FANUC Series 16*i*-LB
FANUC Series 160*i*-LB

CONNECTION MANUAL

B-63663EN/01

DEFINITION OF WARNING, CAUTION, AND NOTE

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

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

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

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

* Read this manual carefully, and store it in a safe place.

PREFACE

About this manual

"Connection Manual (Hardware) (B-63523EN)" and "Connection Manual (Function) (B-63523EN-1)" for Series 16*i*/160*i*-MODEL B and this manual are provided to design a laser processing machine.
The "Hardware" and "Function" connection manuals provide general connection information relating to the configuration of a processing system.
FANUC Series 16*i*/160*i*-LB CONNECTION MANUAL provides supplementary information about the laser functions which are not explained in the above two connection manuals ("Hardware" and "Function").

Manual name	Specification number	
CONNECTION MANUAL (HARDWARE)	B-63523EN	
CONNECTION MANUAL (FUNCTION)	B-63523EN-1	
FANUC Series 16*i*/160*i*-LB CONNECTION MANUAL	B-63663EN	*

In addition to the above connection manuals, laser oscillator manuals are available. Refer to these manuals as necessary.

The laser functions are explained as described below.

1. Overview
   This section outlines the various functions. For details, refer to the operator's manual as necessary.
2. Signals
   Explains the names, functions, output conditions, and signal addresses of the signals required to implement each function.
3. Parameters
   Explains the parameters related to each function.
4. Alarms and messages
   Lists the alarms and messages related to each function.
5. Reference
   Lists the related manuals and items.

An address list and signal list are provided in the appendixes of this manual. Refer to these appendixes as necessary.

Applicable product

This manual explains the following product. In the manual, the following abbreviation may be used.

Product name	Abbreviations
FANUC Series 16*i*-LB	16*i*-LB
FANUC Series 160*i*-LB	160*i*-LB

- Representation of bit type and bit-axis type parameters

Data No. Data (#0 to #7 indicate bit positions.)

	#7	#6	#5	#4	#3	#2	#1	#0
0000			SEQ			INI	ISO	TVC

- Representation of parameters other than bit type and bit-axis type parameters

Data No.	Data
1023	

Related manuals of Series Series 16*i*/160*i*-LB

The following table lists the manuals related to Series 16*i*-LB, Series 160*i*-LB. This manual is indicated by an asterisk (*).

Related manuals of Series Series Series 16*i*/160*i*-LB

Manual name	Specification number	
Series 16*i*/18*i*/21*i*/160*i*/180*i*/210*i*/160*i*s/180*i*s/210*i*s-MODEL B DESCRIPTIONS	B-63522EN	
Series 16*i*/160*i*-LBDESCRIPTIONS	B-63662EN	
Series 16*i*/18*i*/21*i*/160*i*/180*i*/210*i*/160*i*s/180*i*s/210*i*s-MODEL B CONNECTION MANUAL (HARDWARE)	B-63523EN	
Series 16*i*/18*i*/21*i*/160*i*/180*i*/210*i*/160*i*s/180*i*s/210*i*s-MODEL B CONNECTION MANUAL (FUNCTION)	B-63523EN-1	
Series 16*i*/160*i*-LBCONNECTION MANUAL	B-63663EN	*
Series 16*i*/160*i*-LBOPERATOR'S MANUAL	B-63664EN	
Series 16*i*/18*i*/21*i*/160*i*/180*i*/210*i*/160*i*s/180*i*s/210*i*s-MODEL B MAINTENANCE MANUAL	B-63525EN	
Series 16*i*/160*i*-LBMAINTENANCE MANUAL	B-63665EN	
Series 16*i*/18*i*/160*i*/180*i*/160*i*s/180*i*s- MODEL B PARAMETER MANUAL	B-63530EN	
Series 16*i*/160*i*-LBPARAMETER MANUAL	B-63670EN	
PROGRAMMING MANUAL		
Macro Compiler/Macro Executor PROGRAMMING MANUAL	B-61803E-1	
C Language Executor PROGRAMMING MANUAL	B-62443EN-3	
FANUC MACRO COMPILER (For Personal Computer) PROGRAMMING MANUAL	B-66102E	
PMC		
PMC Ladder Language PROGRAMMING MANUAL	B-61863E	
PMC C Language PROGRAMMING MANUAL	B-61863E-1	
Network		
I/O Link-II OPERATOR'S MANUAL	B-62714EN	
PROFIBUS-DP Board OPERATOR'S MANUAL	B-62924EN	
FAST Ethernet Board/FAST DATA SERVER OPERATOR'S MANUAL	B-63644EN	
Ethernet Board/DATA SERVER Board OPERATOR'S MANUAL	B-63354EN	
DeviceNet Board OPERATOR'S MANUAL	B-63404EN	
PC function		
Screen Display Function OPERATOR'S MANUAL	B-63164EN	

Related manuals of SERVO MOTOR $\alpha i/\beta i$ series

The following table lists the manuals related to SERVO MOTOR $\alpha i/\beta i$ series.

Manual name	Specification number
FANUC AC SERVO MOTOR αis series FANUC AC SERVO MOTOR αi series DESCRIPTIONS	B-65262EN
FANUC AC SPINDLE MOTOR αi series DESCRIPTIONS	B-65272EN
FANUC AC SERVO MOTOR βis series DESCRIPTIONS	B-65302EN
FANUC AC SPINDLE MOTOR βi series DESCRIPTIONS	B-65312EN
FANUC SERVO AMPLIFIER αi series DESCRIPTIONS	B-65282EN
FANUC SERVO AMPLIFIER βi series DESCRIPTIONS	B-65322EN
FANUC SERVO MOTOR αis series FANUC SERVO MOTOR αi series FANUC AC SPINDLE MOTOR αi series FANUC SERVO AMPLIFIER αi series MAINTENANCE MANUAL	B-65285EN
FANUC SERVO MOTOR βis series FANUC AC SPINDLE MOTOR βi series FANUC SERVO AMPLIFIER βi series MAINTENANCE MANUAL	B-65325EN
FANUC AC SERVO MOTOR αi series FANUC AC SERVO MOTOR βi series PARAMETER MANUAL	B-65270EN
FANUC AC SPINDLE MOTOR αi series FANUC AC SPINDLE MOTOR βi series PARAMETER MANUAL	B-65280EN

Related manuals of SERVO MOTOR α series

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

Manual name	Specification number
FANUC AC SERVO MOTOR α series DESCRIPTIONS	B-65142E
FANUC AC SERVO MOTOR α series PARAMETER MANUAL	B-65150E
FANUC AC SPINDLE MOTOR α series DESCRIPTIONS	B-65152E
FANUC AC SPINDLE MOTOR α series PARAMETER MANUAL	B-65160E
FANUC SERVO AMPLIFIER α series DESCRIPTIONS	B-65162E
FANUC SERVO MOTOR α series MAINTENANCE MANUAL	B-65165E

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

- FANUC SERVO MOTOR α*i* series
- FANUC SERVO MOTOR α series

This manual mainly assumes that the FANUC SERVO MOTOR α*i* series of servo motor is used. For servo motor and spindle information, refer to the manuals for the servo motor and spindle that are actually connected.

