program is called as a subprogram. As with calling by M98, the local variable level remains unchanged before and after an interrupt.
Macro type interrupt	The user macro interrupt program is called as a user macro. As with calling by G65, the local variable level changes before and after an interrupt. No arguments in the main program can be passed to the interrupt program.

Acceptance of user macro interrupt signal (UIT)

A user macro interrupt signal (UIT) is accepted in the following two modes. These two modes are selected by a parameter "#1112 S_TRG".

a. Status trigger mode
b. Edge trigger mode

Status trigger mode	The user macro interrupt signal (UIT) is accepted as valid when it is ON. If the interrupt signal (UIT) is ON when the user macro interrupt function is enabled by M96, the interrupt program is activated. By keeping the interrupt signal (UIT) ON, the interrupt program can be executed repeatedly.
Edge trigger mode	The user macro interrupt signal (UIT) is accepted as valid at its rising edge, that is, at the instance it turns ON. This mode is useful to execute an interrupt program once.



Accepting user macro interrupt signal (UIT)

Returning from user macro interrupt

M99 (P__) ;

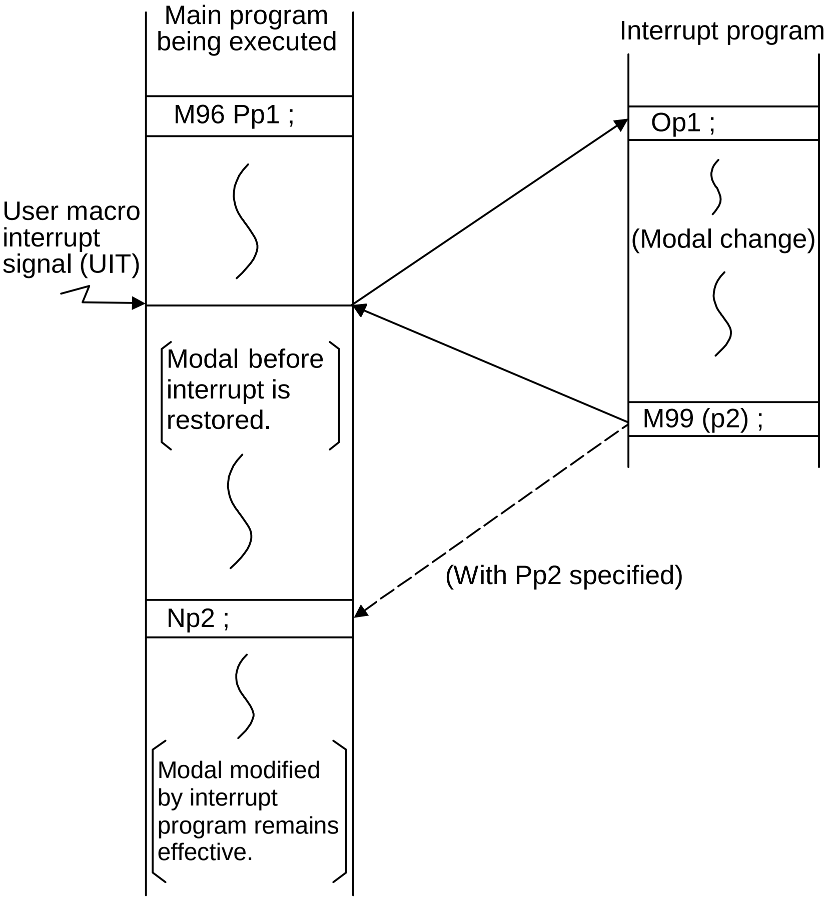
An M99 command is issued in the interrupt program to return to the main program. Address P is used to specify the sequence number of the return destination in the main program. The blocks from the one next to the interrupted block to the last one in the main program are first searched for the block with sequence number Np2 ;. If it is not found, all the blocks before the interrupted one are then searched. Control thus returns to the block with sequence number Np2 ; that is found first in the above search.

(This is equivalent to M99 P__ used after M98 calling.)

Modal information affected by user macro interrupt

If modal information is changed by the interrupt program, it is handled as follows after control returns from the interrupt program to the main program.

Returning with M99 ;	The change of modal information by the interrupt program is invalidated and the original modal information is not restored. With interrupt type 1, however, if the interrupt program contains a move or miscellaneous function (MSTB) command, the original modal information is not restored.
Returning with M99 P__ ;	The original modal information is updated by the change in the interrupt program even after returning to the main program. This is the same as in returning with M99 P__ ; from a program called by M98.


Main program being executed
Interrupt program
M96 Pp1 ;
Op1 ;
User macro interrupt signal (UIT)
(Modal change)
Modal before interrupt is restored.
M99 (p2) ;
(With Pp2 specified)
Np2 ;
Modal modified by interrupt program remains effective.

Modal information affected by user macro interrupt

Modal information variables (#4401 to #4520)

Modal information when control passes to the user macro interrupt program can be known by reading system variables #4401 to #4520.
The unit specified with a command applies.

System variable	Modal information
#4401 ~ #4421	G code (group 01 to group 21)
#4507	D code
#4509	F code
#4511	H code
#4513	M code
#4514	Sequence number
#4515	Program number
#4519	S code
#4520	T code

Some groups are not used.

The above system variables are available only in the user macro interrupt program. If they are used in other programs, program error (P241) results.

M code for control of user macro interrupt

The user macro interrupt is controlled by M96 and M97. However, these commands may have been used for other operation. To be prepared for such case, these command functions can be assigned to other M codes.
(This invalidates program compatibility.)
User macro interrupt control with alternate M codes is possible by setting the alternate M code in parameters "#1110 M96_M" and "#1111 M97_M" and by validating the setting by selecting parameter "#1109 subs_M".
(M codes 03 to 97 except 30 are available for this purpose.)
If the parameter "#1109 subs_M" used to enable the alternate M codes is not selected, the M96 and M97 codes remain effective for user macro interrupt control.
In either case, the M codes for user macro interrupt control are processed internally and not output to the outside.

Parameters

Refer to the Instruction Manual for details on the setting methods.

(1) Subprogram call validity "#1229 set01/bit 0"

1 : Subprogram type user macro interrupt
0 : Macro type user macro interrupt

(2) Status trigger mode validity "#1112 S_TRG"

1 : Status trigger mode
0 : Edge trigger mode

(3) Interrupt type 2 validity "#1113 INT_2"

1 : The executable statements in the interrupt program are executed after completion of execution of the current block. (Type 2)
0 : The executable statements in the interrupt program are executed before completion of execution of the current block. (Type 1)

(4) Validity of alternate M code for user macro interrupt control "#1109 subs_M"

1 : Valid
0 : Invalid

(5) Alternate M codes for user macro interrupt

Interrupt enable M code (equivalent to M96) "#1110 M96_M"
Interrupt disable M code (equivalent to M97) "#1111 M97_M"
M codes 03 to 97 except 30 are available.

Restrictions

(1) If the user macro interrupt program uses system variables #5001 and after (position information) to read coordinates, the coordinates pre-read in the buffer are used.

(2) If an interrupt is caused during execution of the tool diameter compensation, a sequence number (M99 P__ ;) must be specified with a command to return from the user macro interrupt program. If no sequence number is specified, control cannot return to the main program normally.

13.12 Tool change position return; G30.1 ~ G30.5

Function and purpose

By specifying the tool change position in a parameter "#8206 tool change" and also specifying a tool change position return command in a machining program, the tool can be changed at the most appropriate position.
The axes that are going to return to the tool change position and the order in which the axes begin to return can be changed by commands.

Command format

(1) The format of tool change position return commands is as follows.

G30.n ;
n = 1 to 5 Specify the axes that return to the tool change position and the order in which they return.

Commands and return order

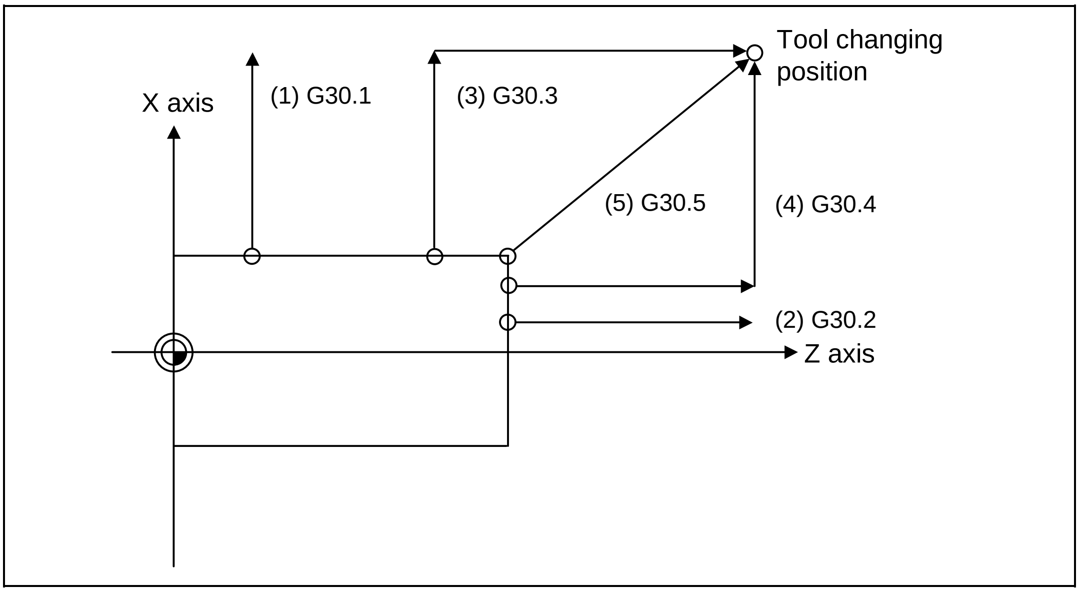
Command	Return order	
G30.1	X axis only	(→ additional axis)
G30.2	Z axis only	(→ additional axis)
G30.3	X axis → Z axis	(→ additional axis)
G30.4	Z axis → X axis	(→ additional axis)
G30.5	X axis • Z axis	(→ additional axis)

(Note 1) An arrow (→) indicates the order of axes that begin to return. A period (•) indicates that the axes begin to return simultaneously.
Example : "Z axis → X axis" indicate that the Z axis returns to the tool change position, then the X axis does.

(2) The tool change position return on/off for the additional axis can be set with parameter "#1092 Tchg_A" for the additional axis. For the order for returning to the tool change position, the axes return after the standard axis completes the return to the tool change position (refer to above table). For specifications having two additional axes, the two additional axes simultaneously return to the tool change position after the standard axis has finished its return to the tool change position.
The additional axis alone cannot return to the tool change position.

Detailed description

(1) The following drawing shows an example of operation during a tool change position return command.



(1) G30.1 command:

X axis only returns to the tool change position. (If the tool change position return is validated for the additional axis, the additional axis also returns to the tool change position after the X axis reaches the tool change position.)

(2) G30.2 command:

Z axis only returns to the tool change position. (If the tool change position return is validated for the additional axis, the additional axis also returns to the tool change position after the Z axis reaches the tool change position.)

(3) G30.3 command:

X axis returns to the tool change position, then the Z axis does the same thing. (If the tool change position return is validated for the additional axis, the additional axis also returns to the tool change position after the X and Z axes reaches the tool change position.)

(4) G30.4 command:

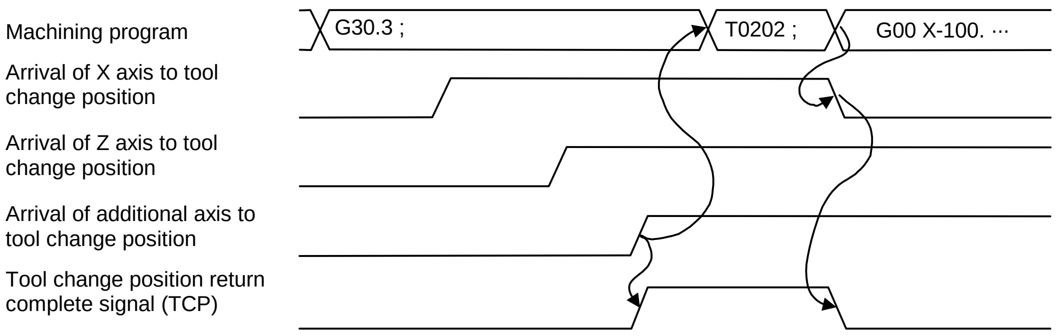
Z axis returns to the tool change position, then the X axis does the same thing. (If the tool change position return is validated for the additional axis, the additional axis also returns to the tool change position after the X and Z axes reaches the tool change position.)

(5) G30.5 command:

X and Z axes return to the tool change position simultaneously. (If the tool change position return is validated for the additional axis, the additional axis also returns to the tool change position after the X and Z axes reaches the tool change position.)

(2) After all necessary tool change position return is completed by a G30.n command, tool change position return complete signal TCP (X64B) is turned ON. When an axis out of those having returned to the tool change position by a G30.n command leaves the tool change position, the TCP signal is turned OFF.
(With a G30.3 command, for example, the TCP signal is turned ON when the Z axis has reached the tool change position after the X axis did (after the additional axis did if additional axis tool change position return is valid). The TCP signal is then turned OFF when the X or Z axis leaves the position. If tool change position return for additional axes is ON with parameter "#1092 Tchg_A", the TCP signal is turned ON when the additional axis or axes have reached the tool change position after the standard axes did. It is then turned OFF when one of the X, Z, and additional axes leaves the position.)

[TCP signal output timing chart] (G30.3 command with tool change position return for additional axes set ON)


Machining program
G30.3 ;
T0202 ;
G00 X-100. ···
Arrival of X axis to tool change position
Arrival of Z axis to tool change position
Arrival of additional axis to tool change position
Tool change position return complete signal (TCP)

(3) Tool compensation data such as tool length offset and tool nose wear compensation are temporarily canceled by the tool change position return command. The machine moves to the tool change position set in the parameters, but because the tool compensation amount is stored in the memory, it moves by the next movement command to a position with the tool compensation applied.

(4) This command is executed by dividing blocks for every axis. If this command is issued during single-block operation, therefore, a block stop occurs each time one axis returns to the tool change position. To make the next axis return to the tool change position, therefore, a cycle start needs to be specified.

13.13 Double-turret mirror image

Function and purpose

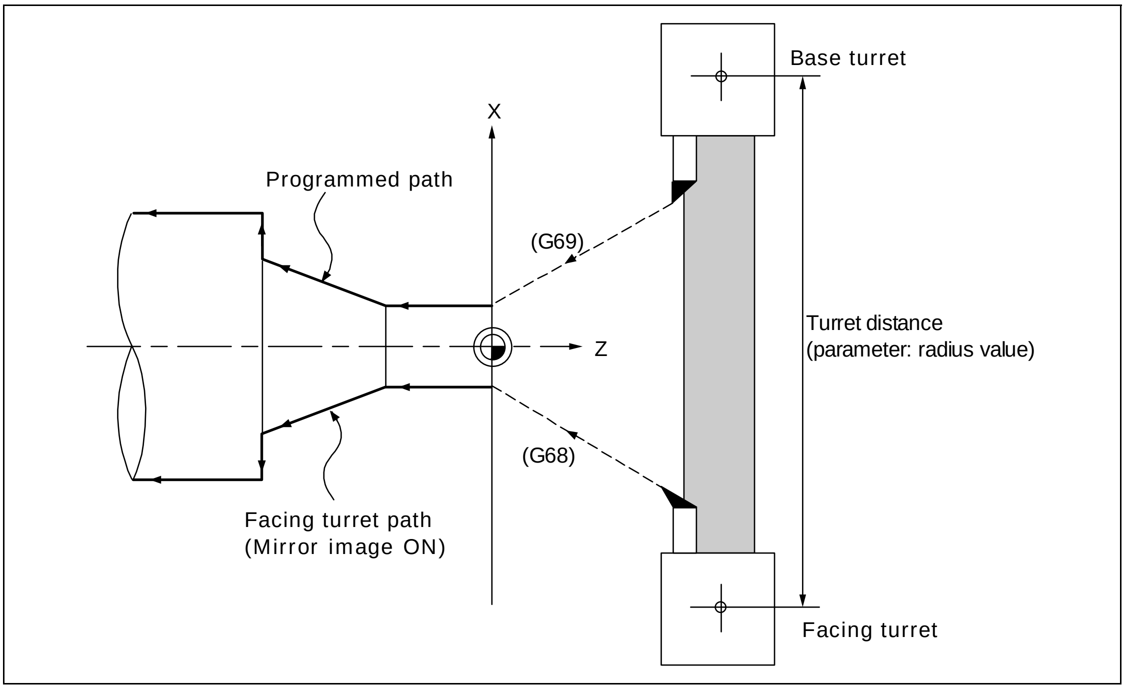
In a machine in which the base turret and double-turret are integrated, this function is used to cut with the double-turret cutter using a program created with the base turret side.
The distance between the two turrets is set in the parameters beforehand.

Command format

G68	Double-turret mirror image ON
G69	Double-turret mirror image cancel

Detailed description

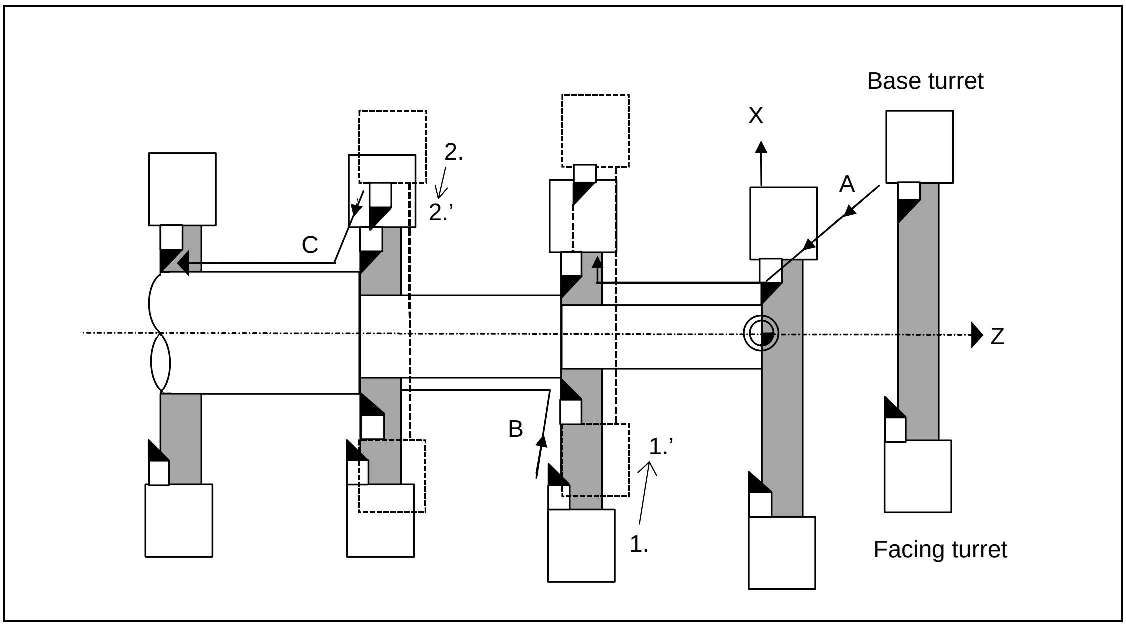
When G68 is commanded, the following program coordinate system is shifted to the double-turret side of the axis.
The axis movement direction is reversed from the program command. When G69 is commanded, the following program coordinate system will be returned to the base turret side.



Example of program and operation

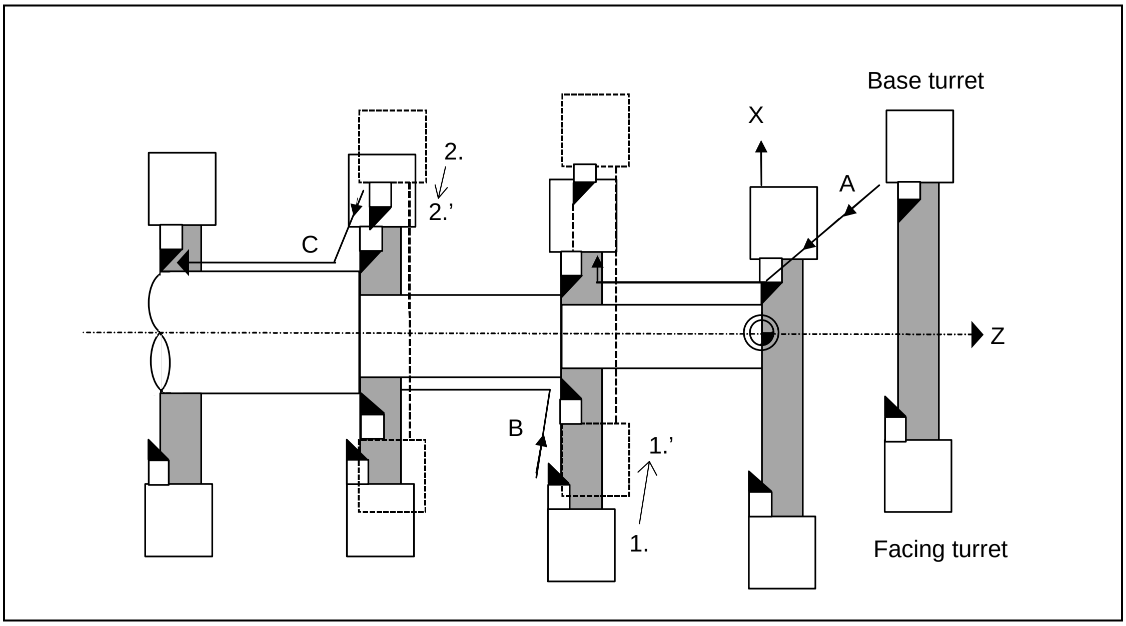
(1) Example of operation by absolute value command

T0101 ; G00 X10. Z0. ; G01 Z–40. F400 ; X20. ;	Base turret selection	Machining with base turret .... A
G68 ; T0202 ; G00 X20. Z–40. ; G01 Z–80. F200 ; X30. ;	Double-turret mirror image ON Facing turret selection……[1]	Machining with facing turret...... B
G69 ; T0101 ; G00 X30. Z–80. ; G01 X30. Z–120. F400 ;	Double-turret mirror image cancel Base turret selection………[2]	Machining with base turret C



(2) Example of operation by incremental value command

T0101 ; G00 X0. Z0. ; G01 Z–40. F400 ; X20. ;	Selection of base turret	Machining with base turret .... A
G68 ; T0202 ; G00 U–10. W0. ; G01 X20. Z–80. F200 ; X30. ;	Double-turret mirror image ON Selection of facing selection …………[1]’	Machining with facing turret...... B
G69 ; T0101 ; G00 U–10. W0. ; G01 X30. Z–120. F400 ;	Double-turret mirror image cancel Selection of base turret …………[2]’	Machining with base turret C

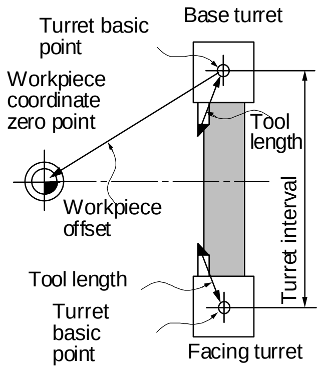
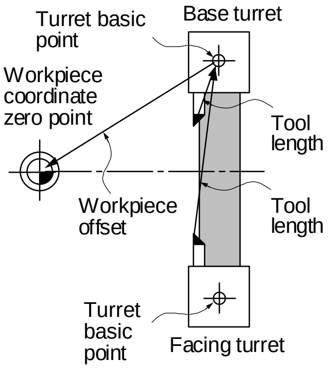
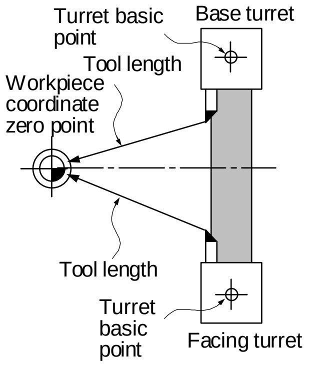


Tool compensation of turret

(1) Tool length offset

The tool length is the distance from the tool nose to the tool length base point. This also applies for the facing turret. Note that the offset amount setting value differs according to the tool length basic point position as shown below. (The settings are approached from the types in the table below.)

Tool length basic point and tool length offset

	Type A	Type B	Type C
Tool length basic point	Each turret basic point	Base turret basic point	Workpiece face center
Workpiece coordinate zero point	Workpiece face center	Workpiece face center	Workpiece face center
Turret interval	Distance between basic points of both turrets (radius value)	0	0
Workpiece offset	Workpiece coordinate zero point – base turret tool length basic point	Workpiece coordinate zero point – base turret tool length basic point	0
Tool length	Tool length basic point – tool nose position	Tool length basic point – tool nose position	Tool length basic point – tool nose position
Outline drawing	 Turret basic point Base turret Workpiece coordinate zero point Tool length Turret interval Workpiece offset Tool length Turret basic point Facing turret	 Turret basic point Base turret Workpiece coordinate zero point Tool length Workpiece offset Tool length Turret basic point Facing turret	 Turret basic point Base turret Tool length Workpiece coordinate zero point Tool length Turret basic point Facing turret

The above outline drawings apply when the machine parameter (base specifications parameter) "mirr_A" is 0. If it is 1, the value is set with the tool of the facing turret in the same direction as the tool of the base turret. At this time, the tool length base point is the tool length base point of the base turret. When "mirr_A" is 1, the sign for the X-axis tool length wear amount for the facing tool is reversed and the tool nose point is set to the opposite side (for instance, 2 → 3). When tool length measurement is executed with "mirr_A" as 0, the data will be accepted with "mirr_A" as 0.

(Setting examples)

	Mirr_A=0		Mirr_A=1	
	X	Z	X	Z
Workpiece offset	–120.	–110.	–120.	–110.
Tool length of base turret	80.	35.	80.	35.
Tool wear amount of base turret	–20.	–5.	–20.	–5.
Tool nose point of base turret	3		3	
Tool length of facing turret	150.	40.	120.	40.
Tool wear amount of facing turret	–20.	–5.	–20.	–5.
Tool nose point of facing turret	2		3	
Distance between turret	0		0	

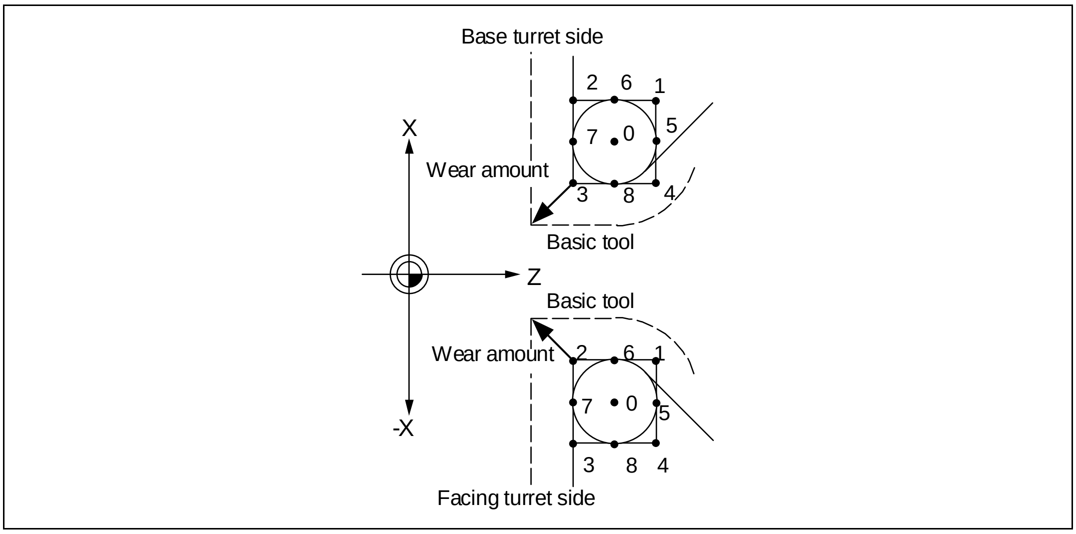
(2) Tool length wear compensation

The tool length wear offset amount is the distance from the current tool nose to the original tool nose. The original tool nose is the tool nose when the tool length offset value was set.

(3) Tool nose point with nose R compensation

The tool nose point with tool nose R compensation is as follows. It is common for both the base and facing turrets.

Tool wear offset amount and nose R tool nose point



(4) Distance between turrets

The distance between the turrets is the distance from the tool length base point of the facing turret to the tool length base point of the base turret. It is set by parameter only for the X axis. "0" is set when the tool length base point is common.
Machine parameter (Base specifications parameter) mirofs
Setting range: 0 to 99999.999 (mm) (radial value)

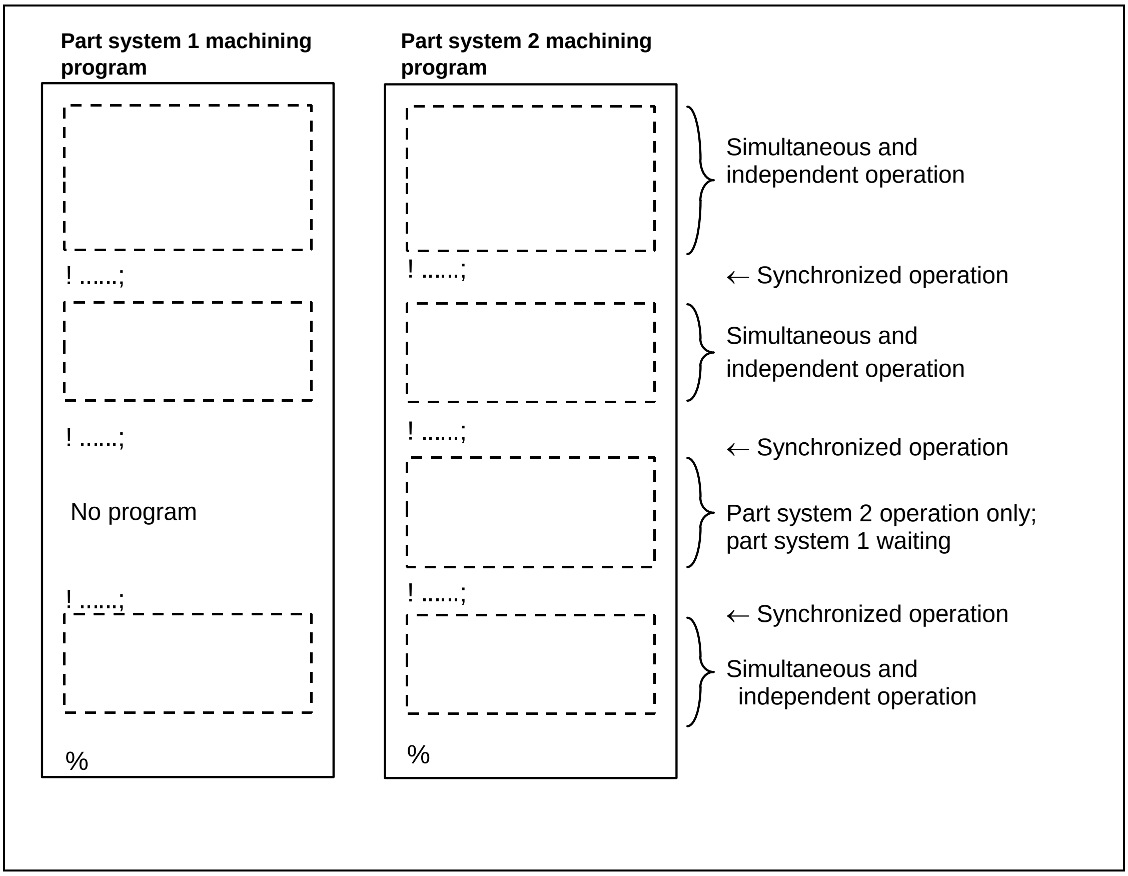
13.14 Synchronizing operation between part systems

⚠CAUTION

⚠ When programming a multi-part system, carefully observe the movements caused by other part systems' programs.

Function and purpose

The multi-axis, multi-part system complex control NC system can simultaneously run multiple machining programs independently. The synchronizing-between-part systems function is used in cases when, at some particular point during operation, the operations of part systems 1 and 2 are to be synchronized or in cases when the operation of only one part system is required.

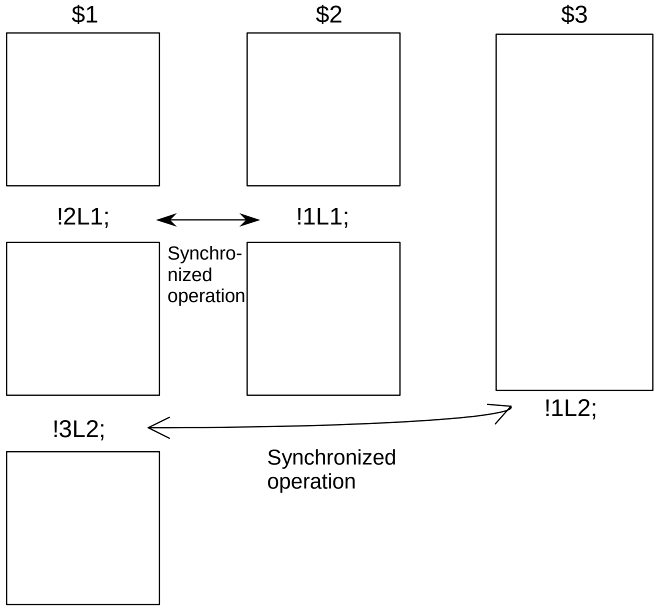

Part system 1 machining program
Part system 2 machining program
! ......;
! ......;
No program
! ......;
%
! ......;
! ......;
! ......;
%
Simultaneous and independent operation
← Synchronized operation
Simultaneous and independent operation
← Synchronized operation
Part system 2 operation only; part system 1 waiting
← Synchronized operation
Simultaneous and independent operation

Command format

(1) Command for synchronizing with nth part system

```
!nLl;
```

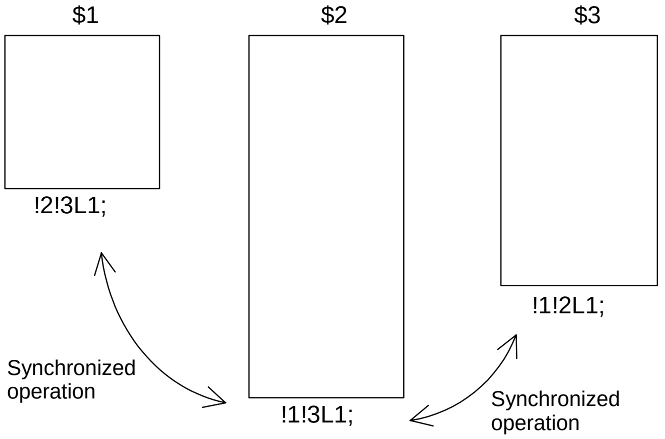
n : Part system number
l : Synchronizing number 01 to 9999



(2) Command for synchronizing among three part systems

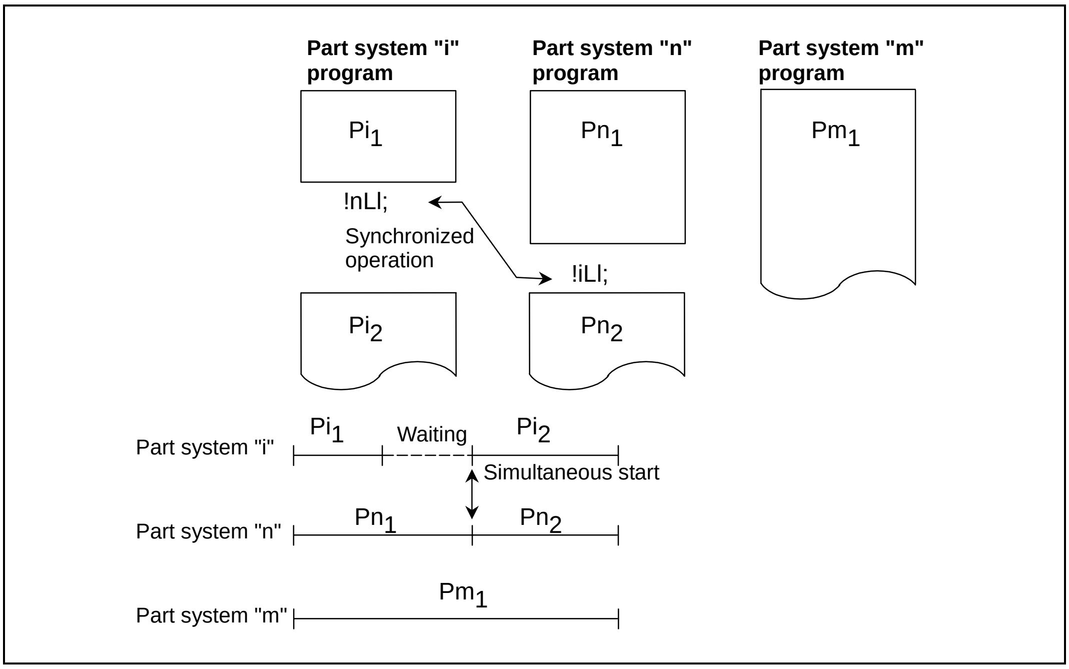
```
!n!m･･･Ll;
```

n, m : Part system number n = m
l : Synchronizing number 01 to 9999

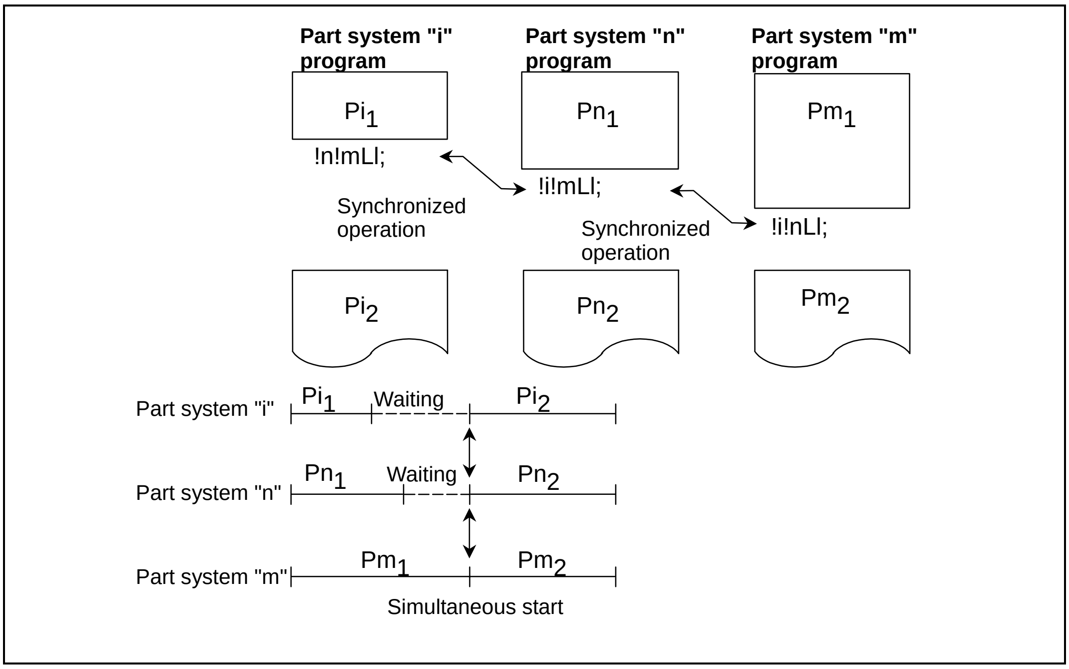


Detailed description

(1) When the "!nLl" code is issued from the part system "i", the operation of that program will wait until the "!iLl" code is issued from the part system "n".
When the "!iLl" code is issued, the programs of both part systems "i" and "n" will start running simultaneously.



(2) Synchronizing among three part systems is as follows. When the "!n!mLl" command is issued from the part system "i", the program of part system "i" operation will wait until the "!i!mLl" command is issued from the part system "n" and the "!i!nLl" command is issued from the part system "m".
When the synchronizing commands are issued, programs of part systems "i", "n" and "m" will start operating simultaneously.



(3) Program error (P35) occurs when an illegal system number has been issued.

(4) The synchronizing command is normally issued in a single block. However, if a movement command or M, S or T command is issued in the same block, whether to synchronize after the movement command or M, S or T command or to execute the movement command or M, S or T command after synchronization will depend on the parameter (#1093 Wmvfin).
#1093 Wmvfin 0: Synchronize before movement command execution.
1: Synchronize after executing movement command.

(5) If there is no movement command in the same block as the synchronizing command, when the next block movement starts, synchronization may not be secured between the part systems. To synchronize the part systems when movement starts after synchronization, issue the movement command in the same block as the synchronizing command.

(6) Synchronizing is done only while the part system to be synchronized is operating automatically. If this is not possible, the synchronizing command will be ignored and operation will advance to the next block.

(7) The L command is the synchronizing identification number. The same numbers are synchronized but when they are omitted, the numbers are handled as L0.

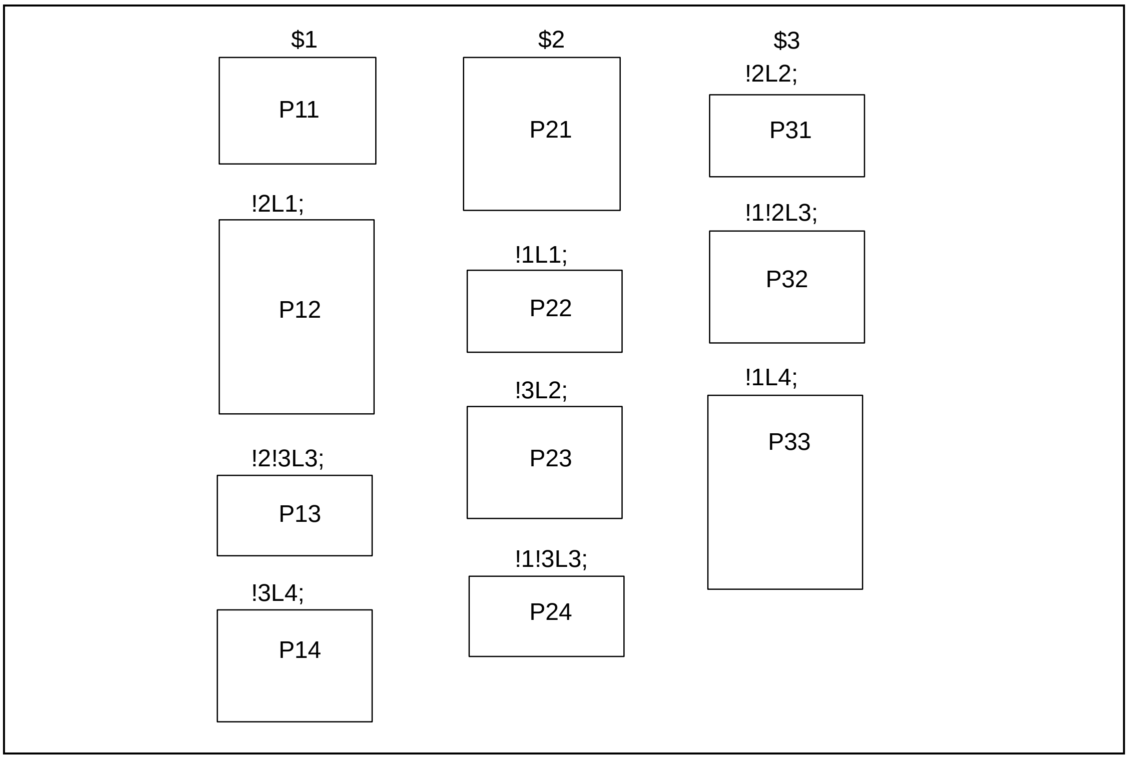
(8) The synchronizing command designates the number of the other part system number to be synchronized, and can also be issued along with its own part system number.

(Example) Part system "i" command: !i!n!mLl;

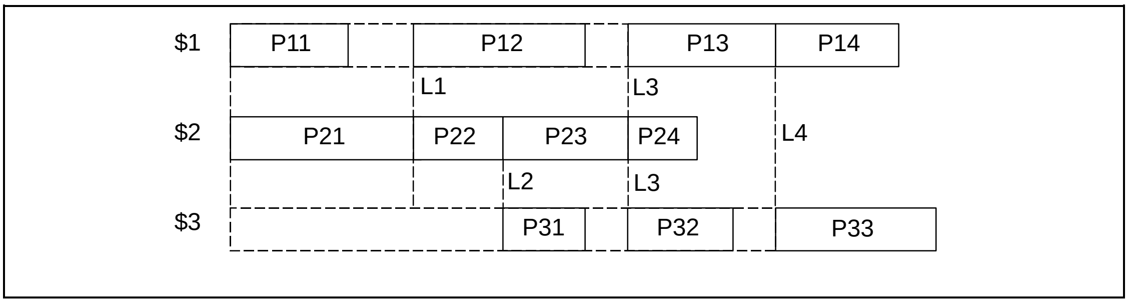
(9) When the part system No. is omitted (when only "!" is issued), part system 1 will be handled as "!2" and part system 2 as "!1". The command using only "!" cannot be used for synchronizing with part system 3 and following.
If the command using only "!" is used for part system 3 or following, the program error (P33) will occur.

(10) "SYN" will appear in the operation status section during synchronization. The synchronizing signal will be output to the PLC I/F. ($1: X63C, $2: X6BC, $3: X73C, $4: X7BC, $5: X83C, $6: X8BC, $7: X93C)

Example of synchronizing between part systems



The above programs are executed as follows:



13.15 Start Point Designation Synchronizing (Type 1); G115

Function and purpose

The part system can wait for the other part system to reach the start point before starting itself.

The synchronization point can be set in the middle of a block.

Command format

!nL1 G115 X_ Z_ C_ ;

!nL1	Synchronizing command
G115	G command
X_ Z_ C_	Start point (Command axis and workpiece coordinate values for checking synchronization of other part system.)

Detailed description

(1) Designate the start point using the workpiece coordinates of the other part system.

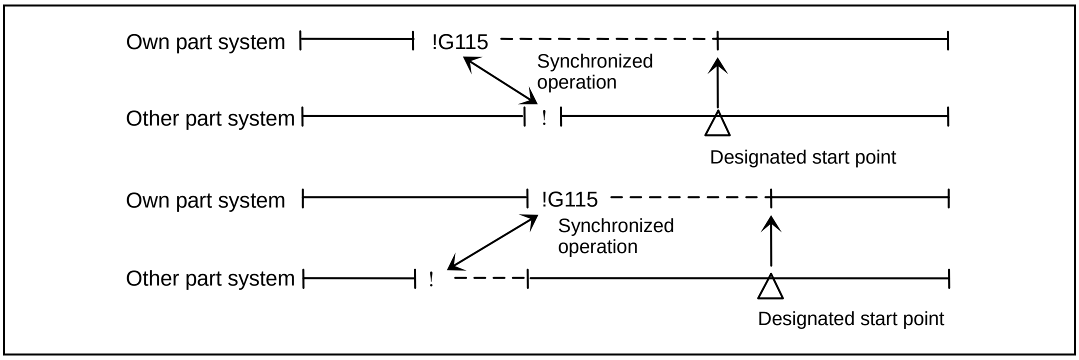
(2) The start point check is executed only for the axis designated by G115.

(Example) !L2 G115 X100.;

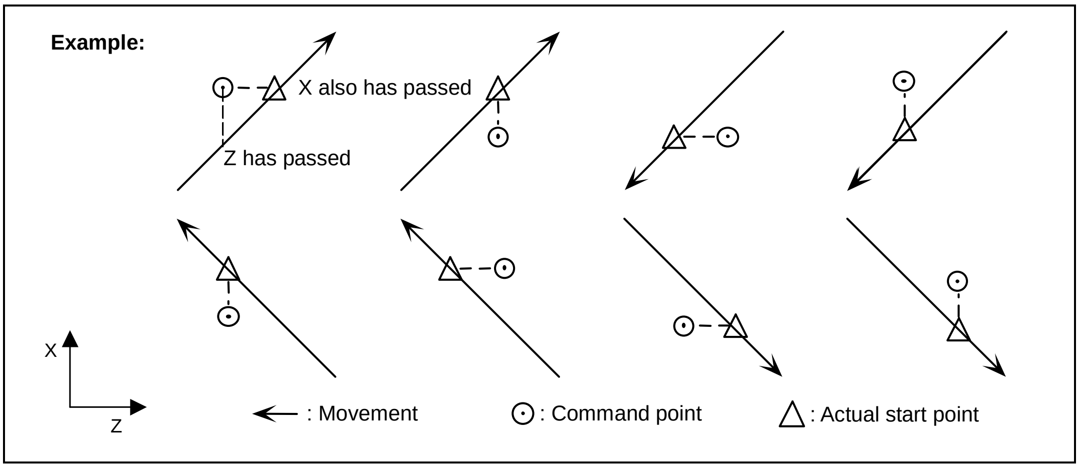
Once the other part system reaches X100., the own part system will start. The other axes are not checked.

(3) The other part system starts first when synchronizing is executed.

(4) The own part system waits for the other part system to move and reach the designated start point, and then starts.

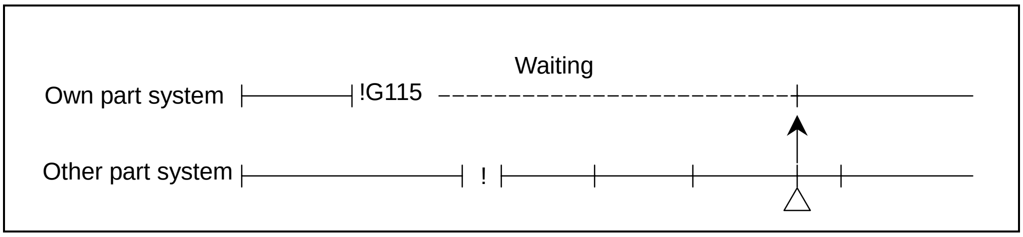


(5) When the start point designated by G115 is not on the next block movement path of the other part system, the own system starts once the other part system has reached all of the start point axis coordinates.

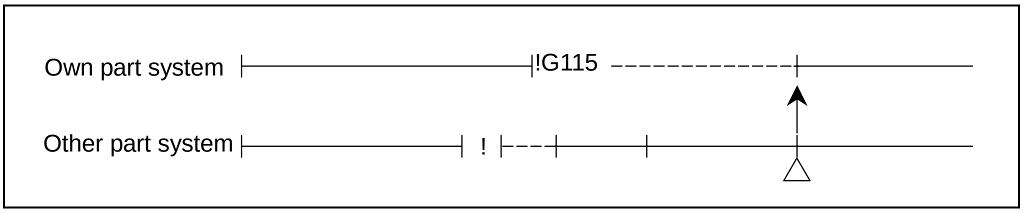


(6) The following operation is executed by parameters (base specification parameter #1229 set01/bit5) when the start point cannot be determined by the next block movement of the other system.

(a) When the parameter is ON
Operation waits until the start point is reached by the movement in the next and subsequent blocks.



(b) When the parameter is OFF
The own part system starts upon completion of the next block movement.



(7) The waiting status continues when the G115 command has been duplicated between part systems.

(8) Designate the start point using the workpiece coordinates of the other part system.

(9) Program error "P33" occurs when the G115 command is issued for 3 part systems.

(10) The single block stop function does not apply for the G115 block.

(11) When the G115 command is issued continuously in 2 or more blocks, the block in which it was issued last will be valid.

(12) A program error (P32) will occur if an address other than an axis is designated in G115 command block.

13.16 Start Point Designation Synchronizing (Type 2); G116

Function and purpose

Starting of the other part system can be delayed until the own part system reaches the designated start point.
The synchronization point can be set in the middle of a block.

Command format

!nL1 G116 X_ Z_ C_ ;

!nL1	Synchronizing command
G116	G command
X_ Z_ C_	Start point (Command axis and workpiece coordinate values for checking synchronization of own part system.)

Detailed description

(1) Designate the start point using the workpiece coordinates of the own part system.

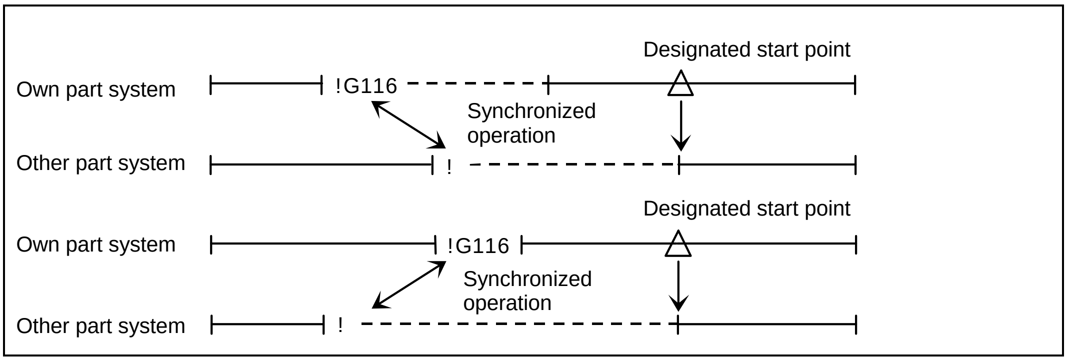
(2) The start point check is executed only for the axis designated by G116.

(Example) !L1 G116 X100.;

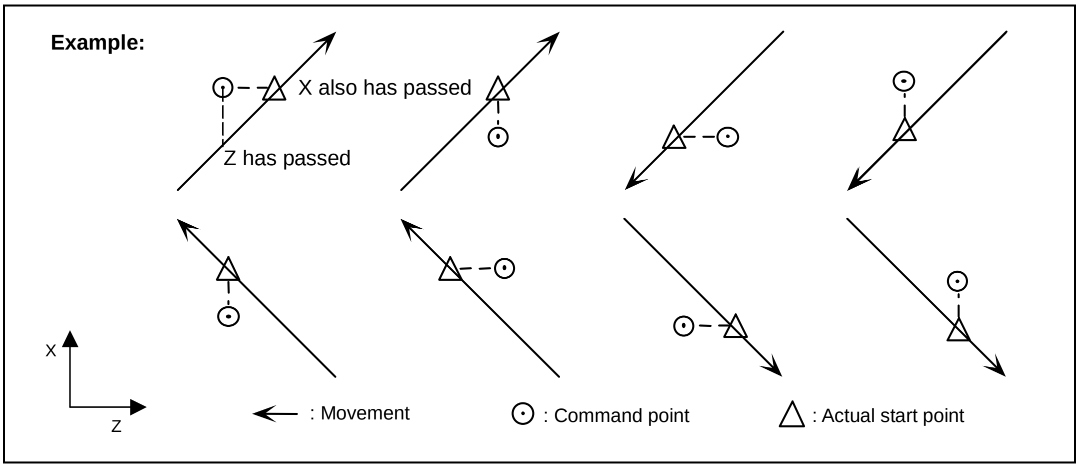
Once the own part system reaches X100., the other part system will start. The other axes are not checked.

(3) The own part system starts first when synchronizing is performed.

(4) The other part system waits for the own part system to move and reach the designated start point, and then starts.