TABLE OF CONTENTS

I. HARDWARE

1 OVERVIEW

1.1 DIFFERENCES BETWEEN Series 16*i*-LB AND Series 16*i*

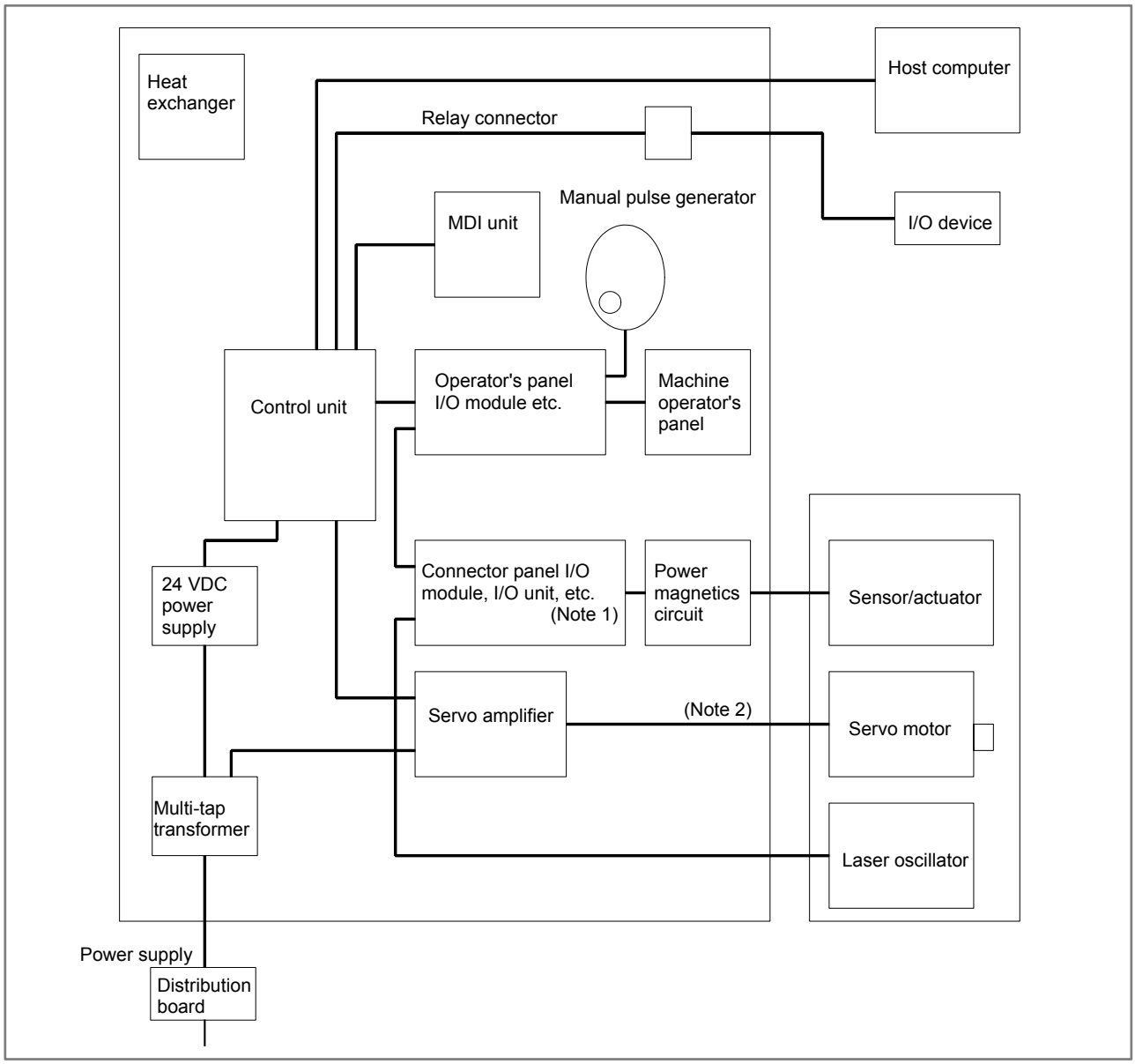
Configure the Series 16*i*-LB system by making connections as described in the "Series 16*i*-B Connection Manual."
For an explanation of the differences between the Series 16*i*-LB and Series 16*i*, refer to this manual as necessary.

1.2 CORRESPONDENCE BETWEEN LASER SERIES AND SOFTWARE SERIES

The FANUC laser series includes the C series, Y series, and YP series. The correspondence between the laser series and the software series are shown below.

Laser series	Oscillator type	Software series
C series	CO_2 laser	B8H1 series
Y series	Continuous output YAG laser	B8H1 series
YP series	Pulse output YAG laser	Not supported

2 CONFIGURATION



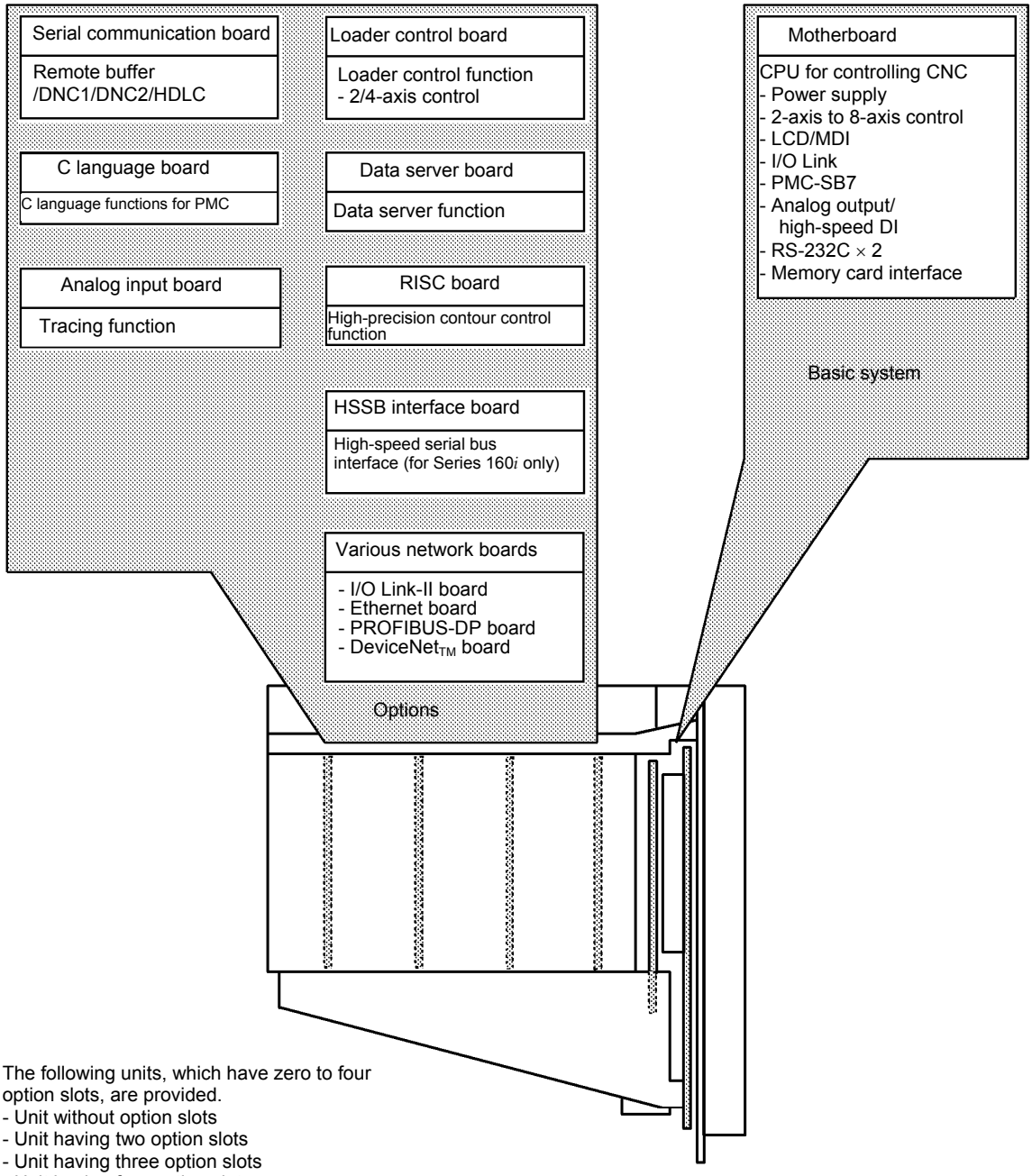
NOTE

1 For information about the I/O unit, refer to the "FANUC I/O Unit-MODEL A Connection and Maintenance Manual (B-61813E)" and "FANUC I/O Unit-MODEL B Connection Manual (B-62163E)."