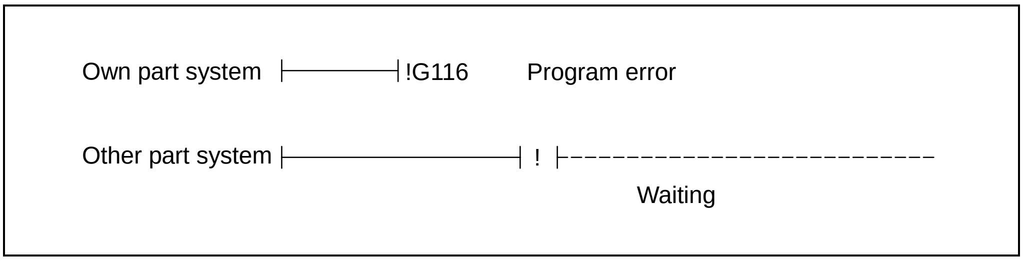


(5) When the start point designated by G116 is not on the next block movement path of the own system, the other system starts once the own system has reached all of the start point axis coordinates.

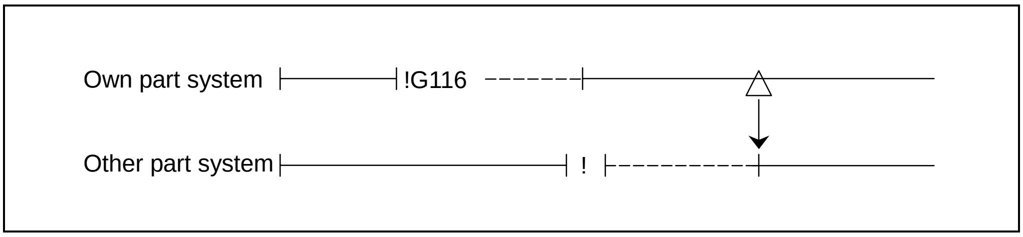


(6) The next operation is executed by parameters (base specification parameter #1229 set01/bit5) when the start point cannot be determined by the next block movement of the own part system.

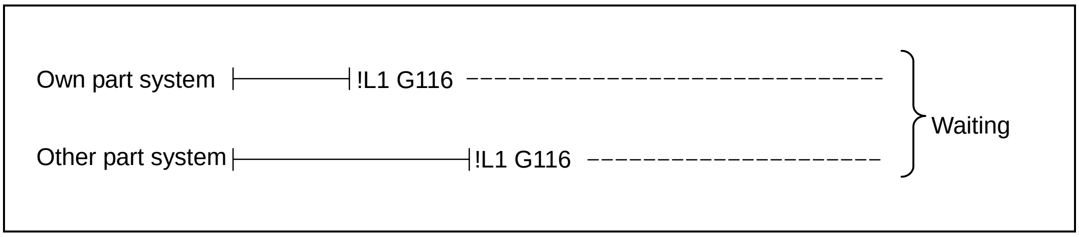
(a) When the parameter is ON
Program error "P33" occurs before the own part system moves.



(b) When the parameter is OFF
The other part system starts upon completion of the next block movement.

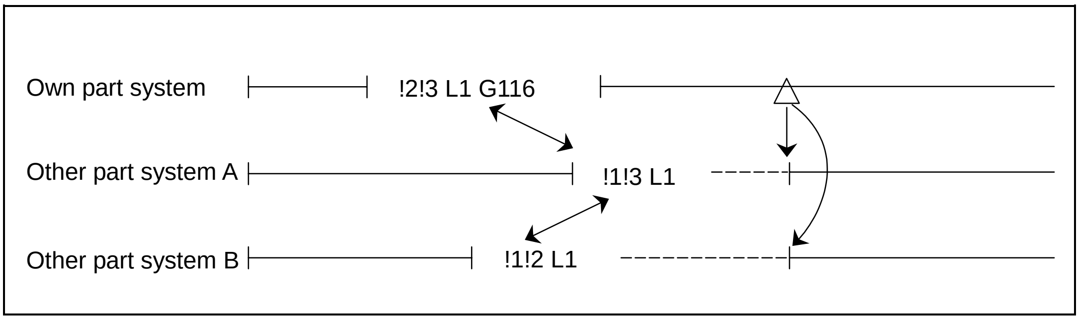


(7) If the G116 command overlaps between part systems, the waiting state will continue.



(8) Designate the start point using the workpiece coordinates of each part system.

(9) The two other part systems start when the G116 command is issued for 3 part systems.



(10) The single block stop function does not apply for the G116 block.

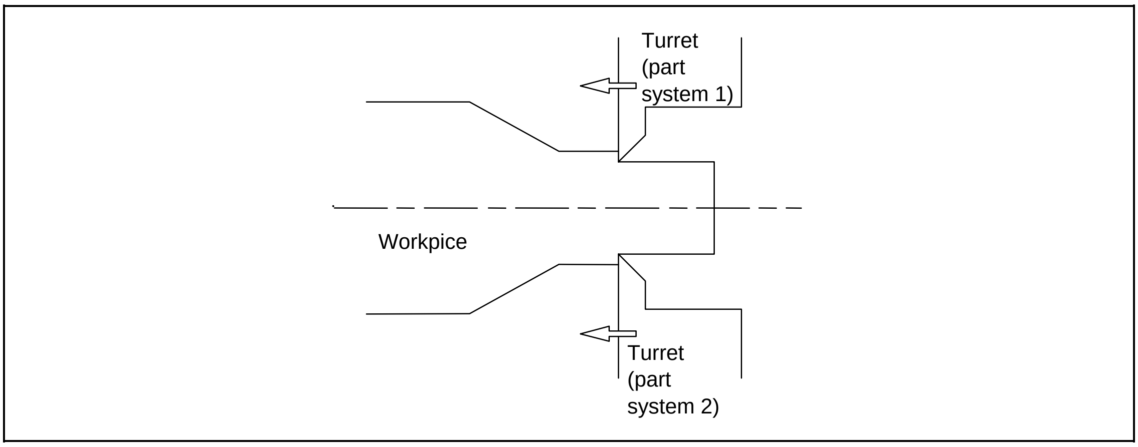
(11) When the G116 command is issued continuously in 2 or more blocks, the block in which it was issued last will be valid.

(12) A program error (P32) will occur if an address other than an axis is designated in G116 command block.

13.17 Balance cut

Function and purpose

The timing for starting the operation of the part system 1 turret and part system 2 turret can be synchronized.



When machining a relatively thin and long workpiece with a lathe, the workpiece could slack, and highly accurate machining may not be possible.
In this case, if the cutters are applied simultaneously from both sides of the workpiece and the workpiece is machined while synchronizing these (balance cut), the slack can be suppressed. Furthermore, the machining time can be shortened by machining with two cutters.
With this function, the movement of two turrets belonging to different part systems can be completely synchronized, so the following type of machining can be done easily.

Command format

G15 ;
G14 ;

G15	Balance cut command ON (modal)
G14	Balance cut command OFF (modal)

Detailed description

(1) Command G15 and G14 in independent blocks.

(2) G15 and G14 are modals. In the CNC's initial state, the G14 balance cut command is OFF.

(3) When the G15 command is issued, the synchronization between part systems will be maintained for all blocks until the G14 command is issued.

(4) The sections of blocks enclosed by G15 and G14 are created in the machining programs for part system 1 and part system 2.
The sections enclosed by G15 and G14 are synchronized one block at a time in each part system.

```
<Part system 1>           <Part system 2>
    :                         :
G15;                      G15;
N10 G01 X10. F100;        N10 G01 X10. F50;
N20 G01 X20.;             N20 G01 X20.;
    :                         :
    :                         :
G14                       G14
    :                         :
```

The start timing of the $1 and $2 blocks is synchronized.

(5) If G15 or G14 is commanded in one part system, movement will not advance until the same G code is commanded in the other part system.

(6) If G15 is commanded in both part system 1 and part system 2, synchronization will be carried out one block at a time until G14 is commanded.

(7) After G14 is commanded in both part systems, part system 1 and part system 2 will operate independently.

Example of operation

```
<System 1>                <System 2>
    ⋮                         ⋮
G15;                      G15;                      …(1)
G00 X40. Z0.              G00 X-40. Z250.           …(2)
G01 W-30. F1000           G01 W-130. F500           …(3)
G01 U40.W-70.             G01 X-80. Z50. F1000      …(4)
G14                       G14                       …(5)
G01 X100.Z50.             S200                      …(6)
G01 Z30.                  G00 X-100.
    ⋮                         ⋮
```

(1) Balance cut is turned ON with the G15 command.

(2) (3) Processing of this block will end faster for part system 1 than part system 2. The part system 1 will wait for the part system 2 process to end, and will shift the next block for both part system 1 and part system 2.

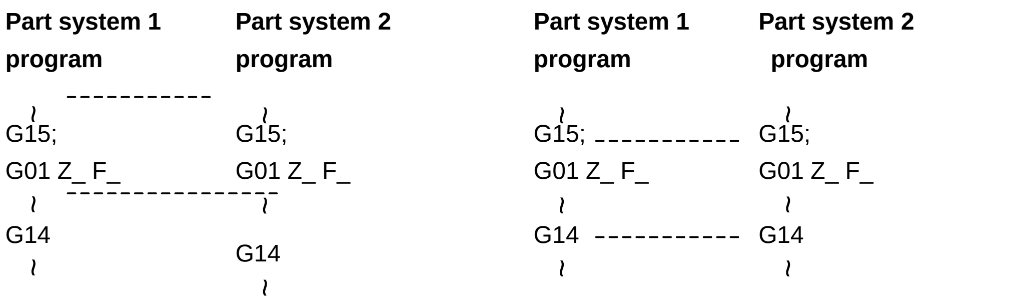
(4) The movement amount and movement speed are the same for each part system, so synchronized movement will take place.

(5) Balance cut is turned OFF with the G14 command.

(6) Each part system will operate independently after this.

Precautions · Restrictions

(1) If G15 is commanded in one part system, the part system will wait for G15 to be commanded in the other part system. Synchronization will start when G15 has been commanded in both part systems. If G14 is commanded first in one part system, the other part system will enter the waiting state. Shifting to the next block will not be possible. Thus, always match the number of blocks between the ON mode and OFF mode for both part system 1 and part system 2 when commanding balance cut.

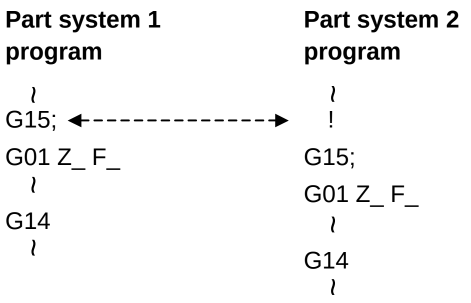


```
Part system 1     Part system 2          Part system 1     Part system 2
program           program                program            program
   ~                 ~                      ~                  ~
G15;              G15;                   G15; ----------- G15;
G01 Z_ F_         G01 Z_ F_              G01 Z_ F_         G01 Z_ F_
   ~                 ~                      ~                  ~
G14                                      G14  ----------- G14
   ~              G14                       ~                  ~
                     ~
```

Part system 1 can shift to the next block, but part system 2 will continue waiting and cannot shift to the next block.

By matching the number of blocks between G15 and G14, both part systems can shift to the blocks following G14.

(2) Take special care when using the synchronizing command with the G15 command.
If one part system is waiting for synchronization with the "!" (synchronization) code and the other part system enters the synchronization state with the G15 command, both part systems will be in the synchronization state, and will not shift to the next block. Command so that waiting for synchronization with G15 and waiting for synchronization with the "!" code do not occur simultaneously.



```
Part system 1          Part system 2
program                program
   ~                      ~
G15; <--------------->    !
G01 Z_ F_              G15;
   ~                   G01 Z_ F_
G14                       ~
   ~                   G14
                          ~
```

Stops in the waiting state at the sections shown with arrows.

(3) If the "!" (synchronization) code is commanded in the G15 mode, it will be handled as a one block command with no movement, and synchronization will not be carried out. Thus, do not command this.

(4) This function is valid only for part system 1 and part system 2. If commanded for the part system 3 and following, a program error P34 will occur.

(5) A block that does not contain movement such as G4, M, S, T, B command or a variable command is handled as 1 block, and synchronization will be carried out.

(6) If G14 is designated when G15 is not commanded (when balance cut is OFF), the G14 command will be handled as a block with no process.

(7) If subprogram call, macro call or PLC interrupt are carried out while balance cut is ON, the block configuring the subprogram will be handled as one block, and synchronization will be carried out.

13.18 2-part system simultaneous thread cutting cycle

Function and purpose

The 2-part system simultaneous thread cutting cycle function allows part system 1 and part system 2 to perform thread cutting simultaneously for the same spindle.
Featured in this cycle is the command (G76.1) for simultaneously cutting threads in two places, which is known as the "2-part system simultaneous thread cutting cycle I".

13.18.1 Parameter setting command

Command format

The various parameters for thread cutting are set by commands.

```
G76 Pmra QΔd Rd;
```

Address		Meaning
P	m	Number of cutting passes for finishing (model) : 00 to 99 (times)
	r	Chamfering amount (model) : 00 to 99 (0.1mm/rev) This sets the chamfering width based on the thread lead 1 across a range from 0.0l to 9.9l with a 2-digit integer with the decimal point omitted.
	a	Tool nose angle (thread angle) (model) : 00 to 99 (°) The angle from 0° to 99° is assigned in 1° units. "m", "r" and "a" are commanded in succession in address P. **(Example)** When "m" = 5, "r" = 1.5 and "a" = 0°, P is 051500 and the leading and trailing "0" cannot be omitted.
Q	Δdmin	Minimum cut amount (modal): 0 to 99999 (µm) This is the clamping value for guaranteeing the cut amount of a single cutting pass and it is valid only for rough cutting. Finishing is performed by the cutting allowance designated separately. When the calculated value for the cut amount of a single cutting pass is less than Δd min, it is clamped by "Δd min".
R	d	Finishing allowance (model) : 0 to 9999 (µm)

Detailed description

(1) The data is set in setup parameters for each part system.

(2) Issue the command for each part system.

13.18.2 2-part system simultaneous thread cutting cycle I ; G76.1

Command format

G76.1 X/U Z/W Ri Pk QΔd Fl;

X/U X-axis end point coordinates of thread section
... The X-axis coordinates of the end point at the thread section are commanded with absolute or incremental values.

Z/W Z-axis end point coordinates of thread section
... The Z-axis coordinates of the end point at the thread section are commanded with absolute or incremental values.

i Taper height component (radial value) at thread section
... A straight thread is created when i = 0.

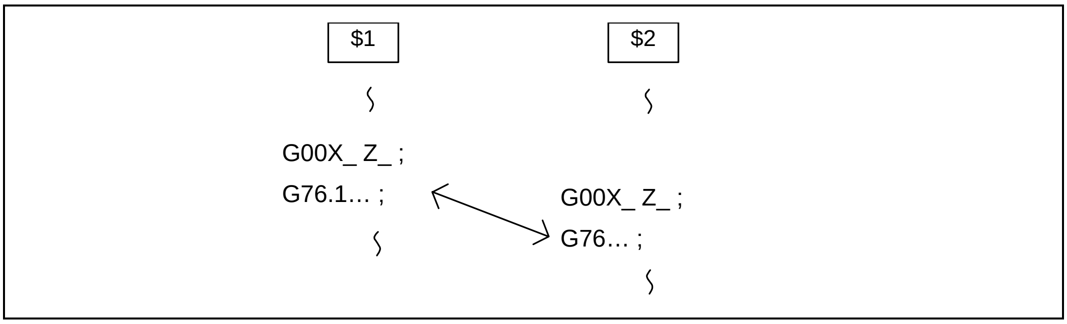
k Thread height
... The thread height is commanded with a positive radial value.

Δd Cut amount
... The cut amount for the first cutting pass is commanded with a positive radial value.

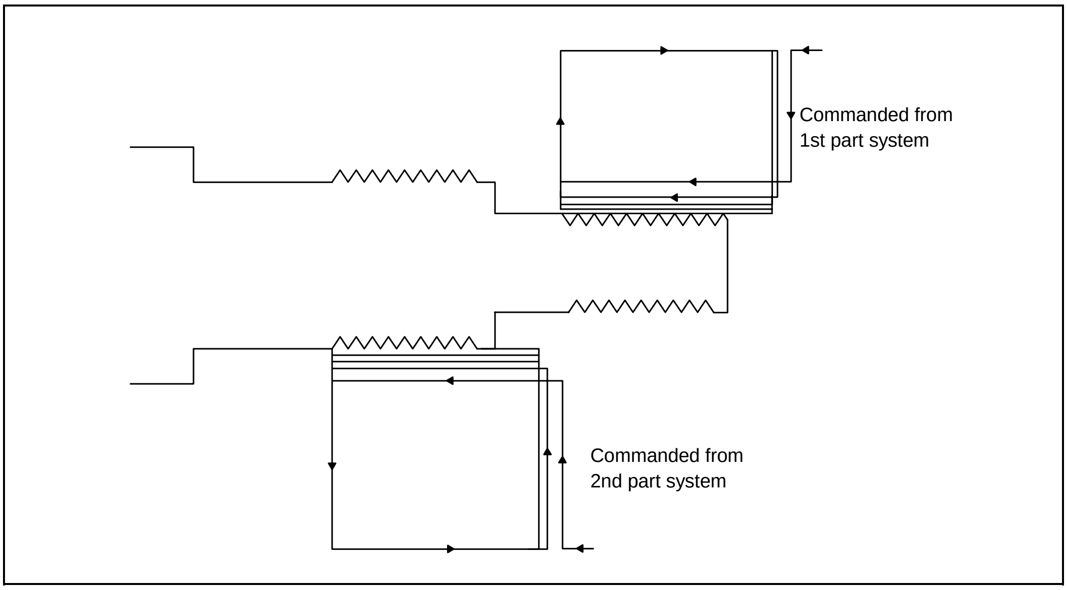
l Thread lead

Detailed description

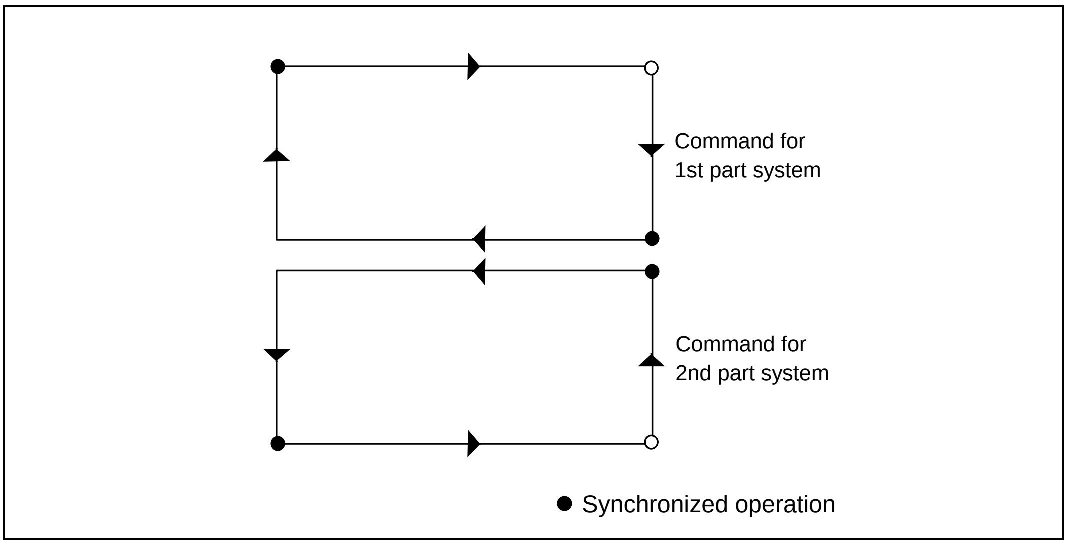
(1) When G76.1 is issued by part system 1 and part system 2, synchronized operation is done until the command is issued to another part system. The thread-cutting cycle starts when the commands are aligned properly.



(2) In the G76.1 cycle, G76.1 is issued simultaneously by part system 1 and part system 2, and the thread is cut in synchronization at the start and end of thread cutting.



(3) In one cycle, operation is synchronized at the start and end of the thread cutting.



(4) The same precautions for thread-cutting command (G33), thread cutting cycle (G78) and compound type thread cutting cycle (G76) apply to this cycle.

(5) As the type threads are cut in two places by the G76.1 command, the various commands do not need to be the same. Each of them can be issued independently.

(6) Thread cutting controls the Z axis position while tracking the spindle encoder rotation. Thus, the relative relation of the spindle position detected by the spindle encoder and the Z axis will change with the following elements.

(a) Z axis feedrate (spindle rotation speed ∗ screw pitch)

(b) Cutting feed acceleration/deceleration time constant

(c) Position loop gain

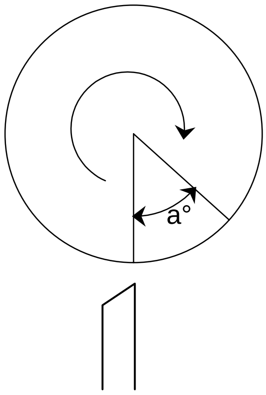
Thus, the above conditions must be the same from the start to end of machining.

13.18.3 2-part system simultaneous thread cutting cycle II ; G76.2

Command format

```
G76.2 X/U_  Z/W_  Ri Pk QΔd Aa F1;
```

(1) Thread cutting start shift angle



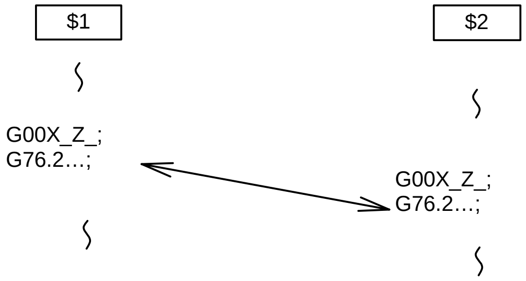
The thread cutting command starts movement after waiting for the spindle encoder's one rotation synchronization signal. However, the start point can be delayed by the a° amount.

a°: Thread cutting start angle

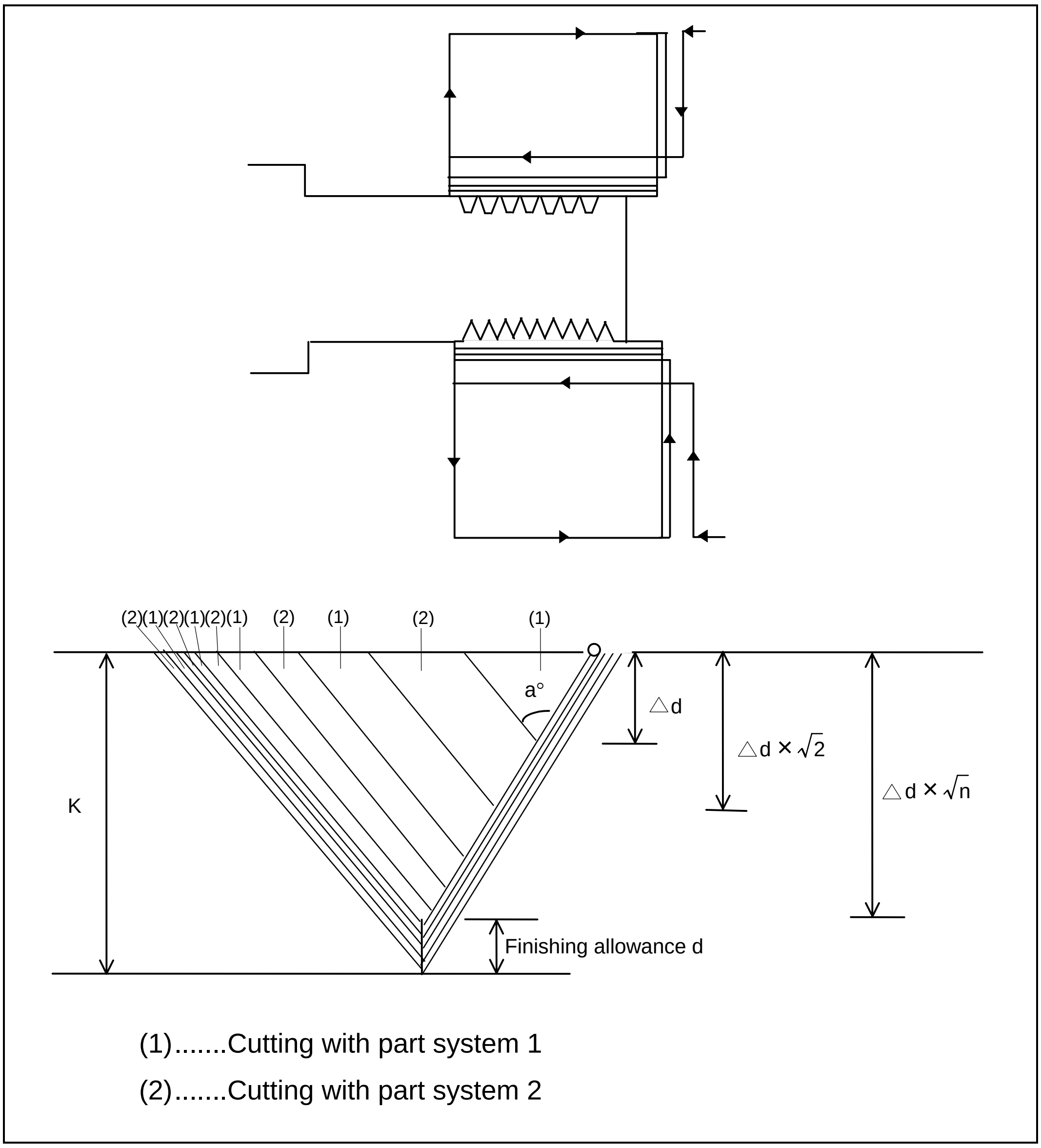
The meanings of the addresses other than A are the same as the 2-part system simultaneous thread cutting cycle I.

Detailed description

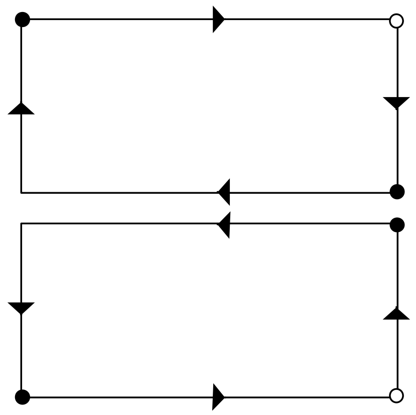
(1) When G76.2 is issued by part system 1 and part system 2, synchronized operation is done until the command is issued to another system. The thread cutting cycle starts when the commands are aligned properly.



(2) G76.2 assumes the same thread cutting, and deeply cuts in with the cutting amount using part system 1 and part system 2 alternately.


(2)(1)(2)(1)(2)(1)
(2)
(1)
(2)
(1)
a°
△d
△d × √2
△d × √n
K
Finishing allowance d
(1).......Cutting with part system 1
(2).......Cutting with part system 2

(3) In one cycle, operation is synchronized at the start and end of the thread-cutting.



● Synchronized operation

(4) The same precautions for thread-cutting command (G33), thread-cutting cycle (G78) and compound thread-cutting cycle (G76) apply to this cycle.

(5) G76.2 is the same thread cutting, so the various parameters, thread section, taper height, screw thread height, cutting amount and thread lead must be commanded to the same values for part system 1 and part system 2.
Note that the start shift angle can be commanded to match the thread cutting state.

(6) Thread cutting controls the Z axis position while tracking the spindle encoder rotation. Thus, the relative relation of the spindle position detected by the spindle encoder and the Z axis will change with the following elements.

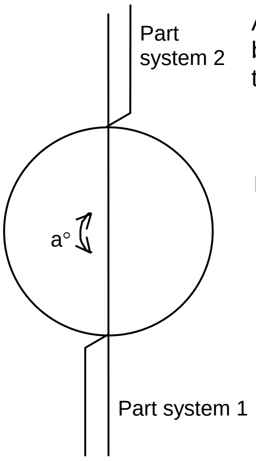
(a) Z axis feedrate (spindle rotation speed ∗ screw pitch)

(b) Cutting feed acceleration/deceleration time constant

(c) Position loop gain

Thus, with G76.2 which is same thread cutting, the parameters must be set so that the conditions are the same for part system 1 and part system 2.

(7) Thread cutting start shift angle command



As shown on the left, if the part system 1 and part system blades oppose at 180°, the part system 1 and part system 2 thread cutting start shift angle difference is set to 180°.