2 For an explanation of the connection between the amplifier and motor, refer to the following manuals:
- FANUC AC SERVO MOTOR α series Descriptions (B-65142E)
- FANUC SERVO AMPLIFIER α series Descriptions (B-65162E)

3 CONTROL UNIT

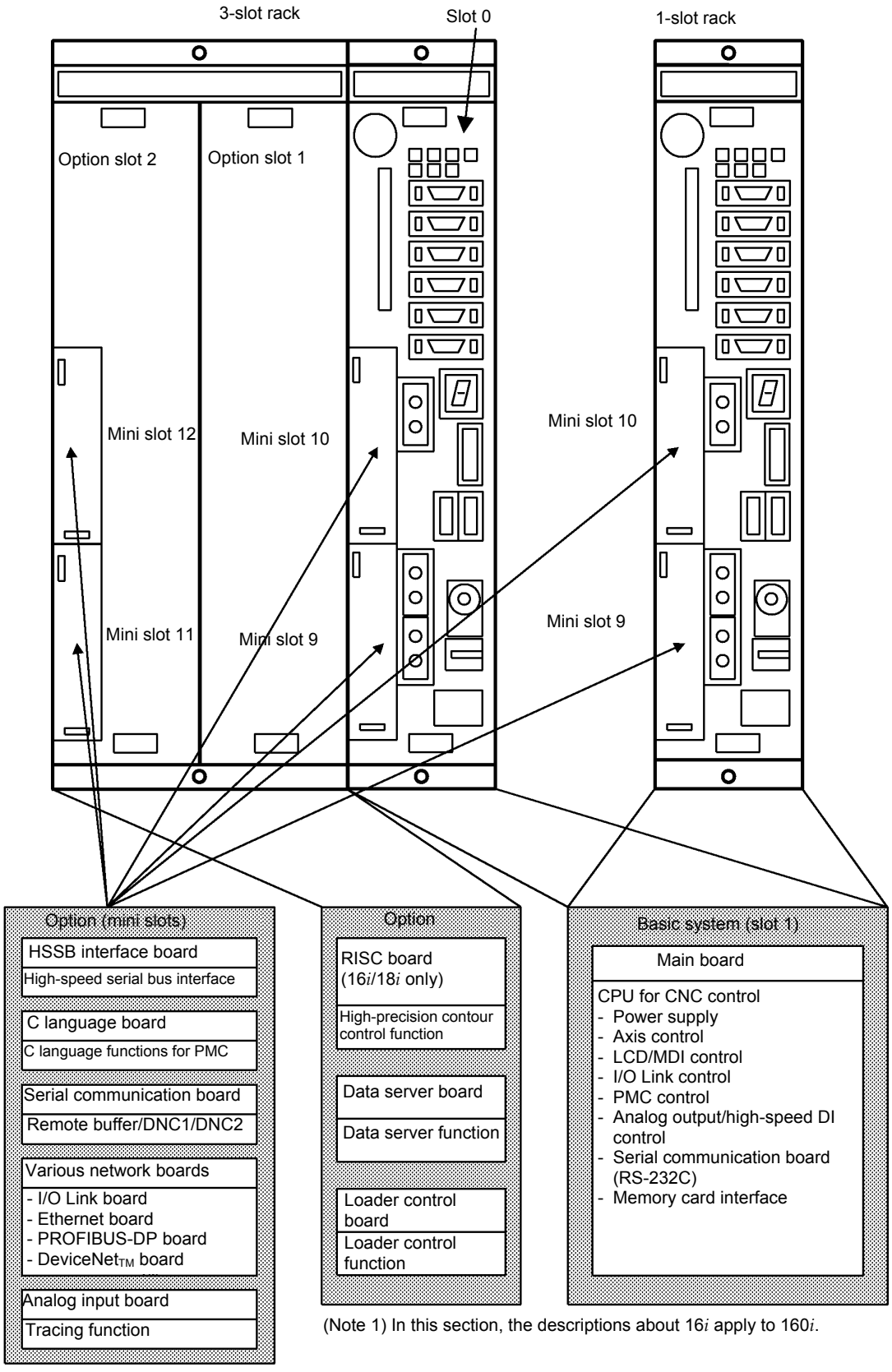
3.1 CONFIGURATION OF THE CONTROL UNIT



The following units, which have zero to four option slots, are provided.
- Unit without option slots
- Unit having two option slots
- Unit having three option slots
- Unit having four option slots

A unit with one or more option slots can have the same number of option boards installed as option slots. (However, there are mounting conditions for each option board. See the provided option mounting conditions.)

Fig. 3.1 (a) Summary of the LCD-mounted type control unit (Series 16*i*/160*i*)



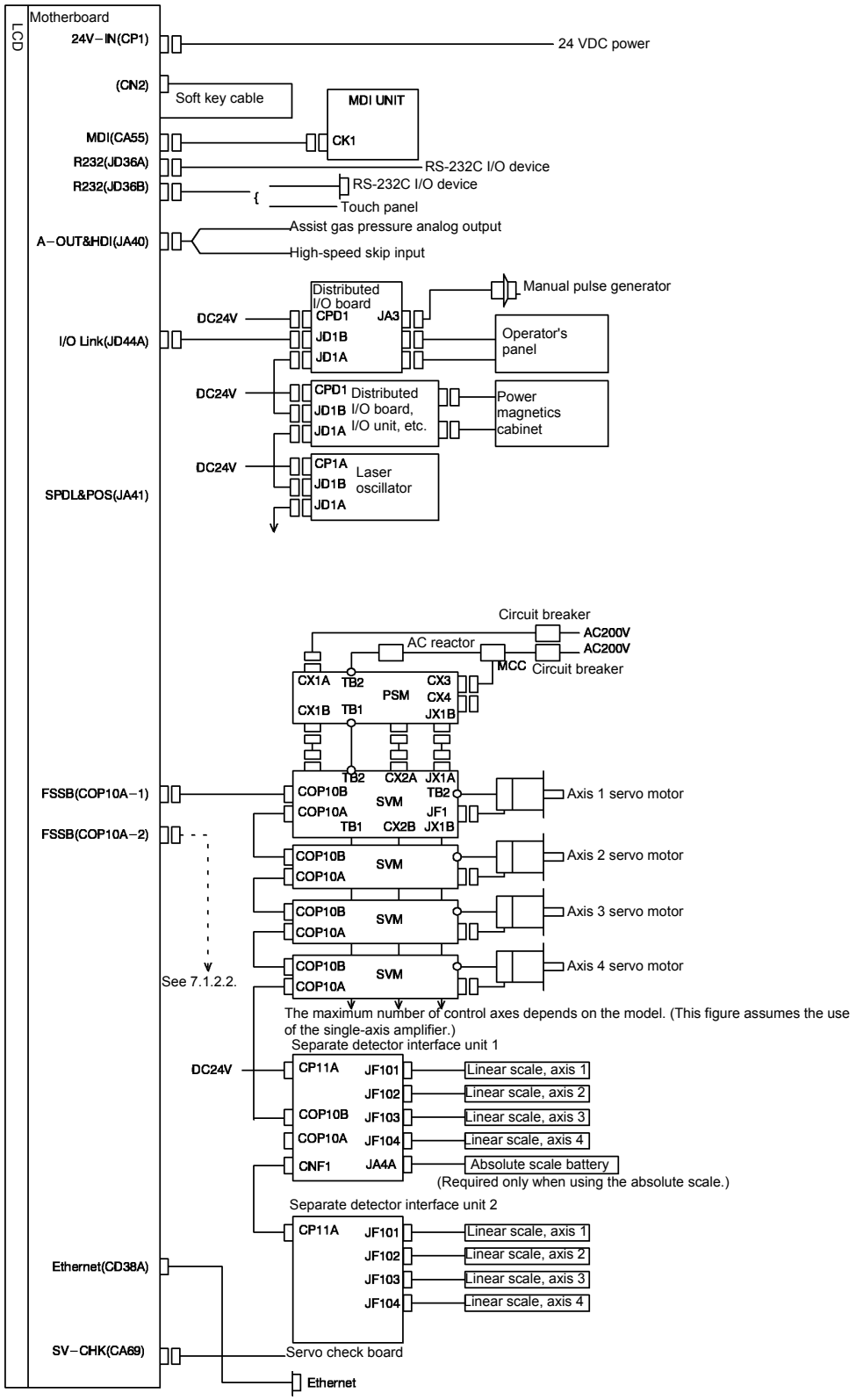
(Note 1) In this section, the descriptions about 16*i* apply to 160*i*.

Fig. 3.1 (b) Summary of the stand-alone type control unit

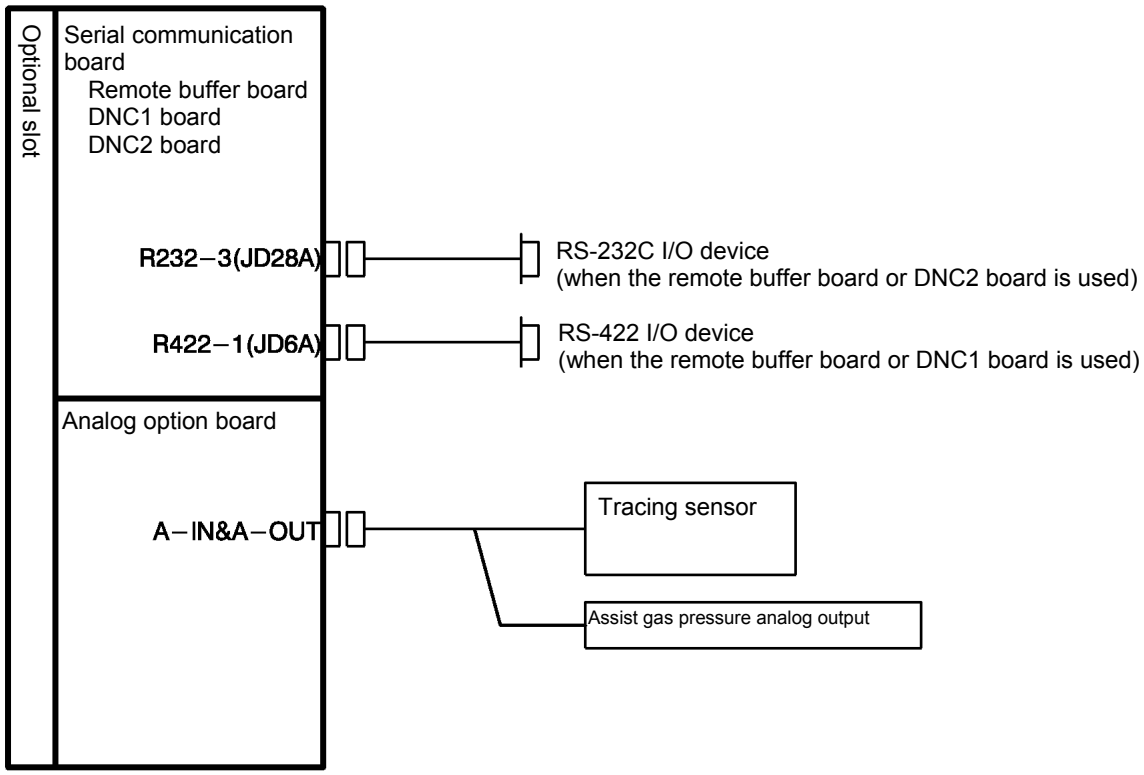
4 TOTAL CONNECTION DIAGRAM

4.1 FOR C SERIES AND Y SERIES OSCILLATORS

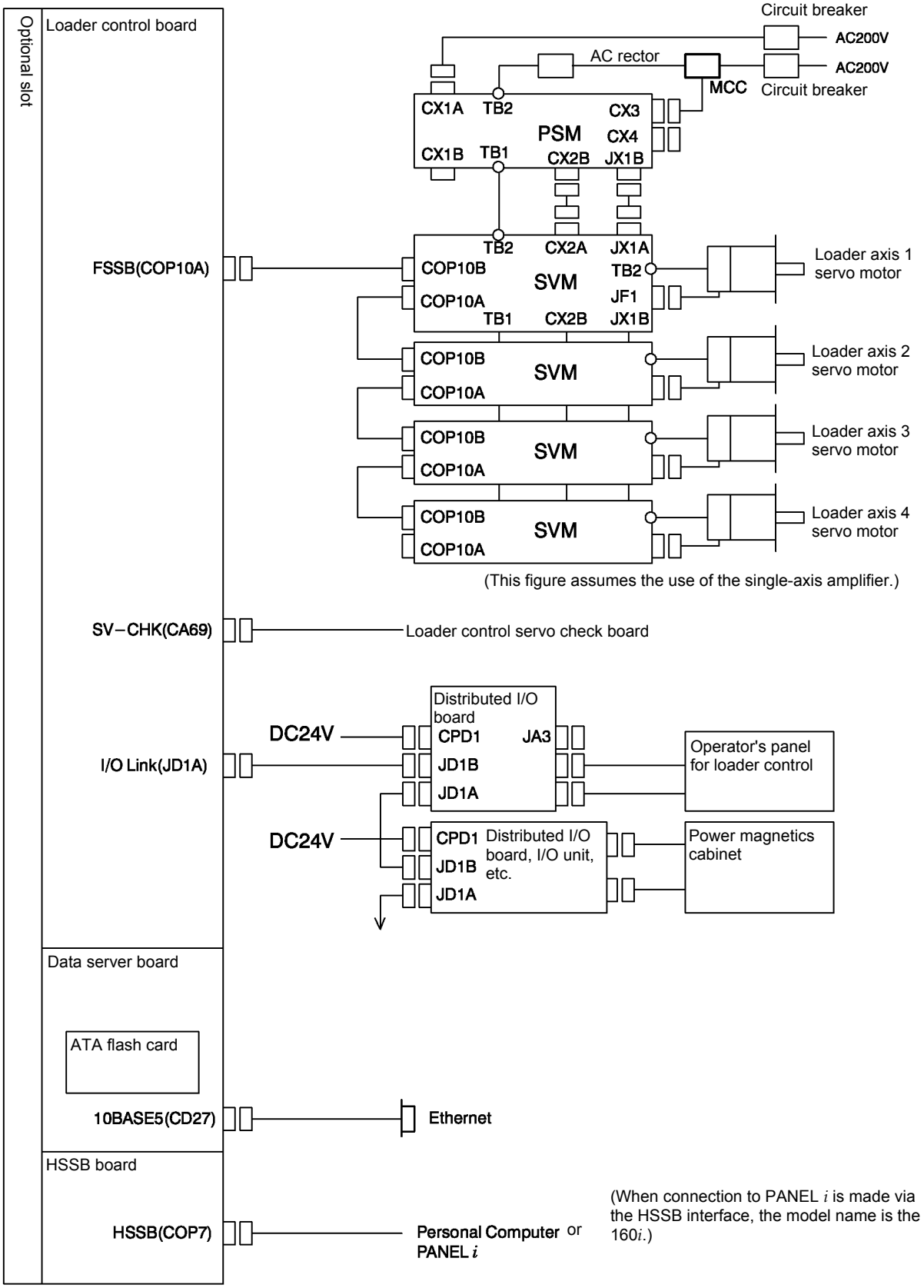
LCD-mounted type control unit (except 160*i* with PC)