Example)

```
 $1                          $2
  ⟆                           ⟆
G76.2X_ Z_ A0.;        G76.2X_ Z_ A180.;
  ⟆                           ⟆
```

(8) When G76.2 and G76.1 are commanded
The part systems, in which each are commanded, will carry out the G76.1 and G76.2 movements. However, G76.2 part system will assume that the other part system is using G76.2 when cutting the threads, so the thread grooves will not be guaranteed.

13.19 Miscellaneous function output during axis movement; G117

Function and purpose

This function controls the timing of the miscellaneous function to be output. The miscellaneous function is output when the position designated in axis movement is reached.

Command format

G117 X_ Z_ M_ S_ T_ (2nd M)_ ;	
X Z	Start point of operation
M_ S_ T_ (2nd M)_	Miscellaneous function

Detailed description

(1) This command is issued independently immediately before the block with the movement command that activates the miscellaneous function.

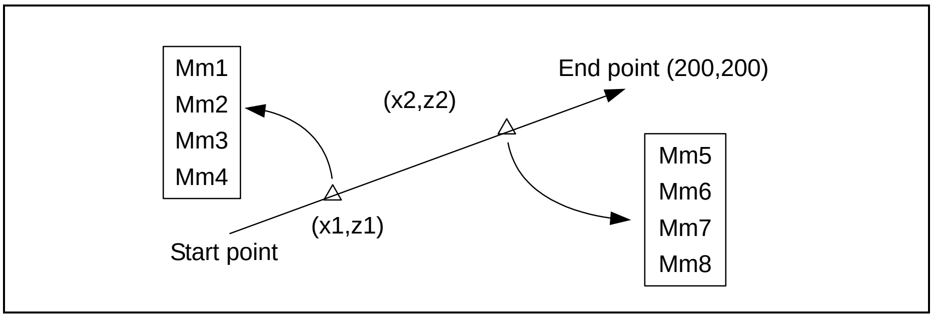
(2) Single block stop does not apply to this command.

(3) The maximum number of groups to which the miscellaneous functions in the G117 block can be issued is as follows:

M commands	: 4 sets
S commands	: 2 sets
T commands	: 1 set
2nd miscellaneous function	: 1 set

(4) This command can be issued in up to two consecutive blocks.
When issued in three or more consecutive blocks, the last two blocks will be valid.

(Example) G117 Xx1 Zz1 Mm1 Mm2 Mm3 Mm4;
G117 Xx2 Zz2 Mm5 Mm6 Mm7 Mm8;
G01 X200 Z200;



(5) When the operating start point commanded by G117 is not on the movement path, the miscellaneous function will be output once the movement has reached all the coordinate values of the operating start point. In addition, only the commanded axis is checked.

(Example) G117 X100. M××; M×× is output when X100. is reached.

(Note) The other axes are not subject to the check.

(6) The completion of the miscellaneous function in the previous group is checked at the operating start point, and the miscellaneous function of the next group is output. Thus, normal PLC interfacing is possible.

(7) A miscellaneous function issued in the same block as the block with the movement command is output before the movement and starts the movement. During movement, operation will not stop at the operating start point. However, at the end point of the block, the completion of all the miscellaneous functions is checked first, and then the execution of the next block is started.

(8) G117 should be issued in the sequence of operating start points. Program error (P33) occurs if the sequence of the operating start point is the reverse of the movements.
When operating start points coincide, the miscellaneous functions are output in the sequence in which they were issued.

(9) When an operating start point cannot be determined by the next block movement, the next operation is performed by the parameter.

Basic specification parameter "#1229 set01/bit5"	**Operation**
ON	Program error P33 occurs before movement
OFF	The functions are output when the next block movement is completed.

(10) The following tables show the combinations of (8) and (9).

G17 First block **Second block**	**During intermediate point movement**	**Not during intermediate point movement**
During intermediate point movement	Refer to (8).	Program error (P33) due to (8).
Not during intermediate point movement	Refer to (9) for second block.	Refer to (9). With output, the sequence of first block, second block is followed regardless of the sequence of the designated points.

Precautions

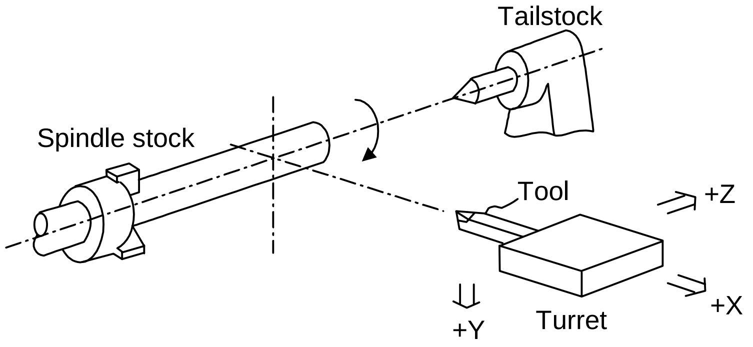
(1) Command G117 in order of the operation start points. If the operation start point order is the opposite of the movement, a program error (P33) will occur.

14. Coordinate System Setting Functions

14.1 Coordinate words and control axes

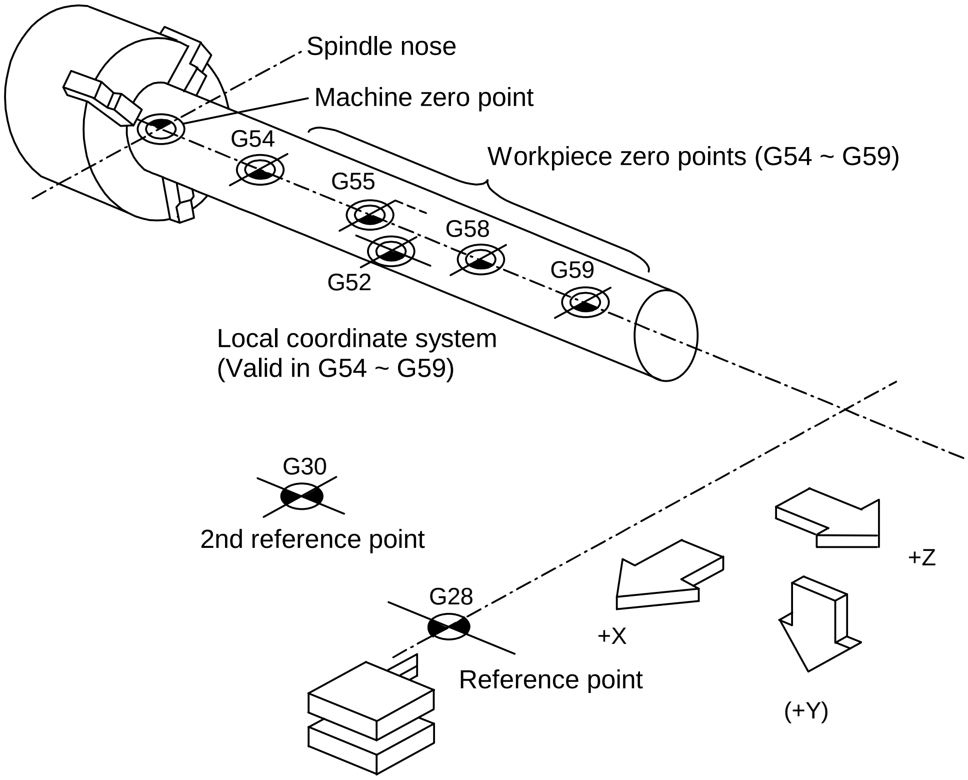
Function and purpose

In the case of a lathe, the axis parallel to the spindle is known as the Z axis and its forward direction is the direction in which the turret moves away from the spindle stock while the axis at right angle to the Z axis is the X axis and its forward direction is the direction in which it moves away from the Z axis, as shown in the figure below.



Coordinate axes and polarities

Since coordinates based on the right hand rule are used with a lathe, the forward direction of the Y axis in the above figure which is at right angles to the X-Z plane is downward. It should be borne in mind that an arc on the X-Z plane is expressed as clockwise or counterclockwise as seen from the forward direction of the Y axis. (Refer to the section on circular interpolation.)

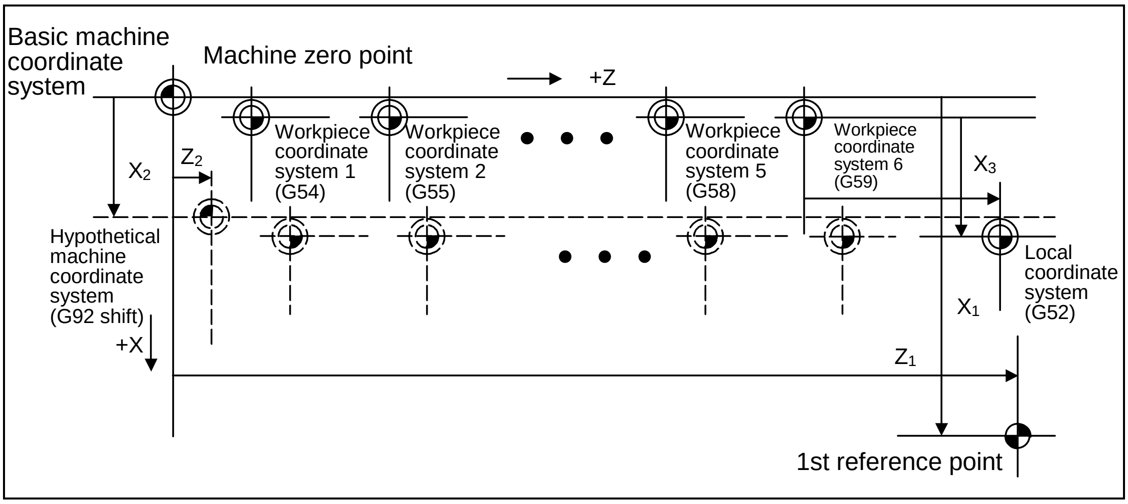


Relationship between coordinates

14.2 Basic machine, workpiece and local coordinate systems

Function and purpose

The basic machine coordinate system is fixed in the machine and it denotes that position which is determined inherently by the machine.
The workpiece coordinate systems are used for programming and in these systems the reference point on the workpiece is set as the coordinate zero point.
The local coordinate systems are created on the workpiece coordinate systems and they are designed to facilitate the programs for parts machining.
Upon completion of the reference point return, the basic machine coordinate system and workpiece coordinate systems (G54 ~ G59) are automatically set with reference to the parameters.
The basic machine coordinate system is set so that the first reference point is brought to the position specified by the parameter from the basic machine coordinate zero point (machine zero point).

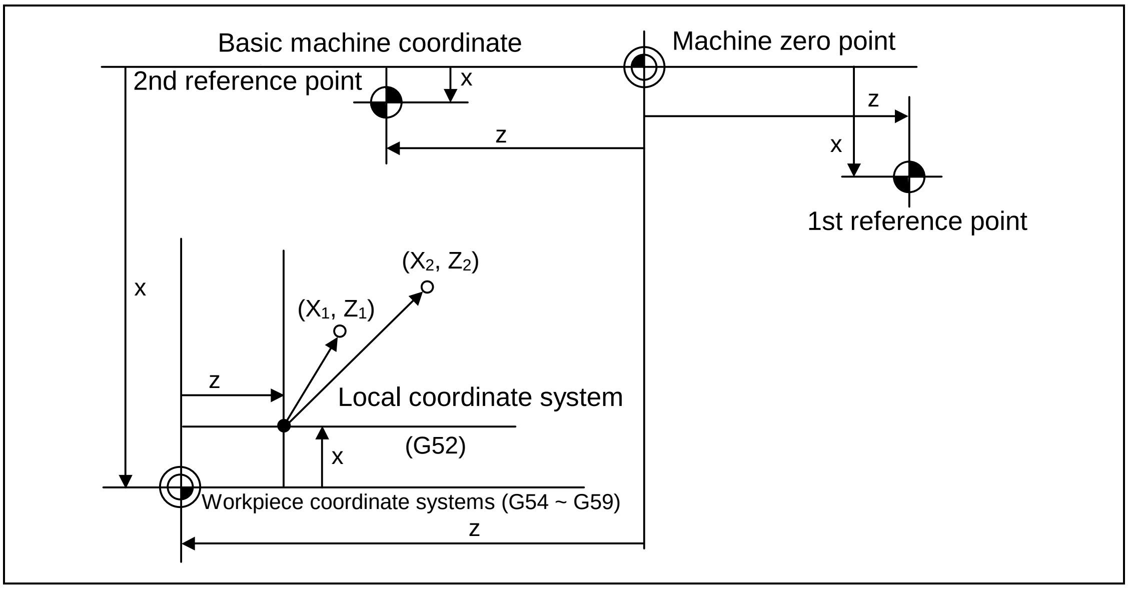

Basic machine coordinate system
Machine zero point
+Z
Workpiece coordinate system 1 (G54)
Workpiece coordinate system 2 (G55)
Workpiece coordinate system 5 (G58)
Workpiece coordinate system 6 (G59)
X2
Z2
X3
Hypothetical machine coordinate system (G92 shift)
+X
Local coordinate system (G52)
X1
Z1
1st reference point

The local coordinate systems (G52) are valid on the coordinate systems designated by workpiece coordinate systems 1 to 6.
The hypothetical machine coordinate system can be set on the basic machine coordinate system using a G92 command. At this time, the workpiece coordinate system 1 to 6 is also simultaneously shifted.

14.3 Machine zero point and 2nd, 3rd, and 4th reference points (Zero point)

Function and purpose

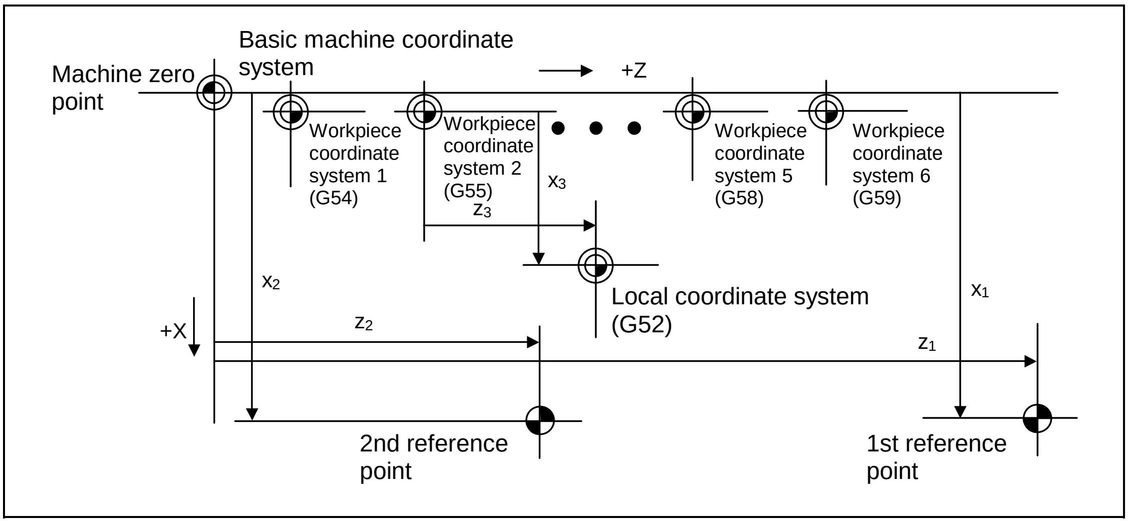
The machine zero point serves as the reference for the basic machine coordinate system. It is inherent to the machine and is determined by the reference (zero) point return.
The 2nd, 3rd, and 4th reference (zero) points relate to the position of the coordinates which have been set beforehand by parameter from the basic machine coordinate system zero point.



14.4 Automatic coordinate system setting

Function and purpose

When the tool has arrived at the reference point by dog-type reference point return after the CNC's power has been turned ON, this function create the various coordinate systems in accordance with the parameter values input beforehand from the setting and display unit.
The actual machining program is programmed over the coordinate systems which have been set above.


Basic machine coordinate system
Machine zero point
+Z
Workpiece coordinate system 1 (G54)
Workpiece coordinate system 2 (G55)
Workpiece coordinate system 5 (G58)
Workpiece coordinate system 6 (G59)
x3
z3
x2
z2
+X
Local coordinate system (G52)
x1
z1
2nd reference point
1st reference point

Detailed description

(1) The coordinate systems created by this function are as follows:

(a) Basic machine coordinate system

(b) Workpiece coordinate systems (G54 ~ G59)
The local coordinate system (G52) is canceled.

(2) The coordinate related parameters all provide the distance from the basic machine coordinate system zero point. Therefore it is decided at which position in the basic machine coordinate system the 1st reference point should be set and then the zero point positions of the workpiece coordinate systems are set.

(3) When the automatic coordinate system setting function is executed, the following functions are canceled: workpiece coordinate system shift based on G92, local coordinate system setting based on G52, workpiece coordinate system shift based on origin setting and workpiece coordinate system shift based on manual interrupt.

(4) When a parameter has been used to select the dog-type of first manual reference point return or automatic reference point return after the power has been turned ON, the dog-type reference point return will be executed for the 2nd and subsequent manual reference point returns or automatic reference point returns.

⚠CAUTION

⚠ **If the workpiece coordinate offset amount is changed during automatic operation (including single block operation), the changes will be valid from the next block of the command several blocks later.**

14.5 Machine coordinate system selection; G53

Function and purpose

The tool is moved to a command position in the basic machine coordinate system, using a G53 command and feed mode command (G01 or G00) and the coordinate command following them.

Command format

G53 G00 Xx Zz αα ;
G53 G00 Uu Ww ββ ;

αα	Additional axis
ββ	Incremental command of the additional axis

Detailed description

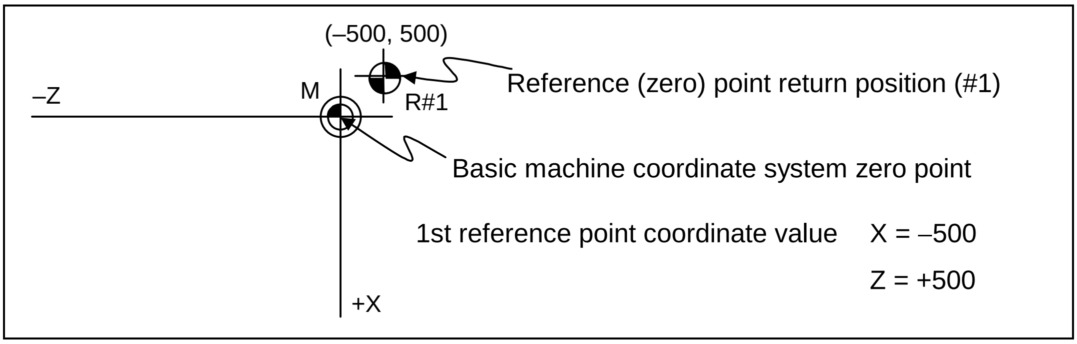
(1) When the power is turned ON, the basic machine coordinate system is automatically set as referenced to the reference (zero) point return position, which is determined by the automatic or manual reference (zero) point return.

(2) The basic machine coordinate system is not changed by the G92 command.

(3) The G53 command is valid only in the block in which it has been designated.

(4) In the incremental value command mode (U,W,β), the G53 command provides movement with the incremental value in the coordinate system being selected.

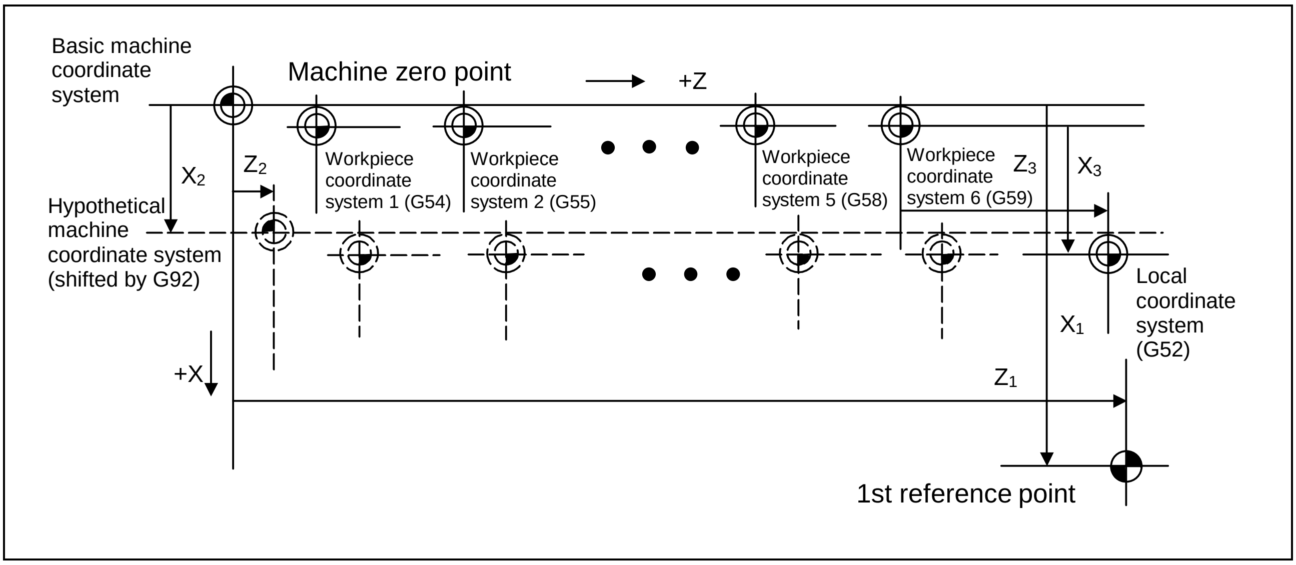
(5) The 1st reference point coordinates denote the distance from the basic machine coordinate system zero point to the reference (zero) point return position.


(–500, 500)
–Z
M
R#1
Reference (zero) point return position (#1)
Basic machine coordinate system zero point
1st reference point coordinate value X = –500
Z = +500
+X

14.6 Coordinate system setting; G92

Function and purpose

This function places the tool at the desired position, and the coordinate system is set by assigning the coordinate system setting command G92 at that position.
This system can be set as desired though normally the X and Y axes are set so that the workpiece center serves as the zero point and the Z axis is set so that the workpiece end serves as the zero point.


Basic machine coordinate system
Machine zero point
+Z
X2
Z2
Workpiece coordinate system 1 (G54)
Workpiece coordinate system 2 (G55)
Workpiece coordinate system 5 (G58)
Workpiece coordinate system 6 (G59)
Z3
X3
Hypothetical machine coordinate system (shifted by G92)
Local coordinate system (G52)
X1
+X
Z1
1st reference point

Command format

G92 Xx_2 Zz_2 $\alpha\alpha_2$;
$\alpha\alpha$ Additional axis

Detailed description

(1) The basic machine coordinate system is shifted by the G92 command, the hypothetical machine coordinate system is created, and at the same time all workpiece coordinate systems 1 to 6 are also shifted.

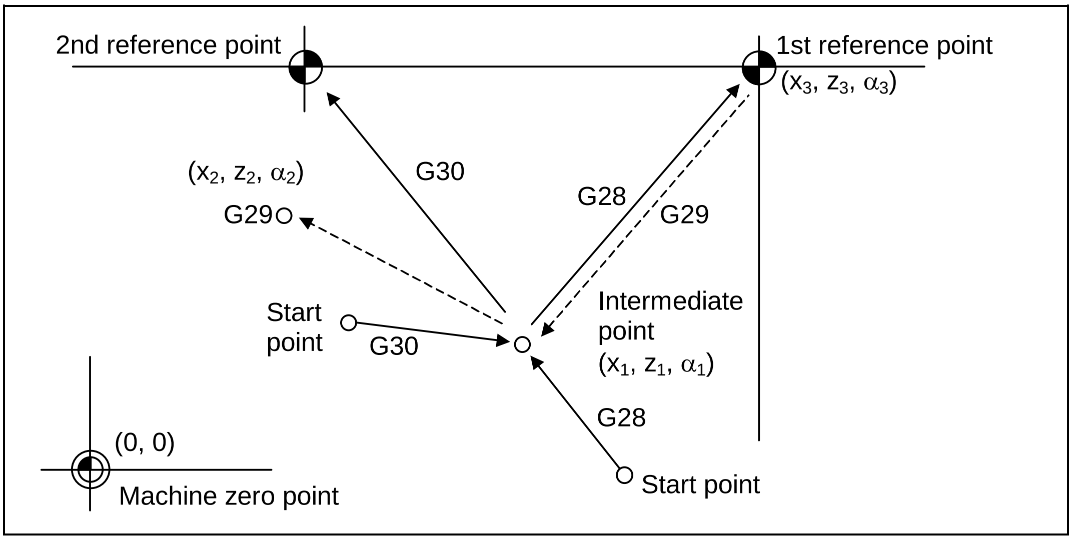
(2) When G92 and S or Q are assigned, the spindle clamp rotation speed is set. (Refer to the section on setting the spindle clamp rotation speed.)

14.7 Reference point (Zero point) return; G28, G29

Function and purpose

(1) After the commanded axes have been positioned by G0, they are returned respectively at rapid traverse to the 1st reference (zero) point when G28 is commanded.

(2) By commanding G29, the axes are first positioned independently at high speed to the G28 or G30 intermediate point and then positioned by G0 at the commanded position.



Command format

G28 Xx_1 Zz_1 $\alpha\alpha_1$;	**Additional axis**	**Automatic reference point return**
G29 Xx_2 Zz_2 $\alpha\alpha_2$;	**Additional axis**	**Start position return**
$\alpha\alpha$1/$\alpha\alpha$2	Additional axis	

Detailed description

(1) The G28 command is equivalent to the following:

G00 Xx_1 Zz_1 $\alpha\alpha_1$;
G00 Xx_3 Zz_3 $\alpha\alpha_3$;

In this case, x_3, z_3 and α_3 are the reference point coordinates and they are set by parameters "#2037 G53ofs" as the distance from the basic machine coordinate system zero point.

(2) After the power has been turned ON, the axes which have not been subject to manual reference (zero) point are returned by the dog-type of return just as with the manual type. In this case, the return direction is regarded as the command sign direction. For the second and subsequent returns, the return is made at high speed to the reference (zero) point which was stored at the first time.

(3) When reference (zero) point return is completed, the zero point arrival output signal is output and also #1 appears at the axis name line on the setting and display unit screen.

(4) The G29 command is equivalent to the following:

$$\left.\begin{array}{l}\text{G00 } Xx_1\ Zz_1\ \alpha\alpha_1\ ;\\ \text{G00 } Xx_2\ Zz_2\ \alpha\alpha_2\ ;\end{array}\right\}\ \begin{array}{l}\text{The rapid traverse (non-interpolation type) independent}\\ \text{for each axis takes place.}\end{array}$$

In this case, x_1, z_1 and α_1 are the coordinate value of the G28 or G30 intermediate point.

(5) Program error (P430) results when G29 is executed when automatic reference (zero) point return (G28) is not performed after the power has been turned ON.

(6) The intermediate point coordinate value (x_1, z_1, α_1) of the positioning point are assigned by absolute/incremental value commands.

(7) G29 is valid for either G28 or G30 but the commanded axes are positioned after a return has been made to the latest intermediate point.

(8) The tool offset will be temporarily canceled during reference point return unless it is already canceled, and the intermediate point will be the offset position.