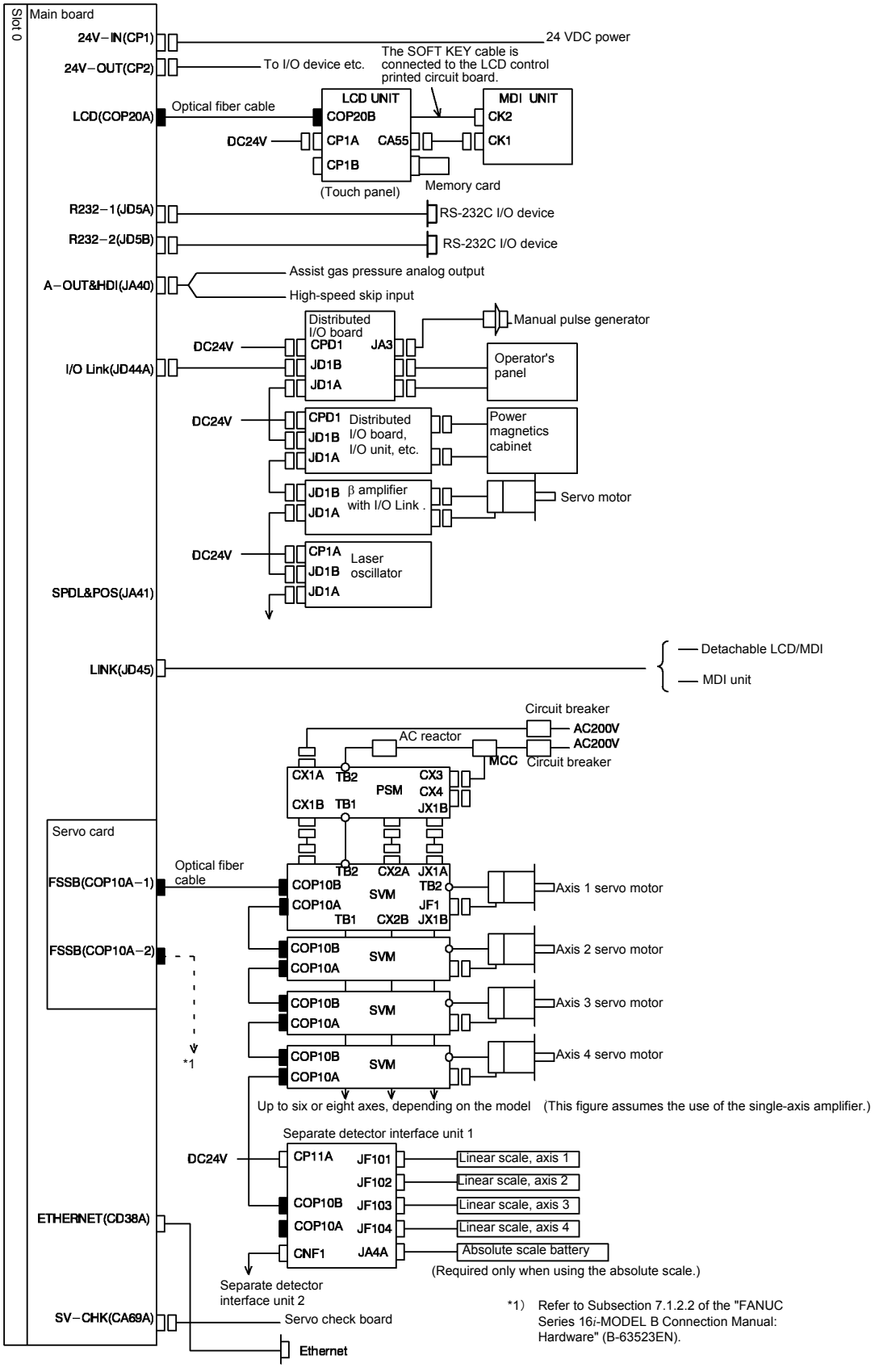
LCD-mounted type control unit (when the option function is provided)



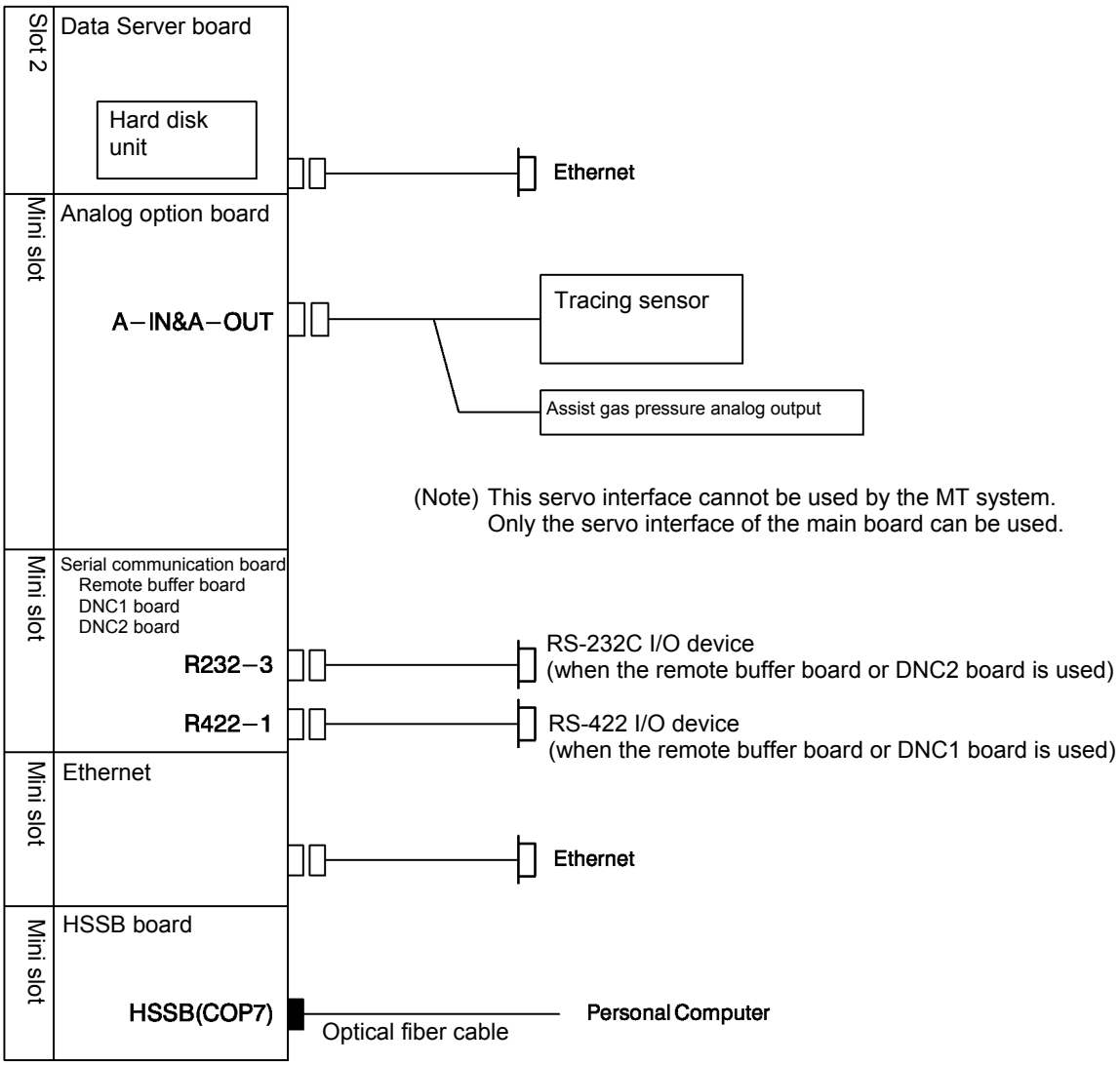
LCD-mounted type control unit (when the option function is provided)



Stand-alone type control unit



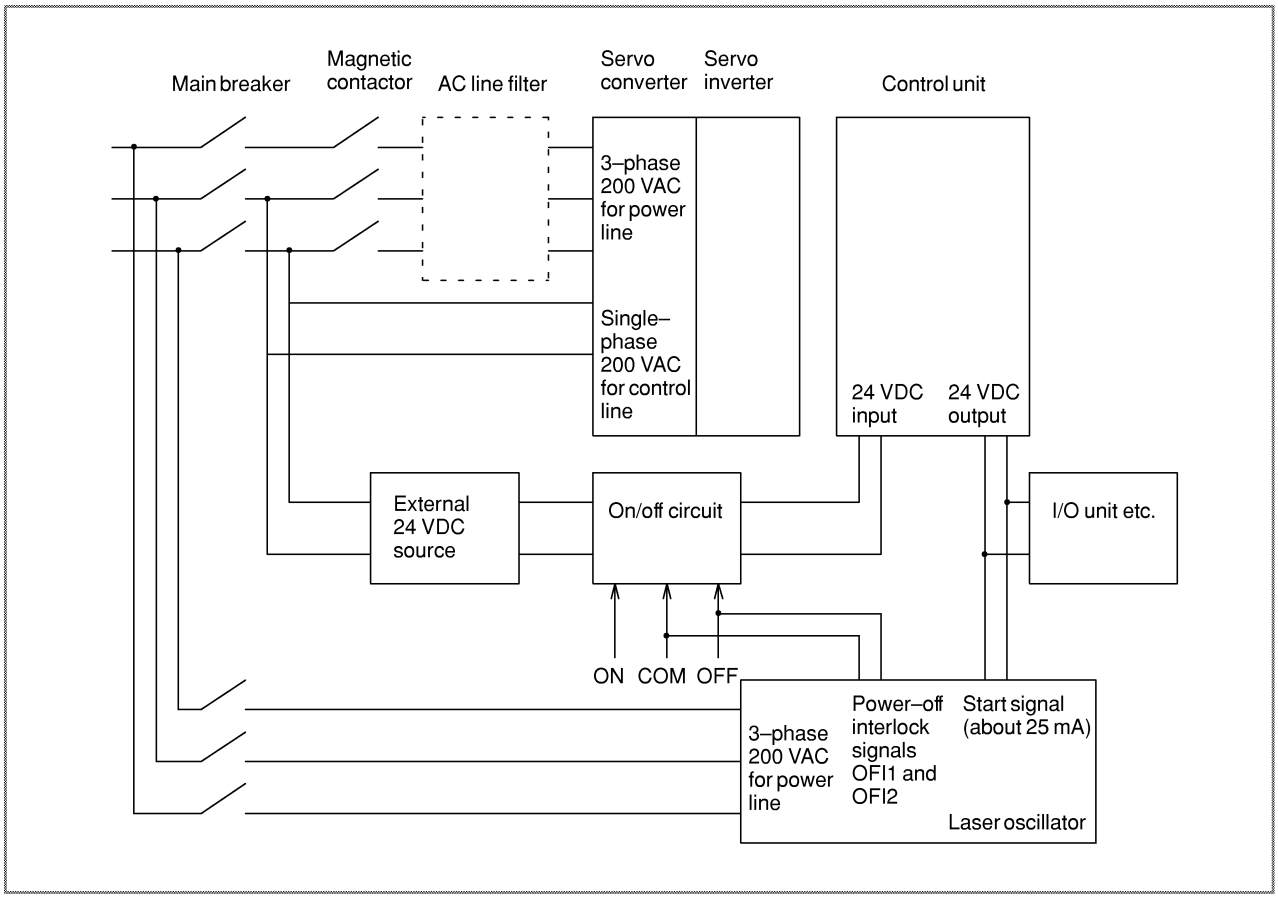
Stand-alone type control unit



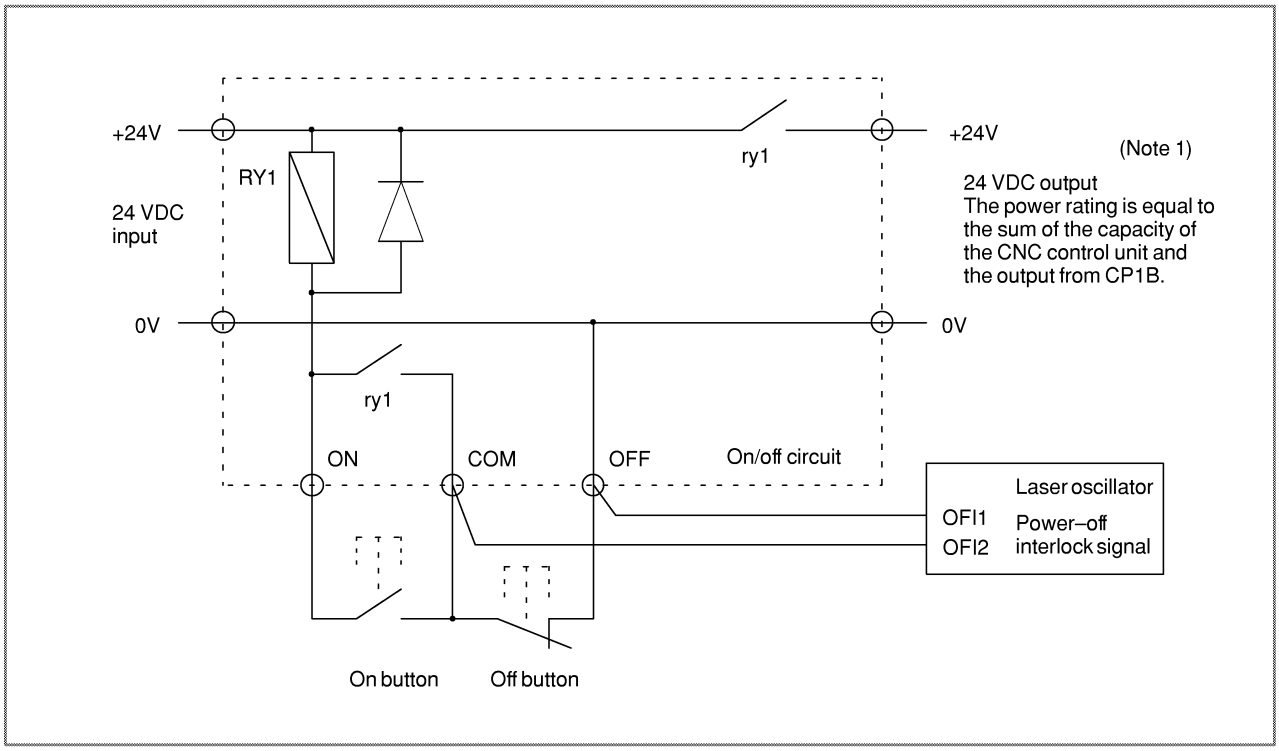
5 POWER SUPPLY

5.1 CONTROL UNIT POWER SUPPLY

Supply power (24 VDC) from an external source to the control unit of the Series 16*i*-LB/160*i*-LB system. Install an external power-on/off switch for the control unit, as shown in the figure below. When the Series 160*i*-LB system with PC functions is used, apply countermeasures to guard against possible destruction of the data on the hard disk due to a momentary power failure; for example, install an uninterruptible power supply. The power rating is equal to the sum of the capacity of the control unit (total power consumption in the unit plus a margin of about 20% to 30%) and the output via the control unit (output from CP1B).