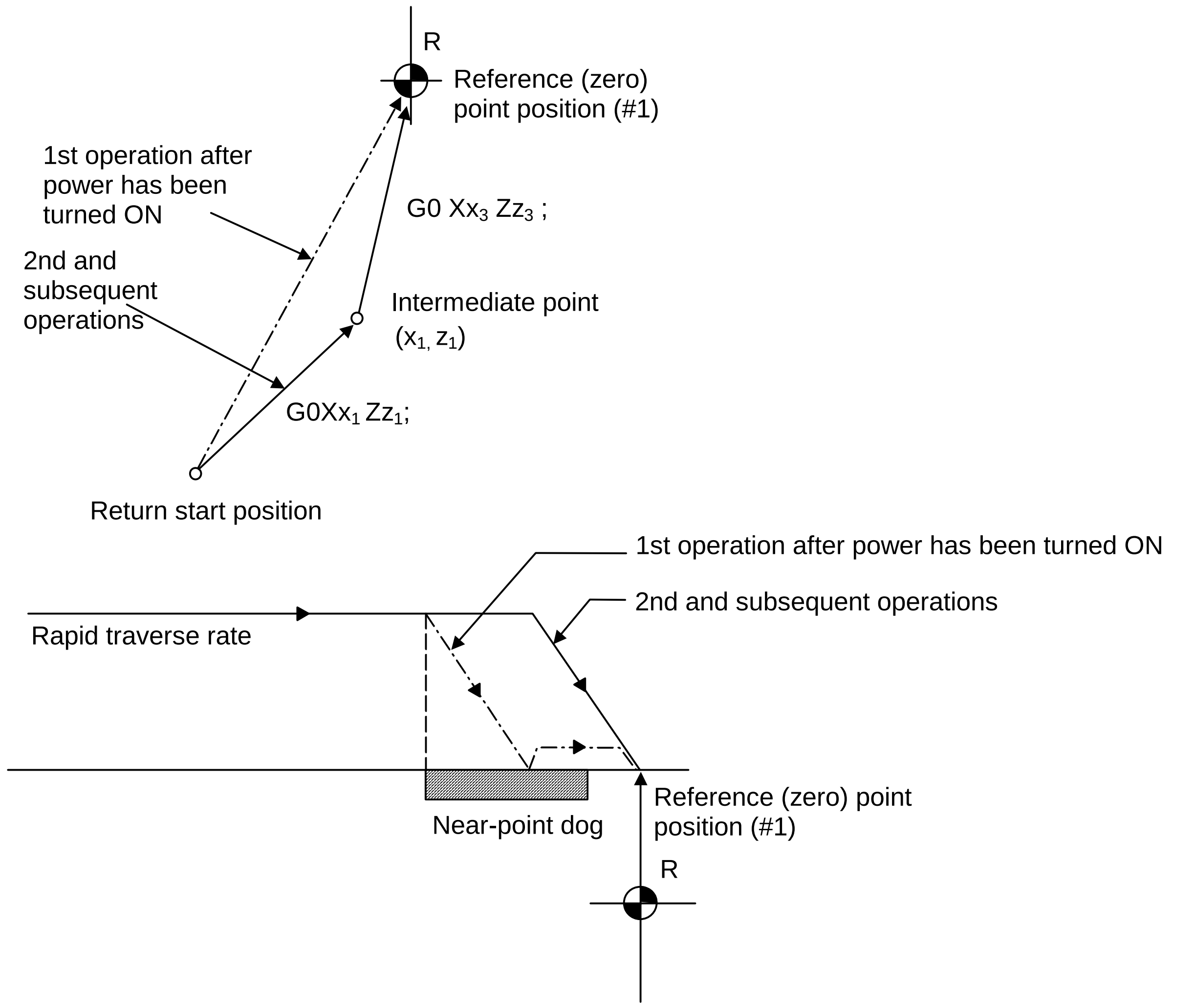
(9) The intermediate point can also be ignored by parameter "#1091 Mpoint" setting.

(10) Control from the intermediate point to the reference (zero) point is ignored for reference (zero) point return in the machine lock status. The next block is executed when the commanded axis survives as far as the intermediate point.

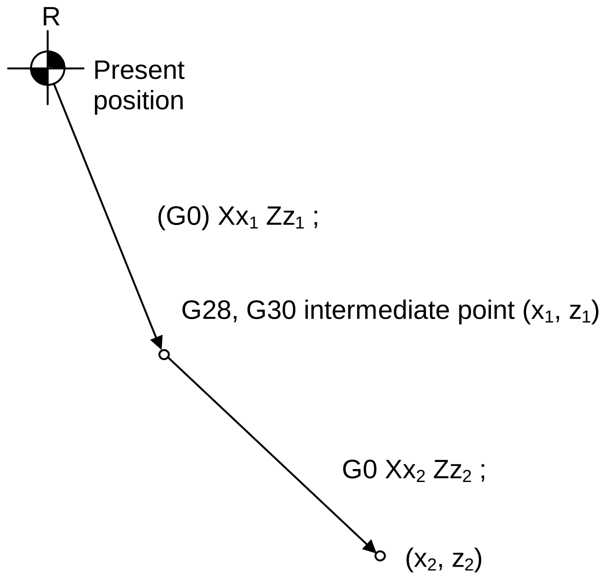
(11) Mirror image is valid from the start point to the intermediate point during reference (zero) point return in the mirror image mode and the tool will move in the opposite direction to that of the command. However, mirror image is ignored from the intermediate point to the reference (zero) point and the tool will move to the reference (zero) point.

Example of program

(Example 1) G28 Xx_1 Zz_1 ;


R
Reference (zero) point position (#1)
1st operation after power has been turned ON
G0 Xx_3 Zz_3 ;
2nd and subsequent operations
Intermediate point (x_1, z_1)
G0Xx_1 Zz_1;
Return start position
1st operation after power has been turned ON
2nd and subsequent operations
Rapid traverse rate
Reference (zero) point position (#1)
Near-point dog
R

(Example 2) G29 Xx_2 Zz_2 ;



(Example 3) G28 Xx_1 Zz_1 ;

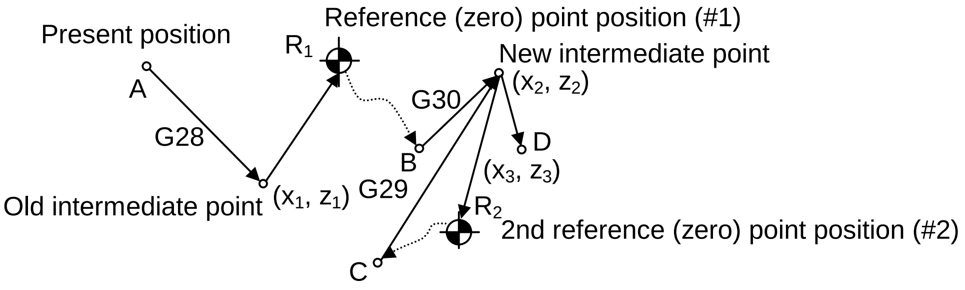
: (From point A to reference (zero) point)

G30 Xx_2 Zz_2 ;

: (From point B to 2nd reference (zero) point)

G29 Xx_3 Zz_3 ;

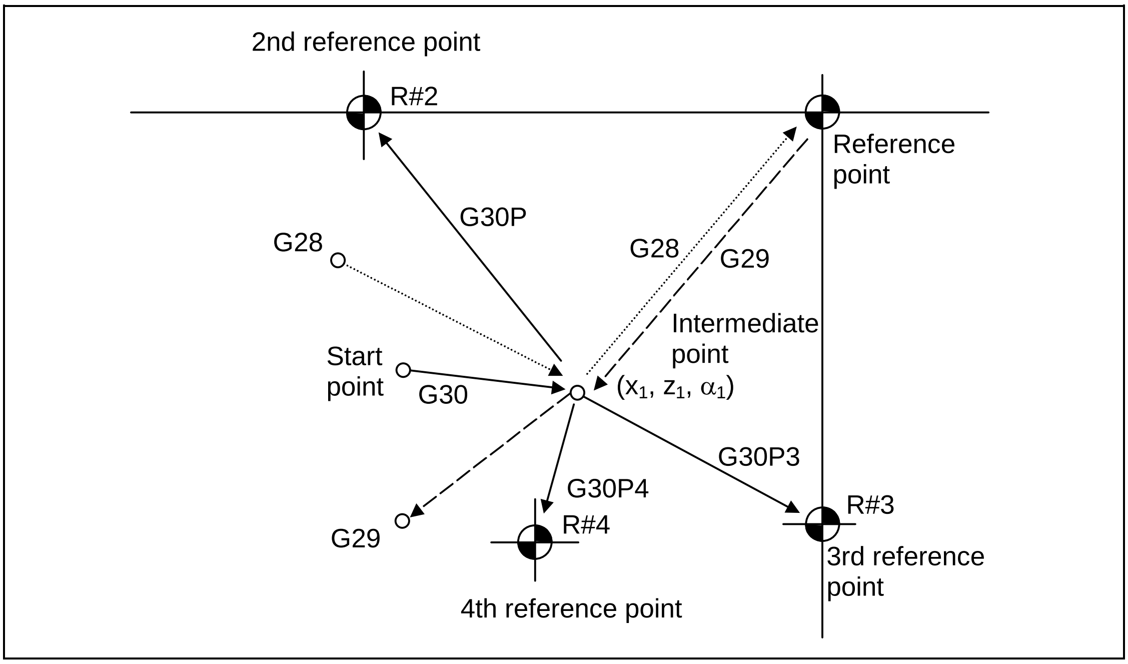
(From point C to point D)



14.8 2nd, 3rd, and 4th reference point (Zero point) return; G30

Function and purpose

The tool can return to the 2nd, 3rd, or 4th reference (zero) point by specifying G30 P2 (P3 or P4).



Command format

G30 P2 (P3, P4) $X x_1$ $Z z_1$ $\alpha \alpha_1$;	
$\alpha \alpha_1$	Additional axis

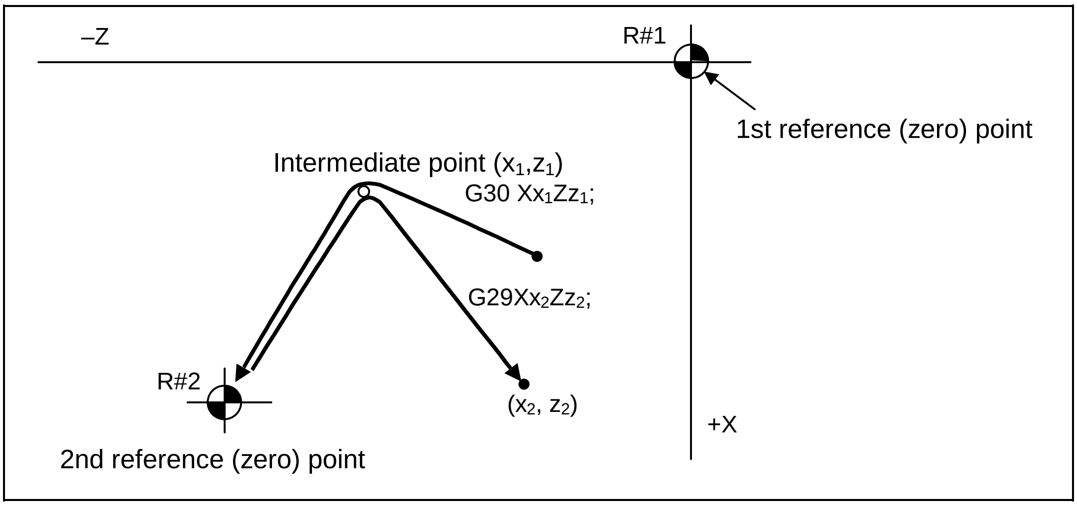
Detailed description

(1) The 2nd, 3rd, or 4th reference (zero) point return is specified by P2, P3, or P4. A command without P or with P0, P1, P5 or a greater P number is ignored, returning the tool to the 2nd reference (zero) point.

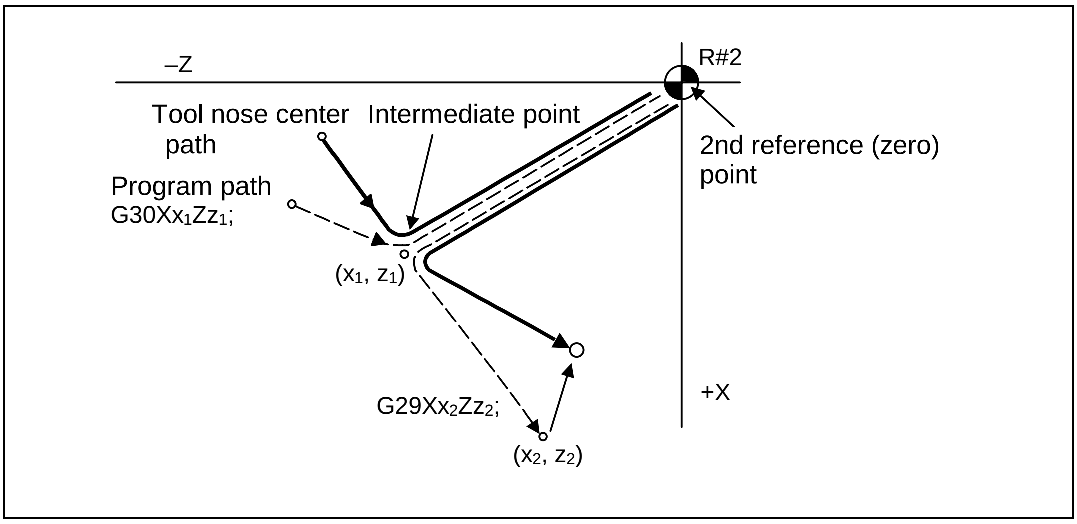
(2) In the 2nd, 3rd, or 4th reference (zero) point return mode, as in the 1st reference (zero) point return mode, the tool returns to the 2nd, 3rd, or 4th reference (zero) point via the intermediate point specified by G30.

(3) The 2nd, 3rd, and 4th reference (zero) point coordinates refer to the positions specific to the machine, and these can be checked with the setting and display unit.

(4) If G29 is specified after completion of returning to the 2nd, 3rd, and 4th reference (zero) points, the intermediate position used last is used as the intermediate position for returning by G29.


–Z
R#1
1st reference (zero) point
Intermediate point (x_1,z_1)
G30 Xx_1Zz_1;
G29Xx_2Zz_2;
R#2
(x_2, z_2)
+X
2nd reference (zero) point

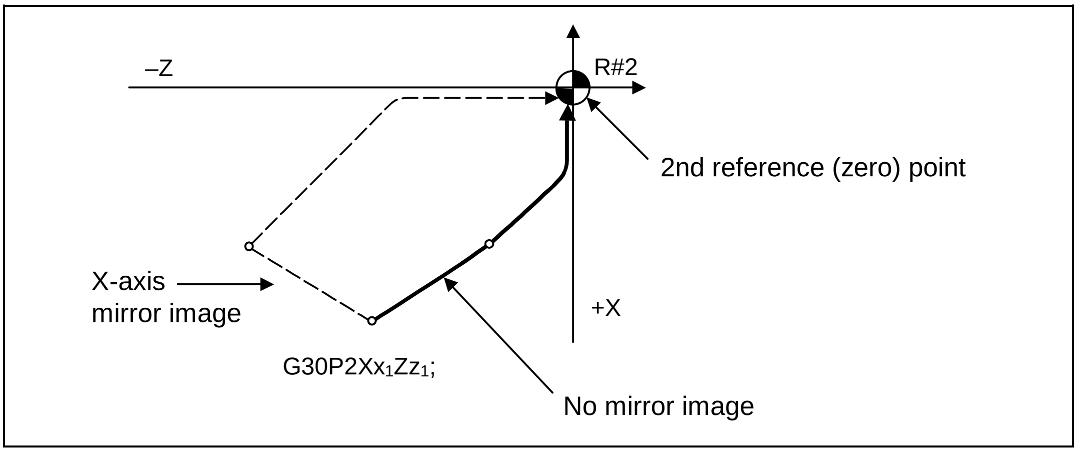
(5) With reference (zero) point return on a plane during compensation, the tool moves without tool nose radius compensation (zero compensation) from the intermediate point as far as the reference (zero) point. With a subsequent G29 command, the tool move without tool nose radius compensation from the reference (zero) point to the intermediate point and it move with such compensation until the G29 command from the intermediate point.



(6) The tool length offset amount for the axis involved is canceled temporarily after the 2nd, 3rd, and 4th reference (zero) point return.

(7) With 2nd, 3rd, and 4th reference (zero) point return in the machine lock status, control from the intermediate point to the reference (zero) point will be ignored. When the designated axis reaches as far as the intermediate point, the next block will be executed.

(8) With 2nd, 3rd, and 4th reference (zero) point return in the mirror image mode mirror image will be valid from the start point to the intermediate point and the tool will move in the opposite direction to that of the command. However, mirror image is ignored from the intermediate point to the reference (zero) point and the tool moves to the reference (zero) point.



14.9 Reference point check; G27

Function and purpose

This command first positions the tool at the position assigned by the program and then, if that positioning point is the 1st reference point, it outputs the reference point arrival signal to the machine in the same way as with the G28 command. Therefore, when a machining program is prepared so that the tool will depart from the 1st reference point and return to the 1st reference point, it is possible to check whether the tool has returned to the reference point after the program has been run.

Command format

G27 Xx_1 Zz_1 $\alpha\alpha_1$ Pp_1 ;

G27	Check command
Xx1 Zz1 αα1	Return control axis
Pp1	Check number P1 : 1st reference point check P2 : 2nd reference point check P3 : 3rd reference point check P4 : 4th reference point check

Detailed description

(1) If the P command has been omitted, the 1st reference point will be checked.

(2) The number of axes whose reference points can be checked simultaneously depends on the number of axes which can be controlled simultaneously.

(3) An alarm will occur if the reference point is not reached after the command is completed.

14.10 Workpiece coordinate system setting and offset; G54 ~ G59

Function and purpose

(1) The workpiece coordinate systems are for facilitating the programming of workpiece machining in which the reference point of the workpiece to be machined is to serve as the zero point.

(2) These commands enable the tool to move to the positions in the workpiece coordinate system. There are 6 workpiece coordinate systems which are used by the programmer for programming. (G54 ~ G59)

(3) Among the workpiece coordinate systems currently selected by these commands, any workpiece coordinate system with coordinates which have been commanded by the present position of the tool is reset. (The "present position of the tool" includes the offset amounts for nose radius, tool length and tool position offset.)

(4) An hypothetical machine coordinate system with coordinates which have been commanded by the present position of the tool is set by this command. (The "present position of the tool" includes the offset amounts for nose radius, tool length and tool position offset.) (G54 ~ G92)

Command format

(1) Workpiece coordinate system selection (G54 ~ G59)

G54 Xx_1 Zz_1 $\alpha\alpha_1$;	
$\alpha\alpha$1	Additional axis

(2) Workpiece coordinate system setting (G54 ~ G59)

(G54) G92 Xx_1 Zz_1 $\alpha\alpha_1$;	
$\alpha\alpha$1	Additional axis

Detailed description

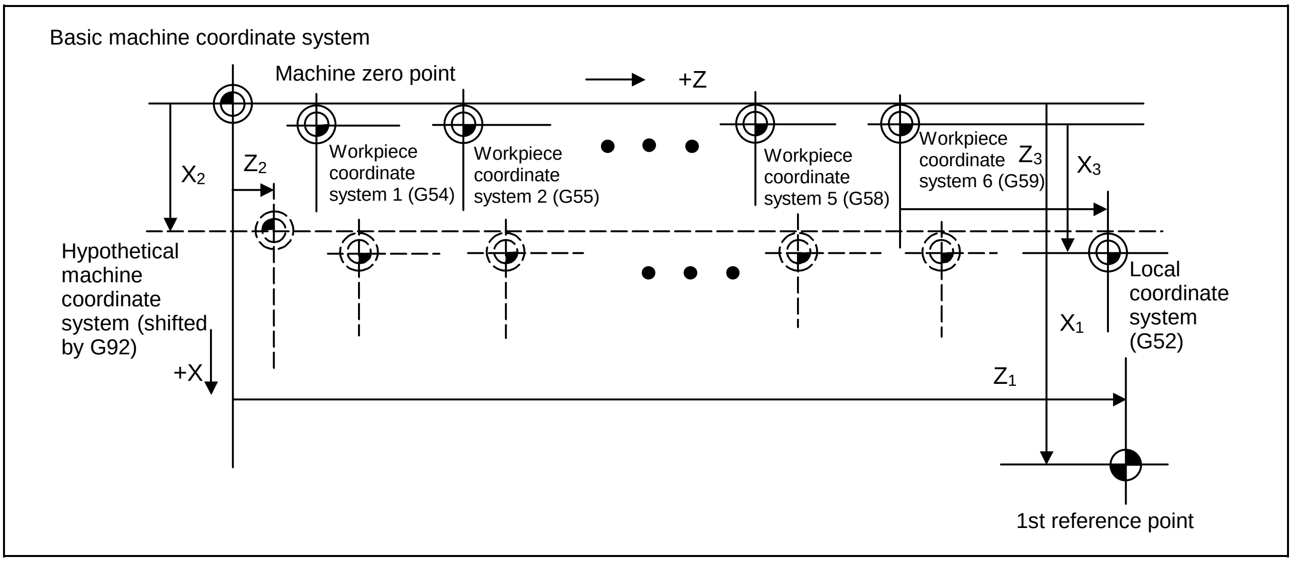
(1) With any of the G54 to G59 commands, the nose radius offset amounts for the commanded axes will not be canceled even if workpiece coordinate system selection is commanded.

(2) The G54 workpiece coordinate system is selected when the power is turned ON.

(3) Commands G54 to G59 are modal commands (group 12).

(4) The coordinate system will move with G92 in a workpiece coordinate system.

(5) The offset setting in a workpiece coordinate system denotes the distance from the basic machine coordinate system zero point.


Basic machine coordinate system
Machine zero point
+Z
X2
Z2
Workpiece coordinate system 1 (G54)
Workpiece coordinate system 2 (G55)
Workpiece coordinate system 5 (G58)
Workpiece coordinate system 6 (G59)
Z3
X3
Hypothetical machine coordinate system (shifted by G92)
+X
Local coordinate system (G52)
X1
Z1
1st reference point

(6) The offset settings of workpiece coordinate systems can be changed any number of times. (They can also be changed by G10 L2 Pp$_1$ Xx$_1$ Zz$_1$.)

Handling when L or P is omitted

G10 L2 Pn Xx Zz ; n=0 : Set the offset amount in the external workpiece coordinate system.

n=1 to 6 : Set the offset amount in the designated workpiece coordinate system.

Others : The program error (P35) will occur.

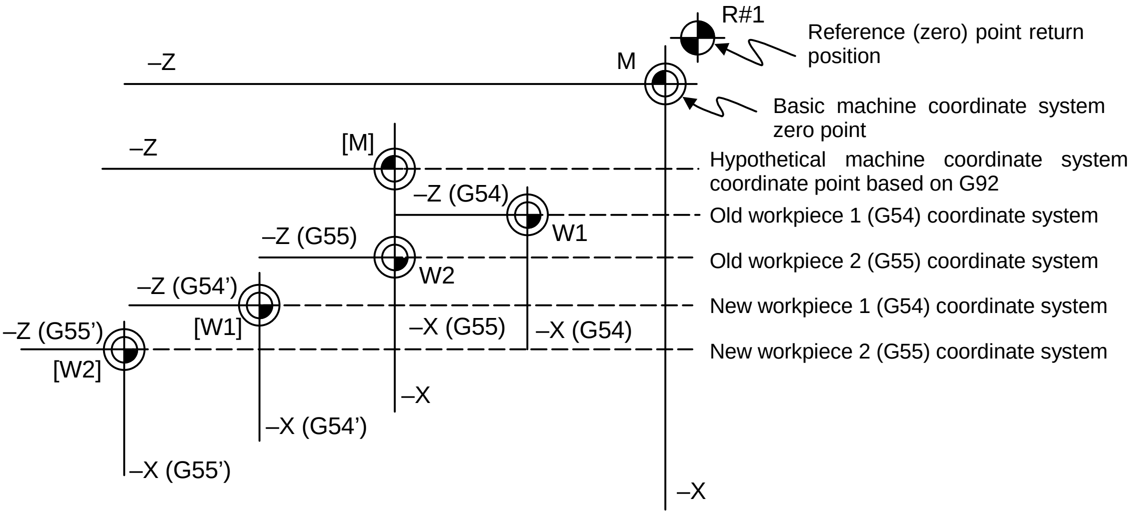
G10 L2 Xx Zz ; Set the offset amount in the currently selected workpiece coordinate system.

G10 L20 Xx Zz ; Set the offset amount in the currently selected workpiece coordinate system.
When in G54 to G59 modal, the program error (P33) will occur.

G10 Pn Xx Zz ;
G10 Xx Zz ; } L10 (tool offset) will be judged if there is no L value.

(7) A new workpiece coordinate system 1 is set by issuing the G92 command in the G54 (workpiece coordinate system 1) mode. At the same time, the other workpiece coordinate systems 2 to 6 (G55 ~ G59) will move in parallel and new workpiece coordinate systems 2 to 6 will be set.

(8) A hypothetical machine coordinate system is formed at the position which deviates from the new workpiece reference (zero) point by an amount equivalent to the workpiece coordinate system offset amount.


R#1
Reference (zero) point return position
–Z
M
Basic machine coordinate system zero point
–Z
[M]
Hypothetical machine coordinate system coordinate point based on G92
–Z (G54)
Old workpiece 1 (G54) coordinate system
W1
–Z (G55)
Old workpiece 2 (G55) coordinate system
W2
–Z (G54')
New workpiece 1 (G54) coordinate system
–Z (G55')
[W1]
–X (G55)
–X (G54)
New workpiece 2 (G55) coordinate system
[W2]
–X
–X (G54')
–X (G55')
–X

After the power has been turned ON, the hypothetical machine coordinate system is matched with the basic machine coordinate system by the first automatic (G28) or manual reference (zero) point return.

(9) By setting the hypothetical machine coordinate system, the new workpiece coordinate system will be set at a position which deviates from that hypothetical machine coordinate system by an amount equivalent to the workpiece coordinate system offset amount.

(10) When the first automatic (G28) or manual reference (zero) point return is completed after the power has been turned ON, the basic machine coordinate system and workpiece coordinate systems are set automatically in accordance with the parameter settings.

(11) If G54 X– ; is commanded after the reference return (both automatic or manual) executed after the power is turned ON, the program error (P62) will occur. (A speed command is required as the movement will be controlled with the G01 speed.)

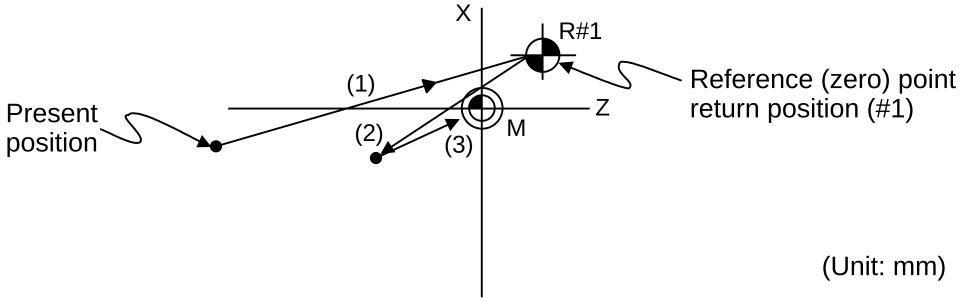
⚠CAUTION

⚠ **If the workpiece coordinate system offset amount is changed during single block stop, the new setting will be valid from the next block.**

Example of program

(Example 1)

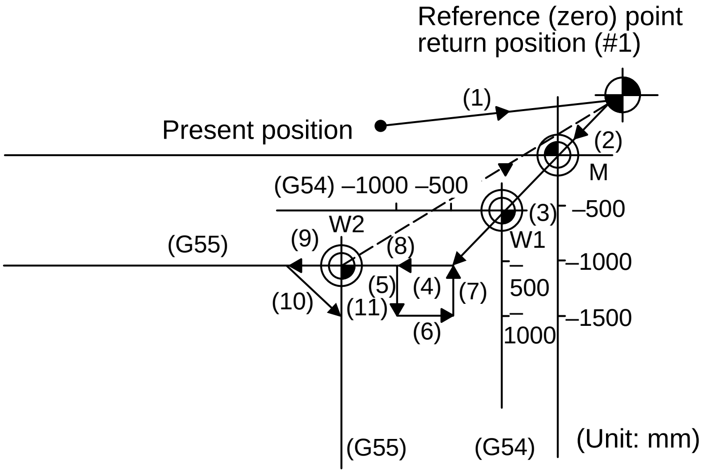
```
(1) G28 X0 Z0 ;
(2) G53 X–500 Z–1000 ;
(3) G53 X0 Z0 ;
```



When the 1st reference point coordinate is zero, the basic machine coordinate system zero point and reference (zero) point return position (#1) will coincide.