Sample on/off circuit
The figure below shows a sample on/off circuit. Select the circuit devices according to the actual power rating. Connect the OFF and COM lines to the OF11 and OF12 contacts of the laser oscillator, respectively, so that an interlock can be applied to the power-off switch.



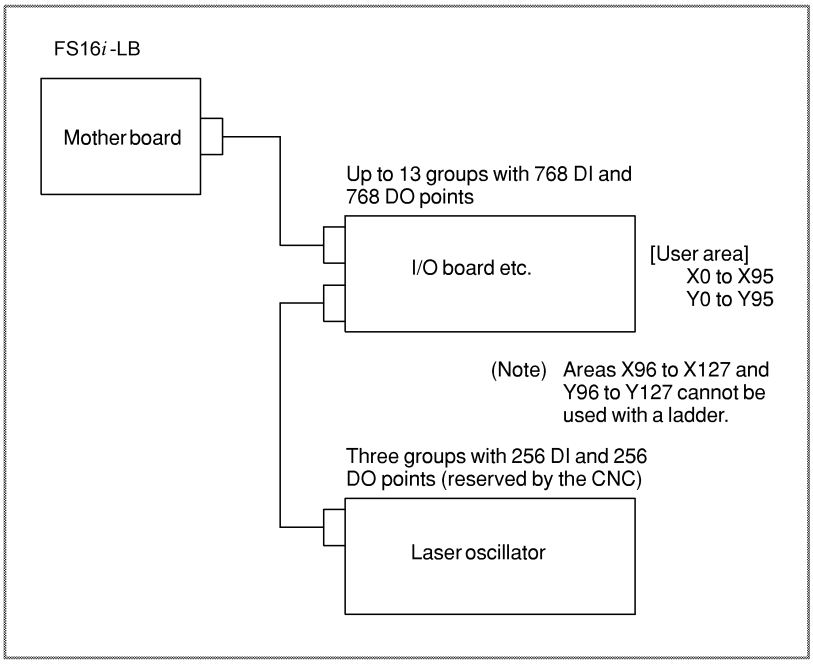
NOTE
1 For the C series and Y series oscillators, laser activation can be performed by the above 24 VDC signal.

5.2 POWER CAPACITY AND HEATING VALUE OF THE ANALOG INPUT BOARD

The analog input board for tracking control requires an input power source with a power voltage of 24 VDC ±10% and a power capacity of 0.3 A. The percentage of ±10% includes instantaneous and ripple voltages.
The heating value is 7 W.
For the power capacities and heating values of other units, refer to the "FANUC Series 16*i*-MODEL B Connection Manual (Hardware) (B-63523EN)".

6 I/O LIMITATION BASED ON LASER OSCILLATOR CONNECTION

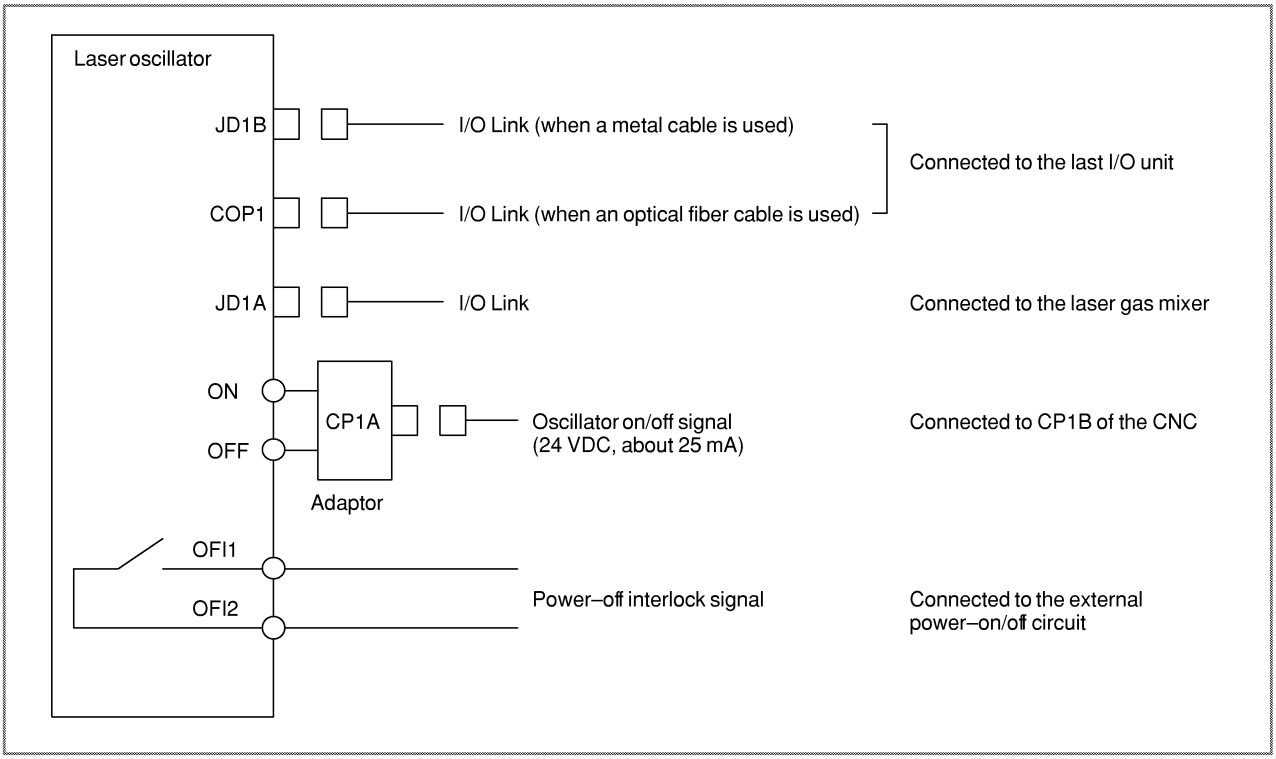
In the FS16*i*-LB system, the laser oscillator is connected in serial via the I/O unit.
For a laser oscillator interface, three groups with 256 DI and 256 DO points are reserved.
The machine can therefore use up to 13 groups with 768 DI and 768 DO points (X0 to X95 and Y0 to Y95).
Areas X96 to X127 and Y96 to Y127 cannot be used, even when a ladder is used to specify writing to these areas.