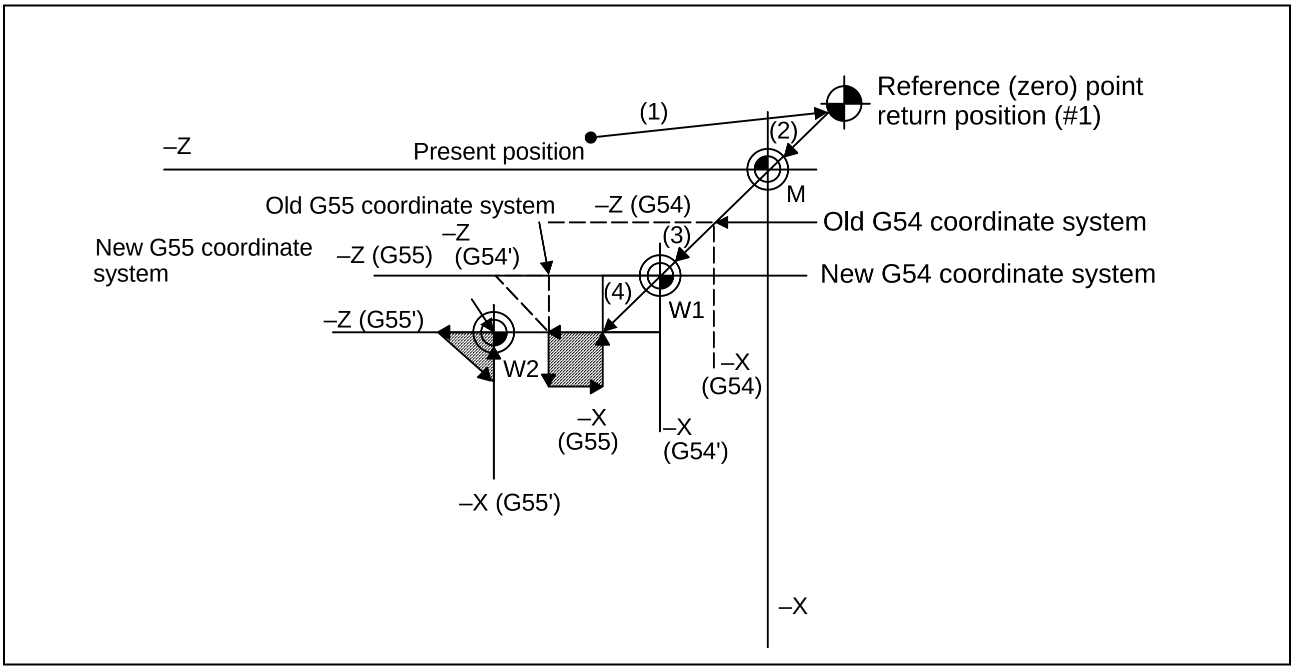
(Example 2)

```
(1)   G28 X0 Z0 ;
(2)   G00 G53 X0 Z0 ;
(3)   G54 X–500 Z –500 ;
(4)   G01 W–500 F100 ;
(5)   U–500 ;
(6)   W+500 ;
(7)   U+500 ;
(8)   G00 G55 X0 Z0 ;
(9)   G01 Z–500 F200 ;
(10)  X–500 Z0 ;
(11)  G28 X0 Z0 ;
```



(Example 3) When workpiece coordinate system G54 has deviated (–500, –500) in Example 2 (It is assumed that (3) to (10) in Example 2 have been entered in subprogram O1111.)

(1) G28 X0 Z0 ;	
(2) G00 G53 X0 Z0 ;	(Not required when there is no basic machine coordinate system offset.)
(3) G54 X–500 Z–500 ;	Amount by which workpiece coordinate system deviates
(4) G92 X0 Z0 ;	New workpiece coordinate system is set.
(5) M98 P1111 ;	



(Note) The workpiece coordinate system will deviate each time steps (3) to (5) are repeated. The reference point return (G28) command should therefore be issued upon completion of the program.

14.11 Local coordinate system setting; G52

Function and purpose

The local coordinate systems can be set independently on the G54 ~ G59 workpiece coordinate systems using the G52 command so that the commanded position serves as the programmed zero point.
The G52 command can also be used instead of the G92 command to change the deviation between the zero point in the machining program and the machining workpiece zero point.

Command format

```
G54 (G54 to G59) G52 Xx1 Zz1 ;
```

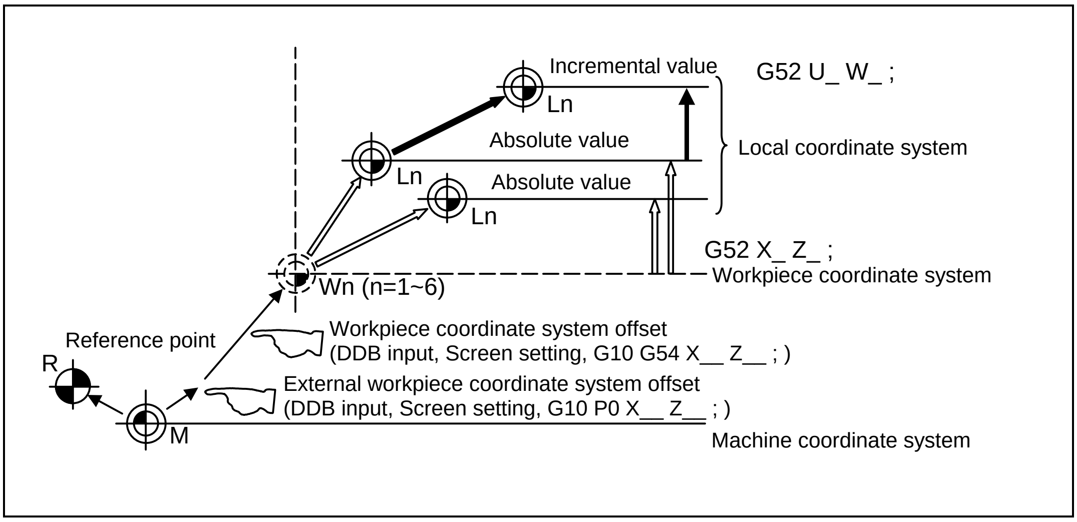
Detailed description

(1) The G52 command is valid until a new G52 command is issued and the tool does not move. This command comes in handy for employing another coordinate system without changing the zero point positions of the workpiece coordinate systems (G54 ~ G59).

(2) The local coordinate system offset is cleared by the reference point (zero point) return or dog-type manual reference (zero) point return after the power is turned ON.

(3) The local coordinate system is canceled by (G54 ~ G59) G52 X0 Z0 ;.

(4) Coordinate commands with the absolute value cause the tool to move to the local coordinate system position.


Incremental value
G52 U_ W_ ;
Ln
Absolute value
Local coordinate system
Ln
Absolute value
Ln
G52 X_ Z_ ;
Workpiece coordinate system
Wn (n=1~6)
Reference point
Workpiece coordinate system offset
(DDB input, Screen setting, G10 G54 X__ Z__ ;)
R
External workpiece coordinate system offset
(DDB input, Screen setting, G10 P0 X__ Z__ ;)
M
Machine coordinate system

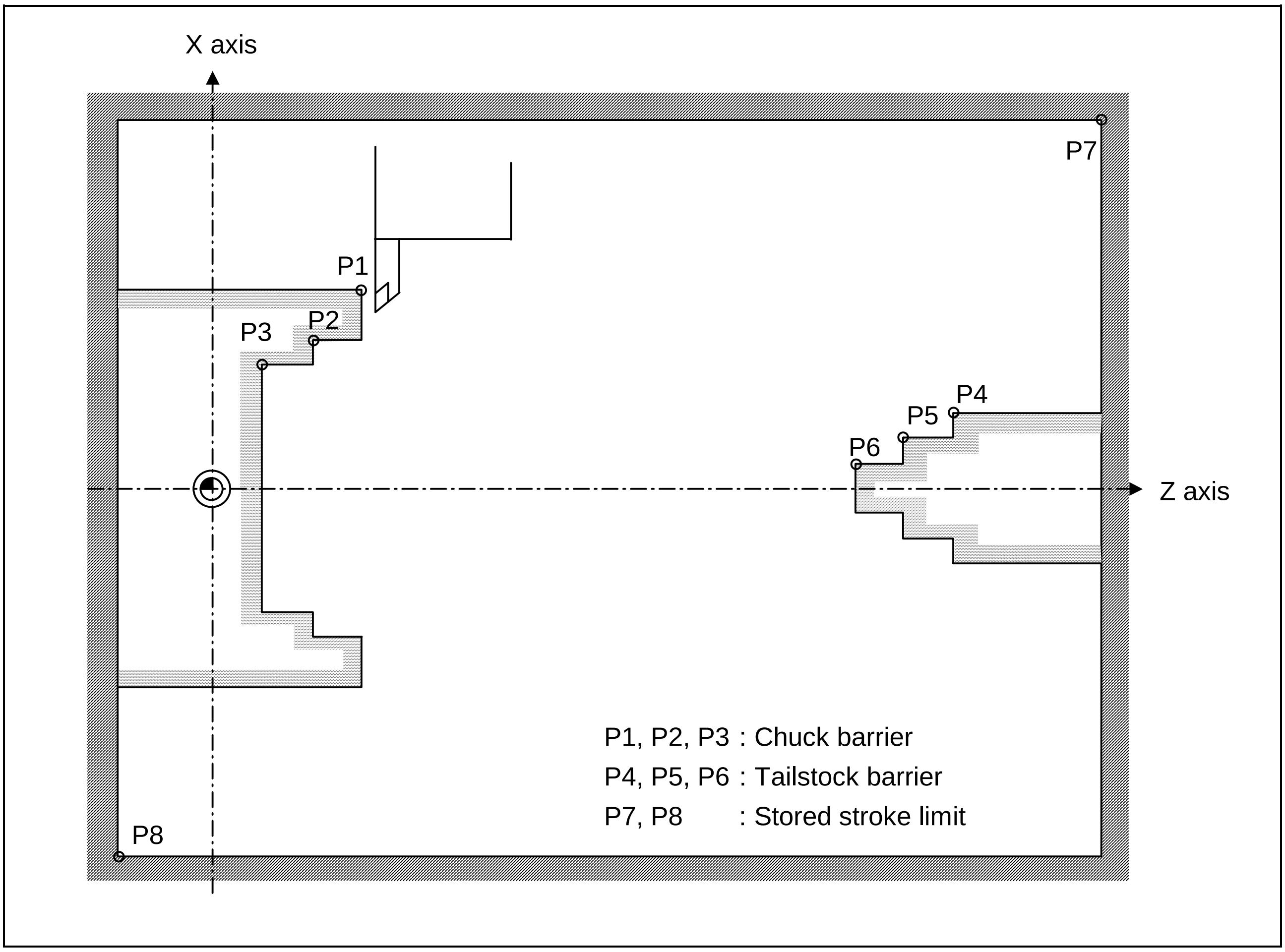
(Note) If the machining program is executed many times repeatedly, the workpiece coordinate system may deviate slightly per execution.
Command to execute reference point return at the program end.

15. Protection Function

15.1 Chuck barrier/tailstock barrier; G22, G23

Function and purpose

By limiting the tool nose movement range, the chuck barrier and tailstock barrier prevent collision with the chuck and tailstock due to programming errors. If movement is commanded which exceeds the region set in the parameters, the tool will automatically stop at the barrier boundary.


X axis
P7
P1
P2
P3
P4
P5
P6
Z axis
P8
P1, P2, P3 : Chuck barrier
P4, P5, P6 : Tailstock barrier
P7, P8 : Stored stroke limit

Command format

G22;	**Barriers valid**
G23;	**Barriers invalid**

Set G22 and G23 commands in independent blocks.

Detailed description

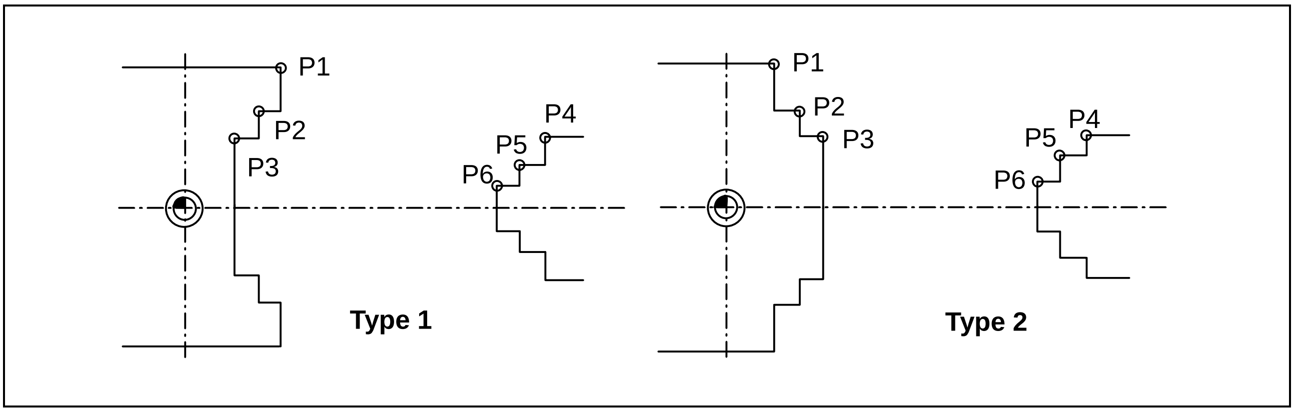
(1) An alarm will appear if the machine stops because it was about to exceed the set region. Reset to cancel this alarm.

(2) This function is also valid during machine lock.

(3) This function is validated when all axes in which chuck barrier and tailstock barrier are set have finished their reference point returns.

(4) When there is a stored stroke check function, and the stored stroke limit region is set, the chuck barrier/tailstock barrier function is validated simultaneously with the stored stroke check function.

Setting the chuck barrier/tailstock barrier

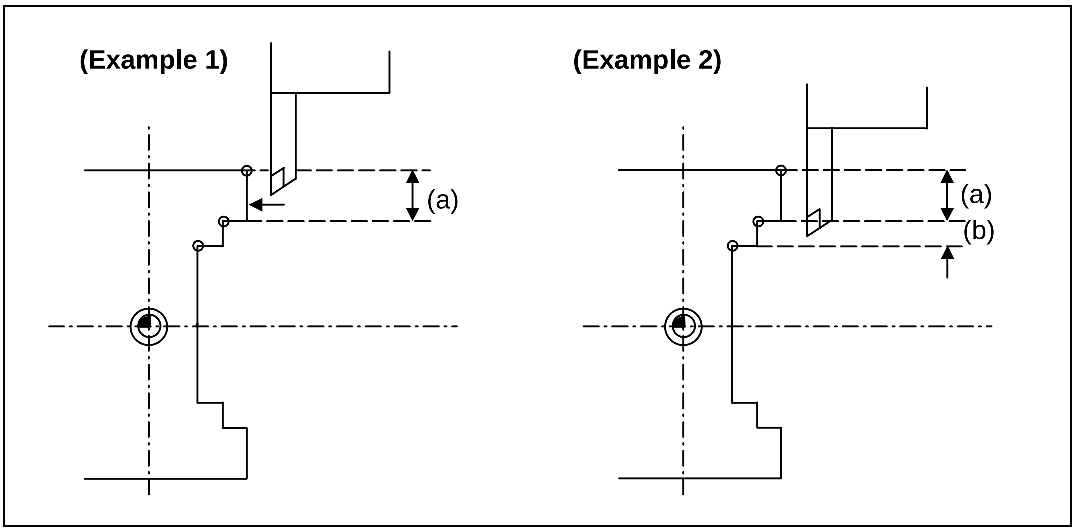


(1) Three points can be input as parameters for both the chuck barrier and tailstock barrier. Set in the machine coordinate system.
Points P1, P2 and P3 are for the chuck barrier. Points P4, P5 and P6 are for the tailstock barrier.

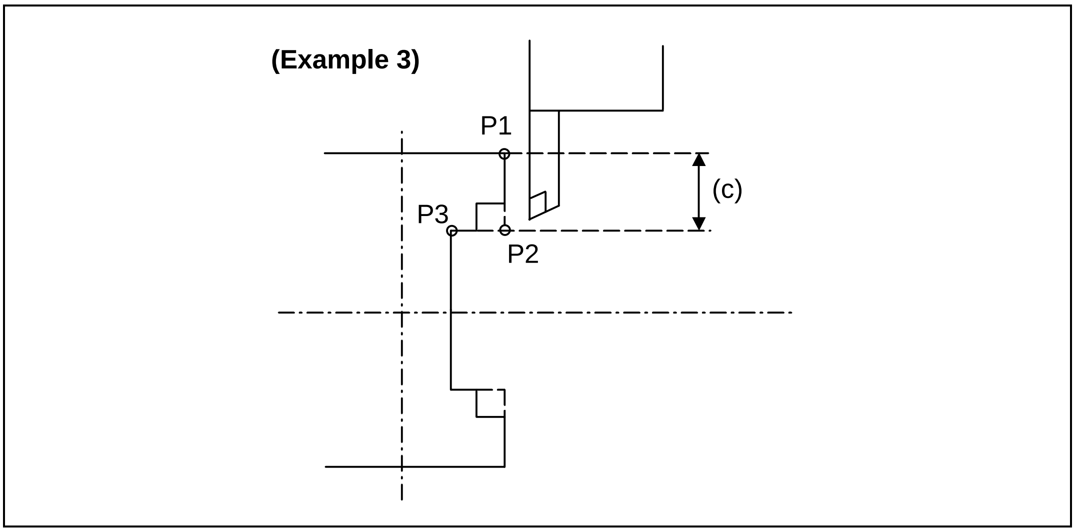
(2) The barrier region should be a symmetric shape regarding the Z axis. When the X axis coordinates of barrier point P_ are a negative value, reverse the sign to the positive side, then convert and check.
The absolute value of each barrier point's X axis coordinates must be set as follows.
P1 ≥ P2 ≥ P3, P4 ≥ P5 ≥ P6
(Note that the Z axis coordinates do not have to follow this setting.)

Restrictions

(1) There is only one checkpoint from the tool regarding the chuck barrier/tailstock barrier. Therefore, the following cautions must be observed.
In the following examples, when the barrier points are set to be checked by the hypothetical tool nose point and the tool moves in the direction of the arrow in the drawing, the following situation may occur.
In Example 1, there is a checkpoint in the range "a", so the tool will automatically stop at the barrier boundary. However, in Example 2 there is a checkpoint in range "b", so the chuck and tool may collide in range "a".



To avoid this, Example 3 is given. In this example, if the barrier points P1, P2 and P3 are set and the checkpoint is set in range "c", the tool can be stopped at the barrier boundary.



(2) When the tool enters the barrier region and an alarm occurs, the tool may move in the opposite direction from which it came, once the alarm is canceled by resetting.

(3) There is no barrier region for axes without a reference point return function. Thus, there is no barrier alarm for that axis.

(4) When the tool enters a canceled barrier region, and that barrier is then validated, an alarm will result immediately if the tool is moved.
If the alarm is canceled with reset in this manner, invalidate the barrier before escaping or change the value set for each barrier point.

(5) The soft limit is valid even if the barrier is invalid.

16. Measurement Support Functions

16.1 Automatic tool length measurement; G37

Function and purpose

These functions issue the command values from the measuring start position as far as the measurement time, move the tool in the direction of the measurement position, stop the machine once the tool has arrived at the sensor, cause the NC system to calculate automatically the difference between the coordinate values at that time and the coordinate values of the commanded measurement position and provide this difference as the tool offset amount.
When offset is already being applied to a tool, it moves the tool toward the measurement position with the offset still applied, and if a further offset amount is generated as a result of the measurement and calculation, it provides further compensation of the present offset amount.

Command format

G37 α_ R_ D_ F_ ;

α　Measuring axis address and coordinates of measurement position .... X, Z

R　This commands the distance between the measurement position and point where the movement is to start at the measuring speed (Radius value fixed, incremental value)

D　This commands the range within which the tool is to stop. (Radius value fixed, incremental value)

F　This commands the measuring speed.

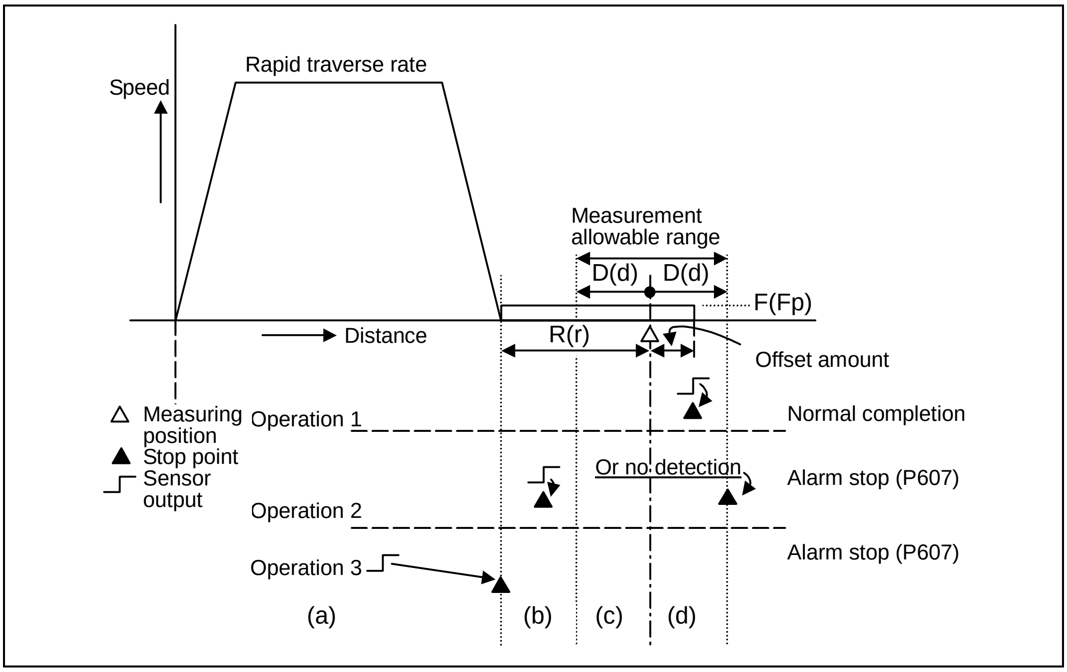
When R_, D_ or F_ is omitted, the value set in the parameter is used instead.

<Parameter>　("TLM" on machining parameter screen)

• #8004	Measuring feedrate (Fp)	:	0 ~ 60000 (mm/min)
• #8005	Deceleration range r	:	0 ~ 99999.999 (mm)
• #8006	Measurement range d	:	0 ~ 99999.999 (mm)

Detailed description

(1) Operation with G37 command



(2) The sensor signal (measuring position arrival signal) is used in common with the skip signal.

(3) The feedrate will be 1mm/min if the F command and parameter measurement speed are 0.

(4) During the synchronous feed mode, the axis will move at the synchronous feedrate [mm/rev].

(5) An updated offset amount is valid unless it is assigned from the following T command of the G37 command.

(6) Excluding the corresponding values at the PLC side, the delay and fluctuations in the sensor signal processing range from 0 to 0.2ms.
As a result, the measuring error shown below is caused.

Maximum measuring error [mm] = Measuring speed [mm/min] × 1/60 × 0.2 [ms]/1000

(7) The machine position coordinates at that point in time are ready by sensor signal detection, and the machine will overtravel and stop at a position equivalent to the servo droop.

Maximum overtravel [mm] = Measuring speed [mm/min] × 1/60 × 1/Position loop gain [1/s]

The standard position loop gain is 33 [1/s].

Precautions

(1) Program error (P600) results if G37 is commanded when the automatic tool length measurement function is not provided.

(2) Program error (P604) results when no axis has been commanded in the G37 block or when two or more axes have been commanded.

(3) Program error (P605) results when the T code is commanded in the G37 block. If the low-order digit or two digits is 0, the (4) error will occur.

(4) Program error (P606) results when T code is not commanded prior to the G37 block. When the low-order digit or two digits is 0, the program error (P606) will occur even if T is commanded.

(5) Program error (P607) results when the sensor signal was input outside the allowable measuring range or when the sensor signal was not detected even upon arrival at the end point. If the sensor signal stays ON during operation 3 in the above example, it will be judged as a normal measurement even when the (b) region is not present.

(6) When a manual interrupt is applied while the tool is moving at the measuring speed, a return must be made to the position prior to the interrupt and then operation must be resumed.

(7) The data commanded in G37 or the parameter setting data must meet the following conditions:

$|\text{Measurement point – start point}|$ > R command or parameter r >
D command or parameter d

(8) When the D command and parameter d in (7) above are zero, operation will be completed normally only when the commanded measurement point and sensor signal detection point coincide. Otherwise, program error (P607) will results.

(9) When the R and D commands as well as parameters r and d in (7) above are all zero, program error (P607) will result regardless of whether the sensor signal is present or not after the tool has been positioned at the commanded measurement point.

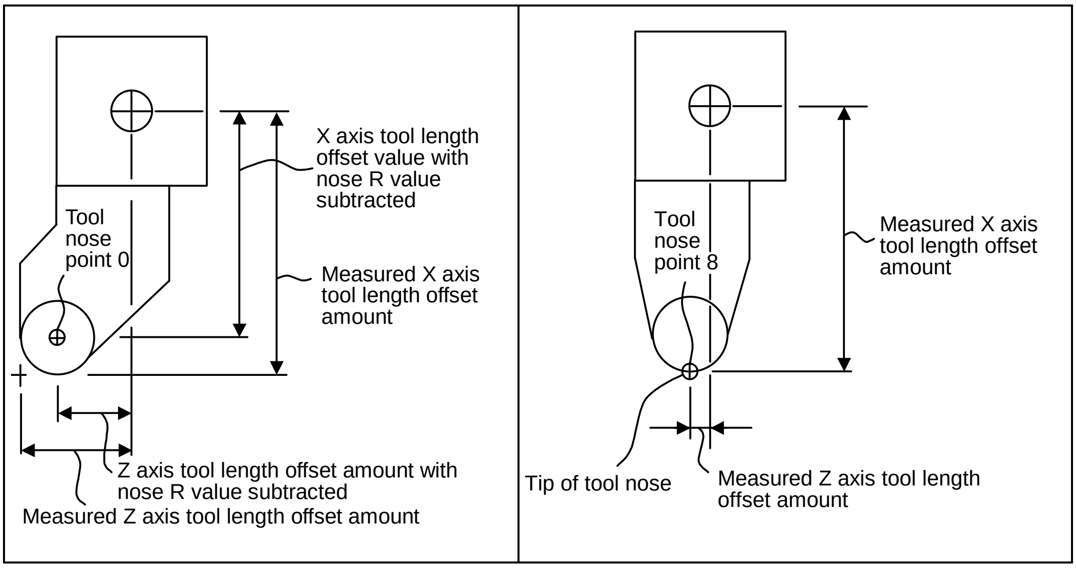
(10) When the measurement command distance < measurement allowable range, it becomes the measurement allowable range for all axes.

(11) When the measurement command distance < measurement speed movement distance, all axes move at the measurement speed.

(12) When the measurement allowable range > measurement speed movement distance, the axis moves in the measurement allowable range at the measurement speed.

(13) Always cancel nose R compensation before commanding G37.

(14) Calculate the tool length offset amount without regard for the nose R value and tool nose point No., even if the nose R compensation option is attached.
To set the tool nose point No. to 0, subtract the nose R value from the measured tool length offset amount and set.
When the tool nose point No. (tool nose shape) is 5, 6, 7, or 8, measure the tool length at the tool tip.


X axis tool length offset value with nose R value subtracted
Tool nose point 0
Measured X axis tool length offset amount
Z axis tool length offset amount with nose R value subtracted
Measured Z axis tool length offset amount
Tool nose point 8
Measured X axis tool length offset amount
Tip of tool nose
Measured Z axis tool length offset amount

16.2 Skip function; G31

Function and purpose

When the skip signal is input externally during linear interpolation based on the G31 command, the machine feed is stopped immediately, the remaining distance is discarded and the command in the following block is executed.

Command format

G31 Xx/Uu Zz/Ww Ff ;	
x, z, u, w	Axis coordinate value; they are commanded as absolute or incremental values.
f	Feedrate (mm/min)

Linear interpolation can be executed using this function. If the skip signal is input externally while this command is being executed, the machine will stop, the remaining commands will be canceled and operation will be executed from the next block.

Detailed description

(1) If Ff is commanded as the feedrate in the same block as G31 command, commanded speed "f" will apply; if it not commanded, the value set in the parameter "#1174 skip_F" will serve as the feedrate. In either case, the F modal will not be updated.

(2) Normally, the machine will not automatically accelerate or decelerate with the G31 block. However, setting the base specification parameter "#21101 add01/bit3" to "1" allows the automatic acceleration/deceleration valid.
In such case, the acceleration/deceleration will apply following to the cutting feed acceleration/deceleration pattern set with the axis specification parameter "#2003 smgst".
Since the deceleration at skip signal input follows the cutting feed acceleration/deceleration pattern mentioned above, the coasting amount from the skip signal input to stop may be larger than the normal specifications (when automatic acceleration/deceleration is invalid)

(3) The stop condition (such as feed hold, stroke end) is also valid for the G31 block.

(4) With the normal specifications, override and dry run are invalid during execution of G31 block. However, setting the base specification parameter "#21101 add01/bit3" to "1" allows the override and dry run.

(5) The G31 command is unmodal and so it needs to be commanded each time.

(6) If the skip signal is input during G31 command start, the G31 command will be completed immediately.
When a skip signal has not been input until the G31 block completion, the G31 command will also be completed upon completion of the movement commands.

(7) When the G31 command is issued during nose R compensation, program error (P608) will result.

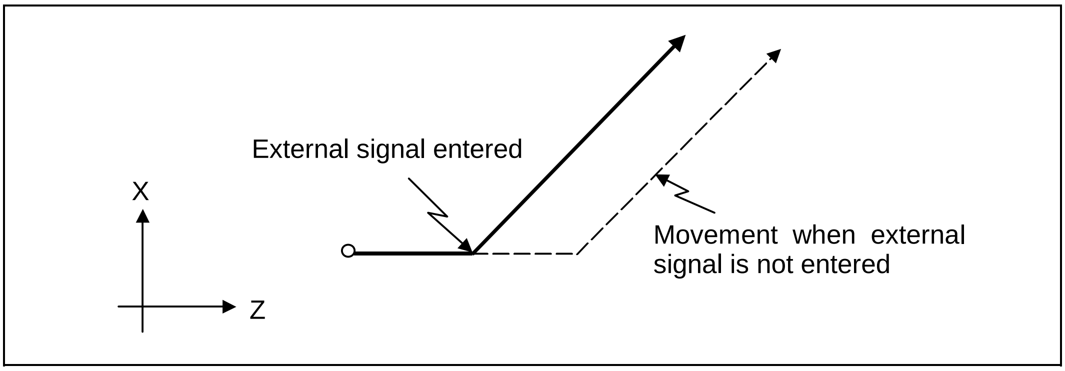
(8) When there is no F command in the G31 command and the parameter speed is also zero, program error (P603) will result.

(9) If only the Z axis is commanded when the machine lock is ON or the Z axis cancel switch is ON, the skip signal will be ignored and execution will continue as far as the end of the block.

Execution of G31

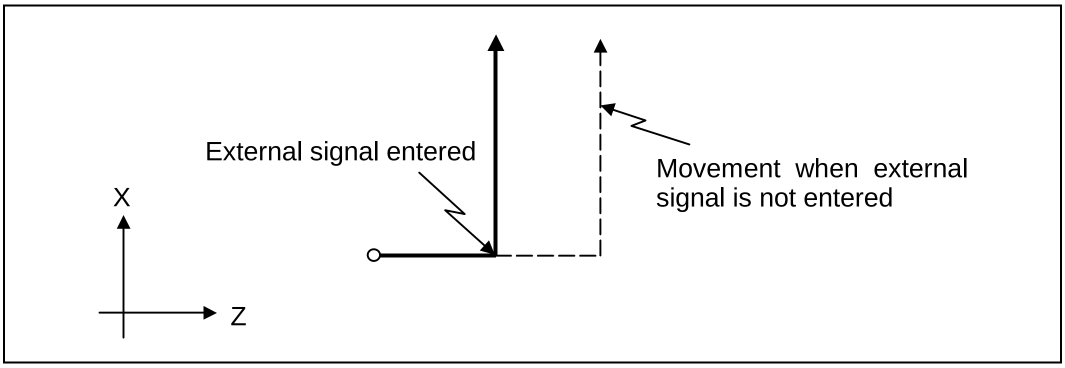
(Example 1) When the next block is an incremental value command

```
G31 Z1000 F100 ;
G01 U2000 W1000 ;
```



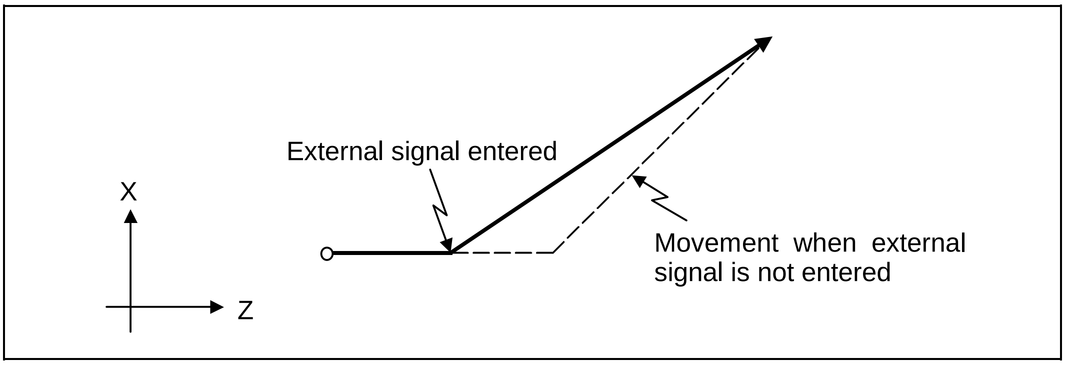
(Example 2) When the next block is a one axis movement command with absolute value

```
G31 Z1000 F100 ;
G01 X1000 ;
```



(Example 3) When the next block is a two axes movement command with absolute value

```
G31 Z1000 F100 ;
G01 X1000 Z2000 ;
```



Detailed description (Readout of skip coordinates)

As the skip signal inputting coordinate positions have been stored in the system variables #5061 (1st axis) ~ #506n (nth axis), it is possible to use them with user macro.

```
       ≀
G00 X–100. ;
G31 X–200. F60 ;
#101 = #5061
       ≀
```

Skip command

Skip signal input coordinate values (workpiece coordinate system) are readout to #101.

Detailed description (G31 coasting)

The amount of coasting from when the skip signal is input during the G31 command until the machine stops differs according to the parameter "#1174 skip_F" or F command in G31.

The time to start deceleration to a stop after responding to the skip signal is short, so the machine can be stopped precisely with a small coasting amount. The coasting amount can be calculated from the following formula.

$$\delta_0 = \frac{F}{60} \times Tp + \frac{F}{60} \times (t_1 \pm t_2) = \frac{F}{60} \times (Tp + t_1) \pm \frac{F}{60} \times t_2$$

δ_0 : Coasting amount (mm)

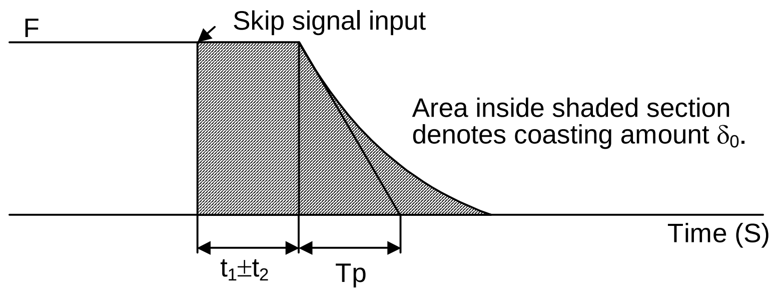
F : G31 skip speed (mm/min)

Tp : Position loop time constant (s) = (position loop gain)$^{-1}$

t_1 : Response delay time (s) = (Time from when skip signal is detected, PC is passed, and control unit is reached.)

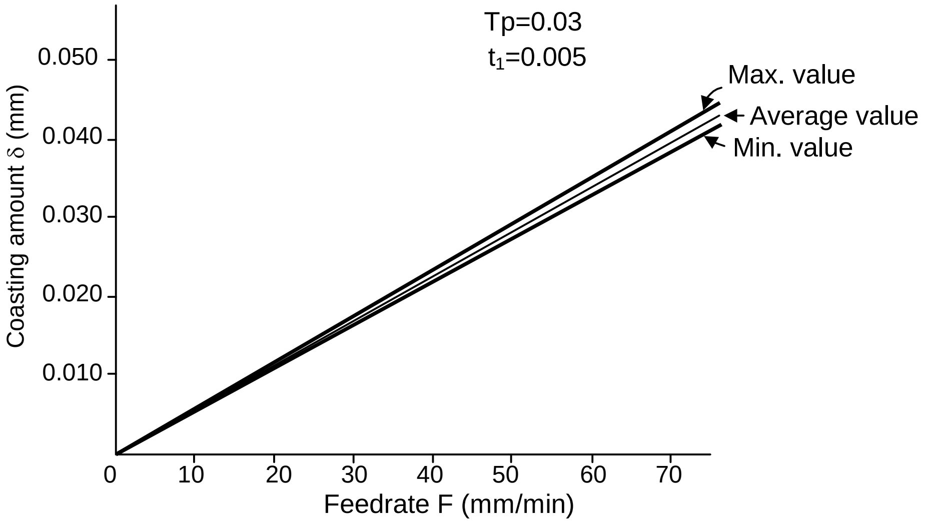
t_2 : Response error time 0.001 (s)

When G31 is used for calculation, the value calculated from the section indicated by δ_1 in the above equation can be compensated, however, δ_2 results in calculation error.


F
Skip signal input
Area inside shaded section denotes coasting amount δ_0.
Time (S)
$t_1 \pm t_2$
Tp

Stop pattern with skip signal input

The relationship between the coasting amount and speed when Tp is 30ms and t_1 is 5ms is shown in the following figure.



Relationship between coasting amount and feedrate (example)

(Note) When the base specification parameter "#21101 add01/bit3" is set to "1", the automatic acceleration/deceleration becomes valid for the deceleration at skip signal input.
Thus, the coasting amount from the skip signal input to stop may be larger than when the automatic acceleration/deceleration is invalid.

Detailed description (Skip coordinate readout error mm)

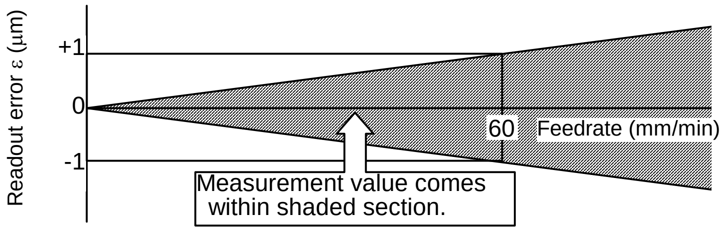
(1) Skip signal input coordinate readout

The coasting amount based on the position loop time constant Tp and cutting feed time constant Ts is not included in the skip signal input coordinate values.

Therefore, the workpiece coordinate values applying when the skip signal is input can be read out across the error range in the following formula as the skip signal input coordinate values. However, coasting based on response delay time t_1 results in a measurement error and so compensation must be provided.

$$\varepsilon = \pm \frac{F}{60} \times t_2$$

ε : Readout error (mm)
F : Feedrate (mm/min)
t_2 : Response error time 0.001 (s)



Readout error of skip input coordinates

Readout error of skip signal input coordinates
Readout error with a 60mm/min feedrate is as follows:

$$\varepsilon = \pm \frac{60}{60} \times 0.001 = \pm 0.001 \text{ (mm)}$$

Measurement value is within readout error range of ±1 μm.

(2) Readout of other coordinates

The readout coordinate values include the coasting amount. Therefore, when coordinate values are required with skip signal input, refer to the section on the G31 coasting amount to compensate the coordinate value. As in the case of (1), the coasting amount based on the delay error time t_2 cannot be calculated, and this generates a measuring error.

Examples of compensating for coasting

(1) Compensating for skip signal input coordinates

#110 = Skip feedrate ;
#111 = Response delay time t_1 ;

```
            ≀
G31 X100. F100 ;  ─────────── Skip command
G04 ; ─────────────────────── Machine stop check
#101 = #5061 ;  ───────────── Skip signal input coordinate readout
#102 = #110∗#111/60 ; ─────── Coasting amount based on response delay time
#105 = #101–#102 ; ────────── Skip signal input coordinates
            ≀
```

(2) Compensating for workpiece coordinates

#110 = Skip feedrate ;
#111 = Response delay time t_1 ;
#112 = Position loop time constant Tp ;

```
            ≀
G31 X100. F100 ;  ─────────── Skip command
G04 ; ─────────────────────── Machine stop check
#101 = #5061 ;  ───────────── Skip signal input coordinate readout
#102 = #110∗#111/60 ; ─────── Coasting amount based on response delay time
#103 = #110∗#112/60 ; ─────── Coasting amount based on position loop time
                              constant
#105 = #101–#102–#103 ; ───── Skip signal input coordinates
            ≀
```

16.3 Multi-stage skip function; G31.n, G04

Function and purpose

The setting of combinations of skip signals to be input enables skipping under various conditions. The actual skip operation is the same as with G31.
The G commands which can specify skipping are G31.1, G31.2, G31.3, and G04, and the correspondence between the G commands and skip signals can be set by parameters.

Command format

G31.1 Xx Zz αα Ff ;

Xx Zz αα	Command format axis coordinate word and target coordinates
Ff	Feedrate (mm/min)

Same with G31.2 and G31.3; Ff is not required with G04.
As with the G31 command, this command executes linear interpolation and when the preset skip signal conditions have been met, the machine is stopped, the remaining commands are canceled, and the next block is executed.

Detailed description

(1) Feedrate G31.1 set with the parameter corresponds to "#1176 skip1f", G31.2 corresponds to "#1178 skip2f", and G31.3 corresponds to "#1180 skip3f".

(2) A command is skipped if it meets the specified skip signal condition.

(3) The G31.n and G04 commands work the same as the G31 command for other than (1) and (2) above.

(4) The feedrates corresponding to the G31.1, G31.2, and G31.3 commands can be set by parameters.

(5) The skip conditions (logical sum of skip signals which have been set) corresponding to the G31.1, G31.2, G31.3 and G04 commands can be set by parameters.

Parameter setting	Valid skip signal			
	4	3	2	1
1	×	×	×	○
2	×	×	○	×
3	×	×	○	○
4	×	○	×	×
5	×	○	×	○
6	×	○	○	×
7	×	○	○	○
8	○	×	×	×
9	○	×	×	○
10	○	×	○	×
11	○	×	○	○
12	○	○	×	×
13	○	○	×	○
14	○	○	○	×
15	○	○	○	○

(Skip when "○" signal is input.)

Operation

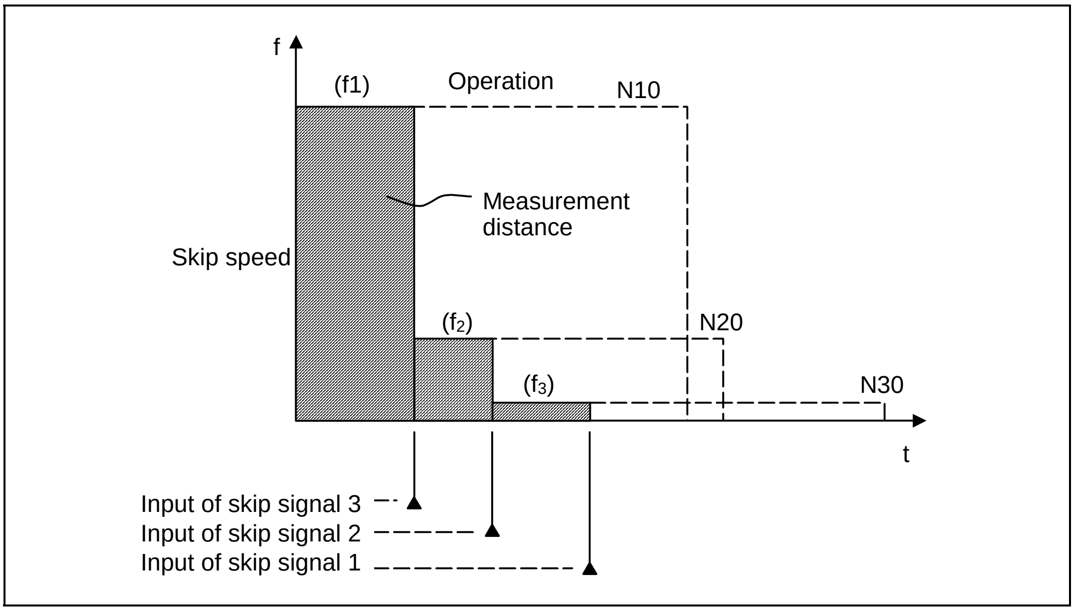
(1) The multi-stage skip function enables the following control, thereby improving measurement accuracy and shortening the time required for measurement.

Parameter settings :

Skip condition	Skip speed
G31.1 : 7	20.0mm/min (f1)
G31.2 : 3	5.0mm/min (f2)
G31.3 : 1	1.0mm/min (f3)

Program example

```
N10 G31.1 X200.0 ;
N20 G31.2 X40.0 ;
N30 G31.3 X1.0 ;
```



(Note 1) If skip signal 1 is input before skip signal 2 in the above operation, N20 is skipped at that point and N30 is also ignored.

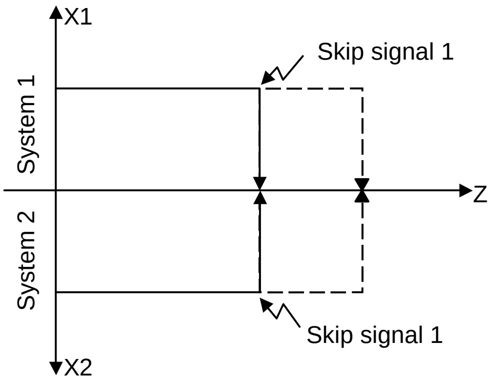
(2) If a skip signal with the condition set during G04 (dwell) is input, the remaining dwell time is canceled and the following block is executed.

16.4 Multi-stage skip function 2 ; G31

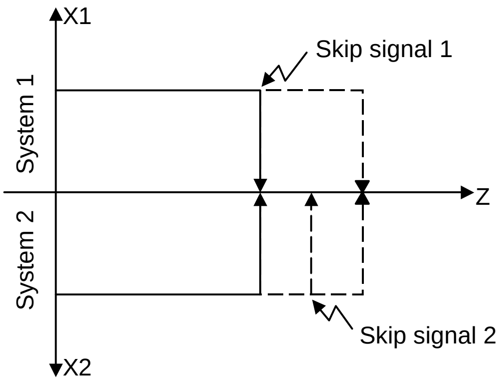
Function and purpose

During linear interpolation, command operation is skipped if skip signal parameter Pp specified with a skip command (G31), which indicates external skip signals 1 to 4, is met.

If multi-stage skip commands are issued simultaneously in different systems, both systems perform skip operation simultaneously if the input skip signals are the same, or they perform skip operation separately according to the earlier skip signal if the input skip signals are different. The skip operation is the same as with a normal skip command (G31 without P command).



Same skip signals input in both systems 1 and 2



Different skip signals input in systems 1 and 2

If the skip condition specified by the parameter "#1173 dwlskp" (indicating external skip signals 1 to 4) is met during execution of a dwell command (G04), the remaining dwell time is canceled and the following block is executed. Similarly, if the skip condition is met during speed dwelling, the remaining speed is canceled and the following block is executed.

Command format

G31 Xx Zz αα Pp Ff ;

Xx Zz αα	Command format axis coordinate word and target coordinates
Pp	Skip signal command
Ff	Feedrate (mm/min)

Detailed description

(1) The skip is specified by command speed f. Note that the F modal is not updated.

(2) The skip signal is specified by skip signal command p. p can range from 1 to 15. If p is specified outside the range, program error (P35) occurs.

Skip signal command P	Valid skip signal			
	4	3	2	1
1	×	×	×	○
2	×	×	○	×
3	×	×	○	○
4	×	○	×	×
5	×	○	×	○
6	×	○	○	×
7	×	○	○	○
8	○	×	×	×
9	○	×	×	○
10	○	×	○	×
11	○	×	○	○
12	○	○	×	×
13	○	○	×	○
14	○	○	○	×
15	○	○	○	○

(Skip when "○" signal is input.)

(3) The specified skip signal command is a logical sum of the skip signals.

(Example) G31 X100. P5 F100 ;

Operation is skipped if skip signal 1 or 3 is input.

(4) If skip signal command Pp is not specified, the skip condition specified by the G31 command works. If speed command Ff is not specified, the skip speed specified by the G31 command parameter works.

Table 2 Relations between skip and multi-stage skip

Skip specifications	×		○	
	Condition	Speed	Condition	Speed
G31 X100 ; (Without P and F)	Program error (P601)		Skip 1	Parameter
G31 X100 P5 ; (Without F)	Program error (P602)		Command value	Parameter
G31 X100 F100 ; (Without P)	Program error (P601)		Skip 1	Command value
G31 X100 P5 F100 ;	Program error (P602)		Command value	Command value

(Note) "Parameter" in the above table indicates that specified with a skip command (G31).

(5) If skip specification is effective and P is specified as an axis address, skip signal command P is given priority and axis address P is ignored.

(Example) G31 P500. F100 ;

This is regarded as a skip signal command and program error (P35) results.

(6) Those items other than (1) to (5) are the same with the ordinary skip function (G31 without P).

APPENDIXES

Appendix 1. Program Parameter Input N No. Correspondence Table

(Note 1) The units in the table indicate the minimum setting units for the parameter data.

(Note 2) The setting ranges given in the table are the setting ranges on the screen. Designate parameters related to the length by doubling the input setting unit. However, the parameters with "●" in "etc" column (ZERO-RTN PARAM 2027, 2028, 2029) must be excluded.

(Example 1) To set 30mm in a parameter when the input setup unit is B (0.001mm) and metric system.
L60000

(Example 2) To set 5 inch in a parameter when the input setup unit is B (0.0001 inch) and inch system.
L100000

(Note 3) The binary type parameters must be converted into byte-type data, and commanded with a decimal data after address D.

(Example 1) Binary data
$01010101_B = 55_H = 85_D$ .... Command 85

(Example 2) ASCII code
"M" = $01001101_B = 4D_H = 77_D$ .... Command 77
(B indicates Binary, H indicates Hexadecimal, and D indicates Decimal.)

P No. 2 (Axis independent parameter)

Parameter No.	Details	N No.	Data type	Setting range	(Unit)	Remarks
#8201	Axis bit parameter 2	896	Bit	Same as above		bit0 : bit1 : bit2 : bit3 : bit4 : bit5 : bit6 : Axis removal bit7 :
#8202	Axis bit parameter 1	897	Bit	d0 : No. d bit OFF or d1 : No. d bit ON (d : 0 ~ 7)		bit0 : bit1 : bit2 : Soft limit invalid bit3 : bit4 : bit5 : bit6 : bit7 :
#8204	Soft limit (–) (User stroke end lower limit)	916	2-word	± 99999999 × 2	Interpolation unit	
#8205	Soft limit (+) (User stroke end upper limit)	912	2-word	± 99999999 × 2	Interpolation unit	
#8206	Tool change	924	2-word	± 99999999 × 2	Interpolation unit	

Appendix 1. Program Parameter Input N No. Correspondence Table

P No. 2 (Axis independent parameter)

Parameter No.	Details	N No.	Data type	Setting range	(Unit)	Remarks
#2013	OT-	292	2-word	± 99999999 × 2	Interpolation unit	Axis specifications parameter
#2014	OT+	288	2-word	± 99999999 × 2	Interpolation unit	Axis specifications parameter
#2015	tlml-	300	2-word	± 99999999 × 2	Interpolation unit	Axis specifications parameter
#2016	tlml+	296	2-word	± 99999999 × 2	Interpolation unit	Axis specifications parameter
#2017	tap_g	58	Word	0.25 ~ 200.00	(rad/s)	Axis specifications parameter
#2025	G28rap	260	2-word	1 ~ 999999	(min)	Zero point return parameter
#2026	G28crp	38	Word	1 ~ 60000	(min)	Zero point return parameter
#2027	G28sft	44	Word	0 ~ 65535	(μm)	Zero point return parameter ●
#2029	grspc	42	Word	-32767 ~ 999	(mm)	Zero point return parameter ●
#2028	grmask	40	Word	0 ~ 65535	(μm)	Zero point return parameter ●
#2030	dir(-)	20	Bit2	0 ~ 1		Zero point return parameter
#2031	noref	21	Bit2	0 ~ 1		Zero point return parameter
#2032	nochk	54	Bit0	0 ~ 1		Zero point return parameter
#2037	G53ofs	272	2-word	± 99999999 × 2	Interpolation unit	Zero point return parameter
#2038	#2_rfp	276	2-word	± 99999999 × 2	Interpolation unit	Zero point return parameter
#2039	#3_rfp	280	2-word	± 99999999 × 2	Interpolation unit	Zero point return parameter
#2040	#4_rfp	284	2-word	± 99999999 × 2	Interpolation unit	Zero point return parameter
#2061	OT-1B-	324	2-word	± 99999999 × 2	Interpolation unit	Axis specifications parameter 2
#2062	OT-1B+	320	2-word	± 99999999 × 2	Interpolation unit	Axis specifications parameter 2

Appendix 1. Program Parameter Input N No. Correspondence Table

P No. 5 (PLC constant)

Parameter No.	Details	N No.	Data type	Setting range	(Unit)	Remarks
#6301 ~ #6348	PLC constant	1 ~ 48	2-word	0 ~ 99999999		• N No. corresponds to the constant No. (# No.) on the PLC constant screen.

P No. 6 (PLC timer)

Parameter No.	Details	N No.	Data type	Setting range	(Unit)	Remarks
#6000 ~ #6015	10ms addition timer (T0 ~ T15)	0 ~ 15	Word	0 ~ 32767	0.01 s	• Each N No. corresponds to the # No. on the PLC timer screen.
#6016 ~ #6095	10ms addition timer (T16 ~ T95)	16 ~ 95	Word	0 ~ 32767	0.1 s	
#6096 ~ #6103	10ms addition timer (T96 ~ T103)	96 ~ 103	Word	0 ~ 32767	0.1 s	

P No. 7 (PLC counter)

Parameter No.	Details	N No.	Data type	Setting range	(Unit)	Remarks
#6200 ~ #6223	Counter (C0 ~ C23)	0 ~ 23	Word	0 ~ 32767		• N No. corresponds to the # No. on the PLC counter screen.

P No. 8 (Bit selection parameter)

Parameter No.	Details	N No.	Data type	Setting range	(Unit)	Remarks
#6401 ~ #6496	Bit selection parameter	0 ~ 96	Word	8-digit designation (Reading abbreviation not possible) Each bit 0 or 1 d0 : No. d bit OFF or d1 : No. d bit ON (d : 0 ~ 7)		• N No. corresponds to the # No. on the bit selection screen. • N Nos. 49 to 96 are used by the machine maker and Mitsubishi. These must not be used by the user.

Appendix 1. Program Parameter Input N No. Correspondence Table

P No. 11 (Axis common parameters (per part system))

Parameter No.	Details	N No.	Data type	Setting range	(Unit)	Remarks
#8004	Automatic tool length measurement instrument speed	844	2-word	1 ~ 60000	(mm/min)	Machining parameter
#8005	Automatic tool length measurement deceleration range r	836	2-word	0 ~ 99999999 × 2	Interpolation unit	Machining parameter
#8006	Automatic tool length measurement deceleration range d	840	2-word	0 ~ 99999999 × 2	Interpolation unit	Machining parameter
#8008	Automatic corner override max. angle	756	2-word	0 ~ 180	Degree (°)	Machining parameter
#8009	Automatic corner override precorner length	760	2-word	0 ~ 99999999	Interpolation unit	Machining parameter
#8010	Wear data input max. value	776	2-word	0 ~ 99999	Interpolation unit	Machining parameter
#8011	Wear data input max. addition	780	2-word	0 ~ 99999	Interpolation unit	Machining parameter
#8013	G83 return amount	832	2-word	0 ~ 99999999 × 2	Interpolation unit	Machining parameter
#8014	Thread cutting cycle cutoff angle	1011	Byte	0 ~ 89	Degree (°)	Machining parameter
#8015	Thread cutting cycle chamfering amount	1012	Byte	1 ~ 127	0.1 lead	Machining parameter
#8016	G71 cut amount	788	2-word	0 ~ 99999 × 2	Interpolation unit	Machining parameter
#8017	G71 cut amount change amount	792	2-word	0 ~ 99999 × 2	Interpolation unit	Machining parameter
#8301 X	X axis chuck barrier range 1	1136	2-word	± 99999999 × 2	Interpolation unit	Barrier
#8302 X	X axis chuck barrier range 2	1140	2-word	± 99999999 × 2	Interpolation unit	Barrier
#8303 X	X axis chuck barrier range 3	1144	2-word	± 99999999 × 2	Interpolation unit	Barrier
#8304 X	X axis chuck barrier range 4	1148	2-word	± 99999999 × 2	Interpolation unit	Barrier
#8305 X	X axis chuck barrier range 5	1152	2-word	± 99999999 × 2	Interpolation unit	Barrier
#8306 X	X axis chuck barrier range 6	1156	2-word	± 99999999 × 2	Interpolation unit	Barrier
#8301 Z	Z axis chuck barrier range 1	1160	2-word	± 99999999 × 2	Interpolation unit	Barrier
#8302 Z	Z axis chuck barrier range 2	1164	2-word	± 99999999 × 2	Interpolation unit	Barrier
#8303 Z	Z axis chuck barrier range 3	1168	2-word	± 99999999 × 2	Interpolation unit	Barrier
#8304 Z	Z axis chuck barrier range 4	1172	2-word	± 99999999 × 2	Interpolation unit	Barrier

Appendix 1. Program Parameter Input N No. Correspondence Table

P No. 11 (Axis common parameters (per system))

Parameter No.	Details	N No.	Data type	Setting range	(Unit)	Remarks
#8305 Z	Z axis chuck barrier range 5	1176	2-word	± 99999999 × 2	Interpolation unit	Barrier
#8306 Z	Z axis chuck barrier range 6	1180	2-word	± 99999999 × 2	Interpolation unit	Barrier

Appendix 2. Program Error

(The bold characters are the message displayed in the screen.)
These alarms occur during automatic operation, and the causes of these alarms are mainly program errors which occur, for instance, when mistakes have been made in the preparation of the machining programs or when programs which conform to the specification have not been prepared.

Error No.	Details	Remedy
P 10	**EXCS. AXIS No.** The number of axis addresses commanded in the same block exceeds the specifications.	• Divide the alarm block command into two. • Check the specifications.
P 11	**AXIS ADR. ERROR** The axis address commanded by the program and the axis address set by the parameter do not match.	• Revise the axis names in the program.
P 20	**DIVISION ERROR** An axis command which cannot be divided by the command unit has been issued.	• Check the program.
P 30	**PARITY H** The number of holes per character on the paper tape is odd.	• Check the paper tape. • Check the tape puncher and tape reader.
P 31	**PARITY V** The number of characters per block on the paper tape is odd.	• Make the number of characters per block on the paper tape even. • Set the parameter parity V selection off.
P 32	**ADDRESS ERROR** An address not listed in the specifications has been used.	• Check and revise the program address. • Check the specifications.
P 33	**FORMAT ERROR** The command format in the program is not correct.	• Check the program.
P 34	**G-CODE ERROR** A G code not listed in the specifications has been used.	• Check and correct the G code address in the program.
P 35	**CMD-VALUE OVER** The setting range for the addresses has been exceeded.	• Check the program.
P 36	**PROGRAM END ERR** "EOR" has been read during tape and memory operation.	• Enter the M02 and M30 command at the end of the program. • Enter the M99 command at the end of the subprogram.

Appendix 2. Program Error

Error No.	Details	Remedy
P 37	**PROG. NO. ZERO** A zero has been specified for program and sequence numbers.	• The program numbers are designated across a range from 1 to 99999999. • The sequence numbers are designated across a range from 1 to 99999.
P 39	**NO SPEC ERR** A non-specified G code or address was commanded.	• Check the specifications.
P 40	**PREREAD BL. ERR** When cutter compensation is executed, there is an error in the pre-read block and so the interference check is disabled.	• Reconsider the program.
P 60	**OVER CMP. LENG.** The commanded movement distance is excessive. (Over 2^{31})	• Reconsider the axis address command.
P 62	**F-CMD. NOTHING** No feed rate command has been issued.	• The default movement modal command at power on is G01. This causes the machine to move without a G01 command if a movement command is issued in the program, and an alarm results. Use an F command to specify the feed rate. • Specify F with a thread lead command.
P 65	**NO G05P3 SPEC**	• Check the high-speed mode III specifications.
P 70	**ARC ERROR** There is an error in the arc start and end points as well as in the arc center.	• Check the numerical values of the addresses that specify the start and end points as well as the arc center in the program. • Check the "+" and "–" directions of the address numerical values.
P 71	**ARC CENTER** The arc center is not sought during R-specified circular interpolation.	• Check the numerical values of the addresses in the program.
P 72	**NO HELICAL SPEC** A helical command has been issued though it is not included in the specifications.	• Check the helical specifications. • An Axis 3 command was issued by the circular interpolation command. If there is no helical specification, the linear axis is moved to the next block.
P 90	**NO THREAD SPEC** A thread cutting command has been issued though it is not included in the specifications.	• Check the specifications.

Appendix 2. Program Error

Error No.	Details	Remedy
P 93	**SCREW PITCH ERR** The screw pitch has not been set correctly when the thread cutting command is issued.	• Issue the thread cutting command and then set the screw pitch command properly.
P111	**PLANE CHG (CR)** Plane selection commands (G17, G18, and G19) were issued when a coordinate rotation command (G68) was issued.	• Before issuing the plane selection commands, issue G68 and then G69 (coordinate rotation cancel).
P112	**PLANE CHG (CC)** • A plane selection command (G17, G18, G19) has been issued when the cutter compensation command (G41, G42) or nose R compensation command (G41, G42, G46) is issued. • The plane selection command was issued when nose radius compensation is completed, there is no axial movement command after the G40 command, and the compensation has not been canceled.	• Issue the plane selection command after the cutter compensation command or nose radius compensation command has been canceled (issue axial movement command after the G40 cancel command).
P113	**ILLEGAL PLANE** The arc command axis is not on the selected plane.	• Issue arc command on the correctly selected plane.
P122	**NO AUTO C-OVR** An automatic corner override command (G62) has been issued though it is not included in the specifications.	• Check the specifications. • Delete the G62 command from the program.
P130	**2nd AUX. ADDR** The 2nd miscellaneous function address specified in the program does not match that set by the parameter.	• Check and correct the 2nd miscellaneous function address in the program.
P131	**NO G96 SPEC** (No constant peripheral speed) The constant peripheral speed command (G96) was issued despite the fact that such a command does not exist in the specifications.	• Check the specifications. • Change from the constant peripheral speed command (G96) to the speed command (rpm/minute) (G97).
P132	**SPINDLE S = 0** No spindle speed command has been specified.	• Reconsider the program.
P133	**G96 P-No. ERR** An invalid constant peripheral speed control axis has been specified.	• Reconsider the parameter specified for the constant peripheral speed control axis.

Error No.	Details	Remedy
P150	**NO C-CMP SPEC** • Even though there were no nose radius correction specifications, nose radius correction commands (G41, G42, and G46) were issued.	• Check the specifications.
P151	**G2, 3 CMP. ERR** A compensation command (G40, G41, G42, G43, G44, G46) has been issued in the arc mode (G02, G03).	• Issue the linear command (G01) or rapid traverse command (G00) in the compensation command block or cancel block. (Set the modal to linear interpolation.)
P152	**I.S.P NOTHING** In interference block processing during execution of a cutter compensation (G41 or G42) or nose radius compensation (G41, G42, or G46) command, the intersection point after one block is skipped cannot be determined.	• Reconsider the program.
P153	**I.F ERROR** An interference error has arisen while the cutter compensation command (G41, G42) or nose radius compensation command (G41, G42, G46) was being executed.	• Reconsider the program.
P155	**F-CYC ERR (CC)** A canned cycle command has been issued in the cutter compensation mode.	• The cutter compensation mode is established when a canned cycle command is executed and so the cutter compensation cancel command (G40) should be issued.
P156	**BOUND DIRECT** At the start of G46 nose radius compensation, the compensation direction is undefined if this shift vector is used.	• Change the vector to that with which the compensation direction is defined. • Exchange with a tool having a different tip point number.
P157	**SIDE REVERSED** During G46 nose radius compensation, the compensation direction is inverted.	• Change the G command to that which allows inversion of the compensation direction (G00, G28, G30, G33, or G53). • Exchange with a tool having a different tip point number. • Turn on the G46 inversion error avoidance parameter.
P158	**ILLEGAL TIP P.** During G46 nose radius compensation, the tip point is illegal (other than 1 to 8).	• Change the tip point number to a legal one.

<table>
<tr><th>Error No.</th><th>Details</th><th>Remedy</th></tr>
<tr><td><b>P170</b></td><td><b>NO CORR. No.</b>
The compensation number (DOO, TOO, HOO) command was not given when the cutter compensation (G41, G42, G43, G46) command was issued. Alternatively, the compensation number is larger than the number of sets in the specifications.</td><td>• Add the compensation number command to the compensation command block.
• Check the number of compensation number sets a correct it to a compensation number command within the permitted number of compensation sets.</td></tr>
<tr><td><b>P172</b></td><td><b>G10 L-No. ERR</b>
(G10 L-number error)
The L address command is not correct when the G10 command is issued.</td><td>• Check the address L-Number of the G10 command and correct the number.</td></tr>
<tr><td><b>P173</b></td><td><b>G10 P-No. ERR</b>
(G10 compensation error)
When the G10 command is issued, a compensation number outside the permitted number of sets in the specifications has been commanded for the compensation number command.</td><td>• First check the number of compensation sets and then set the address P designation to within the permitted number of sets.</td></tr>
<tr><td><b>P177</b></td><td><b>LIFE COUNT ACT</b>
Registration of tool life management data with G10 was attempted when the used data count valid signal was ON.</td><td>• The tool life management data cannot be registered when counting the used data. Turn the used data count valid signal OFF.</td></tr>
<tr><td><b>P178</b></td><td><b>LIFE DATA OVER</b>
The No. of registration groups, total No. of registered tools or the No. of registrations per group exceeded the specifications range.</td><td>• Review the No. of registrations. The maximum No. of registrations is shown below.
<table>
<tr><th>System</th><th>System 1</th><th>System 2/
System 3</th></tr>
<tr><td>No. of groups</td><td>80</td><td>40/40</td></tr>
<tr><td>No. of tools</td><td>80</td><td>40/40</td></tr>
<tr><td>Per group</td><td colspan="2">16</td></tr>
</table></td></tr>
<tr><td><b>P179</b></td><td><b>GROUP No. ILL.</b>
• When registering the tool life management data with G10, the group No. was commanded in duplicate.
• A group No. that was not registered was designated during the T□□□□99 command.
• An M code command must be issued as a single command but coexists in the same block as that of another M code command.
• The M code commands set in the same group exist in the same block.</td><td>• The group No. cannot be commanded in duplicate. When registering the group data, register it in group units.
• Correct to the correct group No.</td></tr>
</table>

Error No.	Details	Remedy
P180	**NO BORING CYC.** A canned cycle command was issued though there are not canned cycle (G72 – G89) specifications.	• Check the specifications. • Correct the program.
P181	**NO S-CMD (TAP)** The spindle speed command has not been issued when the tapping canned cycle command is given.	• Issue the spindle speed command (S) when the tapping canned cycle command G84, G74 (G84, G88) is given.
P182	**SYN TAP ERROR** Connection to the main spindle unit was not established.	• Check connection to the main spindle. • Check that the main spindle encoder exists.
P183	**PTC/THD, No.** The pitch or thread number command has not been issued in the tap cycle of a boring canned cycle command.	• Specify the pitch data and the number of threads by F or E command.
P184	**NO PTC/THD CMD** The pitch or the number of threads per inch is illegal in the tap cycle of the drilling fixed cycle command.	• Check the pitch or the number of threads per inch.
P185	**NO SYC TAP SPC** A synchronous tapping command (G84R1) was issued although this function was undefined in the specification.	• Check the specification.
P190	**NO CUTTING CYC** A lathe cutting cycle command was input although the lathe cutting cycle was undefined in the specification.	• Check the specification. • Delete the lathe cutting cycle command.
P191	**TAPER LENG ERR** In the lathe cutting cycle, the specified length of taper section is illegal.	• The radius set value in the lathe cycle command must be smaller than the axis shift amount.
P192	**CHAMFERING ERR** Chamfering in the thread cutting cycle is illegal.	• Set a chamfering amount not exceeding the cycle.
P200	**NO MRC CYC SPC** Compound type fixed cycle I command (G70 to G73) was issued although this cycle was undefined in the specification.	• Check the specification.

Appendix 2. Program Error

Error No.	Details	Remedy
P201	**PROG. ERR (MRC)** • When called with a compound type fixed cycle I command, the subprogram contained at least one of the following commands: • Reference point return command (G27, G28, G30) • Thread cutting (G33) • Fixed-cycle skip-function (G31) • The first move block of the finish shape program in compound type fixed cycle I contains an arc command.	• Delete the following G codes from this subprogram that is called with the compound type fixed cycle I commands (G70 to G73): G27, G28, G30, G31, G33, fixed-cycle G-code. • Remove G2 and G3 from the first move block of the finish shape program in compound type fixed cycle I.
P202	**BLOCK OVR (MRC)** The number of blocks in the shape program of the compound type fixed cycle I is over 50.	• Specify 50 or a less value. The number of blocks in the shape program called by the compound type fixed cycle I commands (G70 to G73) must be decreased below 50.
P203	**CONF. ERR (MRC)** The compound type fixed cycle I (G70 to G73) shape program could not cut the work normally because it defined an abnormal shape.	• Check the compound type fixed cycle I (G70 to G73) shape program.
P204	**VALUE ERR (MRC)** A command value of the compound type fixed cycle I (G70 to G76) is illegal.	• Check the compound type fixed cycle (G70 to G76) command value.
P210	**NO PAT CYC SPC** A compound type fixed cycle II (G74 to G76) command was input although it was undefined in the specification.	• Check the specification.
P220	**NO SPECIAL CYC** No special fixed cycle specifications are available.	• Check the specifications.
P221	**NO HOLE (S_CYC)** A 0 has been specified for the number of holes in special fixed cycle mode.	• Reconsider the program.
P222	**G36 ANGLE ERR** A G36 command specifies 0 for angle intervals.	• Reconsider the program.
P223	**G12 G13 R ERR** The radius value specified with a G12 or G13 command is below the compensation amount.	• Reconsider the program.
P224	**NO G12, G13 SPC** There are no circular cutting specifications.	• Check the specifications.

Appendix 2. Program Error

Error No.	Details	Remedy
P230	**NESTING OVER** • A subprogram has been called 8 or more times in succession from the subprogram. • The program in the IC card has been called more than once (the program in the IC card can be called only once at a time).	• Check the number of subprogram calls and correct the program so that it does not exceed 8 times. • When using the IC card, the IC card and the number of IC card program calls.
P231	**NO N-NUMBER** At subprogram call time, the sequence number set at return from the subprogram or specified by GOTO, was not set.	• Specify the sequence numbers in the call block of the subprogram. • When using the IC card, check the program in the IC card and the number of IC card program calls.
P232	**NO PROGRAM No.** The subprogram has not been found when the subprogram is called.	• Enter the subprogram. • Check the program number in the IC card.
P241	**NO VARI NUMBER** The variable number commanded is higher than the numbers in the specifications.	• Check the specifications. • Check the program variable number.
P242	**EQL. SYM. MSSG.** The “=” sign has not been commanded when a variable is defined.	• Designate the “=” sign in the variable definition of the program.
P243	**VARIABLE ERR.** An invalid variable has been specified in the left or right side of an operation expression.	• Correct the program.
P260	**NO COOD-RT SPC** Even though there were no coordinate rotation specifications, a coordinate rotation command was issued.	• Check the specifications.
P270	**NO MACRO SPEC** A macro specification was commanded though there are no such command specifications.	• Check the specifications.
P271	**NO MACRO INT.** A macro interrupt command has been issued though it is not included in the specifications.	• Check the specifications.
P272	**MACRO ILL.** A statement and a macro statement exist together in the same block.	• Reconsider the program and place the executable statement and macro statement in separate blocks.
P273	**MACRO OVERCALL** The frequency of the macro call has exceeded the limit imposed by the specification.	• Reconsider the program and correct it so that the macro calls do not exceed the limit imposed by the specification.

Error No.	Details	Remedy
P275	**MACRO ARG. EX.** The number of macro call argument type II sets has exceeded the limit.	• Reconsider the program.
P276	**CALL CANCEL** A G67 command was issued though it was not during the G66 command modal.	• Reconsider the program. • The G67 command is the call cancel command and so the G66 command must be designated first before it is issued.
P277	**MACRO ALM MESG** An alarm command has been issued in #3000.	• Refer to the operator messages on the DIAG screen. • Refer to the instruction manual issued by the machine manufacturer.
P280	**EXC. [,** The number of parentheses [,] which can be commanded in a single block has exceeded five.	• Reconsider the program and correct it so the number of "[" or "]" does not exceed five.
P281	**[,] ILLEGAL** The number of "[" and "]" parentheses commanded in a single block does not match.	• Reconsider the program and correct it so that "[" and "]" parentheses are paired up properly.
P282	**CALC. IMPOSS.** The arithmetic formula is incorrect.	• Reconsider the program and correct the formula.
P283	**DIVIDE BY ZERO** The denominator of the division is zero.	• Reconsider the program and correct it so that the denominator for division in the formula is not zero.
P284	**INTEGER OVER** In the process of the calculation the integral number has exceeded -2^{31} ($2^{31}-1$).	• Check the arithmetic formula in the program and correct it so that the value of the integral number after calculation does not exceed -2^{31}.
P285	**OVERFLOW VALUE** The variable data has overflowed.	• Check the variable data in the program.
P290	**IF SNT. ERROR** There is an error in the IF conditional GOTO□ statement.	• Reconsider the program.
P291	**WHILE SNT. ERR** There is an error in the WHILE conditional DO□-END□ statement.	• Reconsider the program.
P292	**SETVN SNT. ERR** There is an error in the SETVN □ statement when the variable name setting was made.	• Reconsider the program. • The number of characters in the variable name of the SETVN statement must be 7 or less.
P293	**DO-END EXCESS** The number of □’s for DO-END□ in the WHILE conditional DO□ – END□ statement has exceed 27.	• Reconsider the program and correct it so that the number of ’s in the DO – END statement does not exceed 27.

Appendix 2. Program Error

Error No.	Details	Remedy
P294	**DO-END MMC.** The DO's and END's are not paired off properly.	• Reconsider the program and correct it so that the DO's and END's are paired off properly.
P295	**WHILE/GOTO TPE** There is a WHILE or GOTO statement on the tape during tape operation.	• During tape operation, a program which includes a WHILE or GOTO statement cannot be executed and so the memory operation mode is established instead.
P296	**NO ADR (MACRO)** A required address has not been specified in the user macro.	• Review the program.
P297	**ADR-A ERR.** The user macro does not use address A as a variable.	• Review the program.
P298	**PTR OP (MACRO)** User macro G200, G201, or G202 was specified during tape or MDI operation.	• Review the program.
P300	**VER. NAME ERROR** The variable names have not been commanded properly.	• Reconsider the variable names in the program and correct them.
P301	**VAR NAME DUPLI** The name of the variable has been duplicated.	• Correct the program so that the name is not duplicate.
P360	**NO PROG.MIRR.** A mirror image (G50.1 or G51.1) command has been issued though the programmable mirror image specifications are not provided.	• Check the specifications.
P380	**NO CORNER R/C** A command was issued for corner rounding or corner chamfering though there are no such specifications.	• Check the specifications. • Remove the corner rounding or chamfering command from the program.
P381	**NO ARC R/C SPC** Corner rounding or chamfering was specified in the arc interpolation block although corner chamfering/corner rounding II is unsupported.	• Check the specifications.
P382	**CORNER NO MOVE** The block next to corner rounding/ chamfering is not a movement command.	• Replace the block succeeding the corner rounding/chamfering command by G01 command.
P383	**CORNER SHORT** In the corner rounding or chamfering command, the movement distance was shorter than the value in the corresponding command.	• Make the corner rounding or chamfering less than the movement distance since this distance is shorter than the corner rounding or chamfering.

Error No.	Details	Remedy
P384	**CORNER SHORT** When the corner rounding or chamfering command was input, the movement distance in the following block was shorter than the length of the corner rounding or chamfering.	• Make the corner rounding or chamfering less than the movement distance since this distance in the following block is shorter than the corner rounding or chamfering.
P385	**G0 G33 IN CONR** A block with corner rounding/chamfering was given during G00 or G33 modal.	• Recheck the program.
P390	**NO GEOMETRIC** A geometric command was issued though there are no geometric specifications.	• Check the specifications.
P391	**NO GEOMETRIC 2** There are no geometric IB specifications.	• Check the specifications.
P392	**LES AGL (GEOMT)** The angular difference between the geometric line and line is 1° or less.	• Correct the geometric angle.
P393	**INC ERR (GEOMT)** The second geometric block was specified by an incremental value.	• Specify this block by an absolute value.
P394	**NO G01 (GEOMT)** The second geometric block contains no linear command.	• Specify the G01 command.
P395	**NO ADRS (GEOMT)** The geometric format is invalid.	• Recheck the program.
P396	**PL CHG. (GEOMT)** A plane switching command was executed during geometric command processing.	• Execute the plane switching command before geometric command processing.
P397	**ARC ERR (GEOMT)** In geometric IB, the circular arc end point does not contact or cross the next block start point.	• Recheck the geometric circular arc command and the preceding and following commands.
P398	**NO GEOMETRIC 1B** Although the geometric IB specifications are not included, a geometric command is given.	• Check the specifications.
P420	**NO PARAM IN** Although the programmable parameter input specifications are not provided, the command was given.	• Check the specifications.

Error No.	Details	Remedy
P421	**PRAM. IN ERROR** • The specified parameter number or set data is illegal. • An illegal G command address was input in parameter input mode. • A parameter input command was input during fixed-cycle modal or nose R compensation.	• Check the program.
P430	**AXIS NOT RET.** • A command was issued to move an axis, which has not returned to the reference point, away from that reference point. • A command was issued to an axis removal axis.	• Execute reference point return manually. • The command was issued to an axis for which axis removal is validated so invalidate axis removal.
P431	**NO 2nd REF. SPC** A command for second, third or fourth reference point return was issued though there are no such command specifications.	• Check the specifications.
P434	**COLLATION ERR** One of the axes did not return to the start position when the origin point collate command (G27) was executed.	• Check the program.
P435	**G27/M ERROR** An M command was issued simultaneously in the G27 command block.	• An M code command cannot be issued in a G27 command block and so the G27 command and M code command must be placed in separate blocks.
P436	**G29/M ERROR** An M command was issued simultaneously in the G29 command block.	• An M code command cannot be issued in a G29 command block and so the G29 command and M code command must be placed in separate blocks.
P438	**NOT USE (G52)** A local coordinate system command was issued during execution of the G54.1 command.	• Review the program.
P450	**NO CHUCK BARR.** The chuck barrier on command (G22) was specified although the chuck barrier was undefined in the specification.	• Check the specification.
P460	**TAPE I/O ERROR** An error has arisen in the tape reader or, alternatively, in the printer during macro printing.	• Check the power and cable of the connected devices. • Check the I/O device parameters.

Appendix 2. Program Error

Error No.	Details	Remedy
P461	**FILE I/O ERROR** A file of the machining program cannot be read.	• In memory mode, the programs stored in memory may have been destroyed. Output all of the programs and tool data once and format them. • Ensure that the external device (including a floppy disk drive and IC card) that contains the file is mounted.
P462	**DNC ERROR** A communication error occurred during BTR operation.	• Message "L01 DNC ERROR xxx" appears at the same time. Refer to a description for the error No.
P600	**NO AUTO TLM.** An automatic tool length measurement command (G37) was execute though there are no such command specifications.	• Check the specifications.
P601	**NO SKIP SPEC.** A skip command (G31) was issued though there are no such command specifications.	• Check the specifications.
P602	**NO MULTI SKIP** A multiple skipping command (G31.1, G31.2 or G31.3) was issued though there are no such command specifications.	• Check the specifications.
P603	**SKIP SPEED 0** The skip speed is 0.	• Specify the skip speed.
P604	**TLM ILL. AXIS** No axis or more than one axis was specified in the automatic tool length measurement block.	• Specify only one axis.
P605	**T-CMD IN BLOCK** The T code is in the same block as the automatic tool length measurement block.	• Specify this T code before the block.
P606	**NO T-CMD BEFOR** The T code was not yet specified in automatic tool length measurement.	• Specify this T code before the block.
P607	**TLM ILL. SIGNL** Before the area specified by the D command or decelerating area parameter d, the measurement position arrival signal went on. The signal remains off to the end.	• Check the program.
P608	**SKIP ERROR (CC)** A skip command was specified during cutter compensation processing.	• Specify a diameter cancel (G40) command, or remove the skip command.

Error No.	Details	Remedy
P610	**ILLEGAL PARA.** • G114.1 was commanded when the spindle synchronization with PLC I/F command was selected. • Spindle synchronization was commanded to a spindle that is not connected serially.	• Check the program. • Check the argument of G114.1 command. • Check the state of spindle connection.
P701	**REGARD A POINT** A decimal point was added to a decimal point invalid address.	• Do not add a decimal point to the decimal point invalid address.
P990	**PREPRO S/W ERR** Combining commands that required pre-reading (nose R offset, corner chamfering/corner R, geometric I, geometric IB, and compound type fixed cycle commands) resulted in eight or more pre-read blocks.	• Reduce the number of commands that require pre-reading or delete such commands.

Revision history

Date of revision	Manual No.	Revision details
Oct. 2001	BNP-B2264B	First edition created.
May. 2004	BNP-B2264D	• The contents revised following to the software Ver.C and Ver.D. • Mistakes, etc. were corrected.

Notice

Every effort has been made to keep up with software and hardware revisions in the contents described in this manual. However, please understand that in some unavoidable cases simultaneous revision is not possible.

Please contact your Mitsubishi Electric dealer with any questions or comments regarding the use of this product.

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MITSUBISHI ELECTRIC CORPORATION

HEAD OFFICE : MITSUBISHI DENKI BLDG., 2-2-3, MARUNOUCHI, CHIYODA-KU, TOKYO 100-8310, JAPAN

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