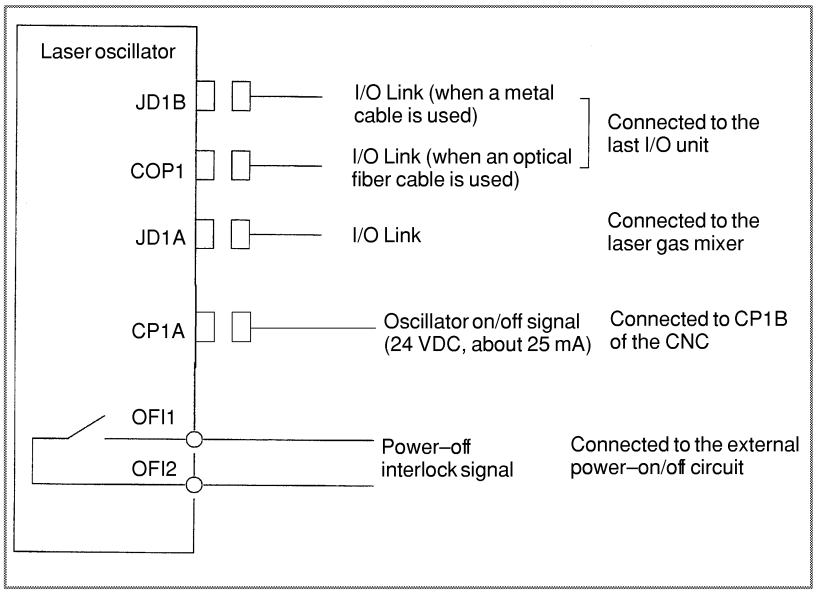
7 LASER OSCILLATOR

7.1 CONNECTION OF THE LASER OSCILLATOR

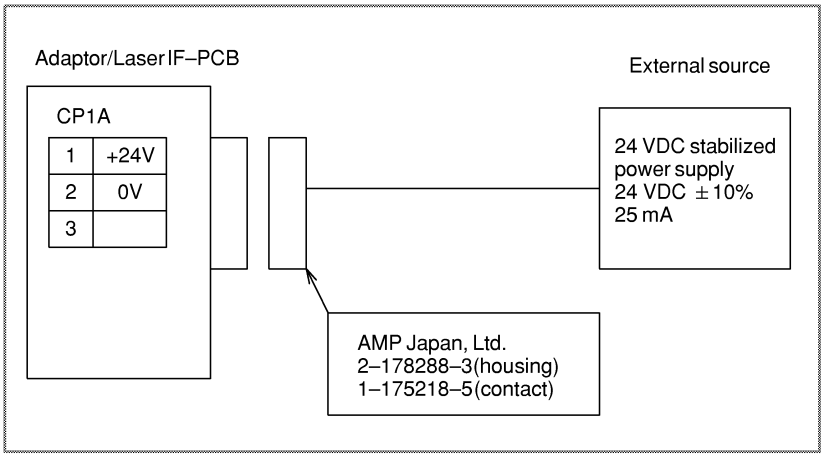
(1) When the version of the laser IF-PCB is earlier than A16B-2100-0141/07D



(2) When the version of the laser IF-PCB is earlier than A16B-2100-0141/07D



7.1.1 Connection of the CP1A



CP1A is placed on the adaptor when the version of the laser IF-PCB (A16B-2100-0141) is earlier than 07D. CP1A is placed on the IF-PCB when the version of the laser IF-PCB is 07D or later.

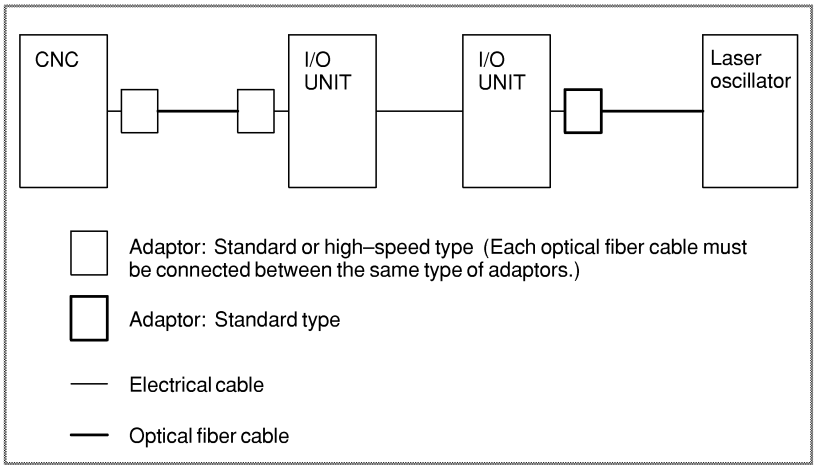
7.2 LASER OSCILLATOR CONNECTION USING AN OPTICAL FIBER CABLE

When one of the following conditions is satisfied, an optical fiber cable must be used to connect the laser oscillator to the I/O link:

(1) The length of the required cable is at least 10 m.
(2) A 5.5-mm^2 grounding line cannot be used to establish a connection between the CNC control unit and the cabinet housing the I/O unit etc., or a connection between the CNC control unit and the laser oscillator.
(3) The cable may be susceptible to high-level noise.
For example, when the cable is placed near any machine which produces high-level magnetic noise, such as a welder. Or, when most of the cable runs parallel to a power line or power magnetics cable.
(4) The laser oscillator to be connected is certified by the CE marking system.

Optical I/O link adaptors

To use optical fiber cables for making connections, optical I/O link adaptors must be used, as shown below.



⚠ CAUTION

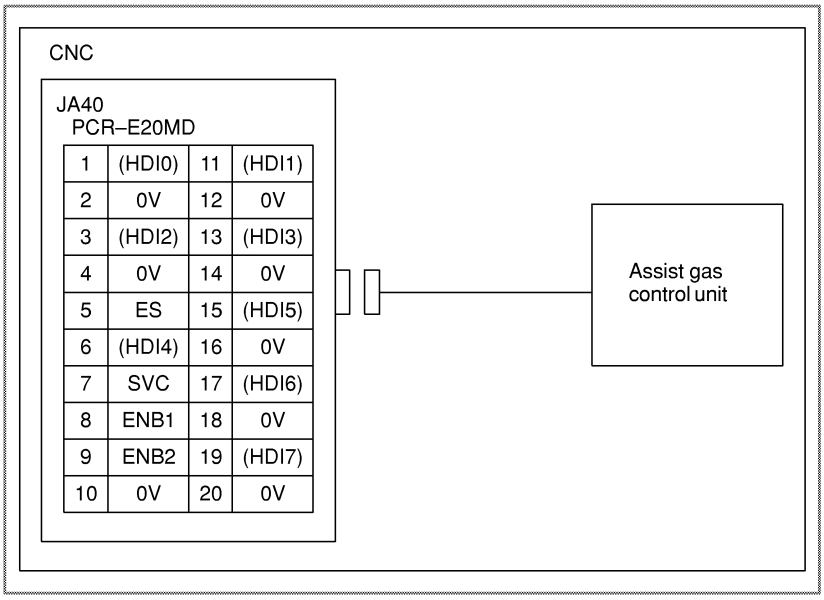
1 To daisy-chain I/O units to a single I/O link, both optical fiber cables and electrical cables can be used.
2 When an optical fiber cable is used, an optical I/O link adaptor must also be used.
3 Two types of optical I/O link adaptors are supported: Standard and high-speed.
4 When four or more optical fiber cables are used (that is, when four or more connections are established), the cables should be of high-speed type.
5 Each laser oscillator contains a standard type adaptor. To establish a connection to the laser oscillator, therefore, an I/O unit must be provided with a standard type I/O link adaptor, because only adaptors of the same type can be connected to each other.

For an explanation of FANUC I/O link connection using electrical cables, or the outside dimensions of optical I/O link adaptors, refer to Chapter 9, "FANUC I/O Link Connection," in the "Series 16*i*-MODEL B Connection Manual (Hardware) (B-63523EN)."

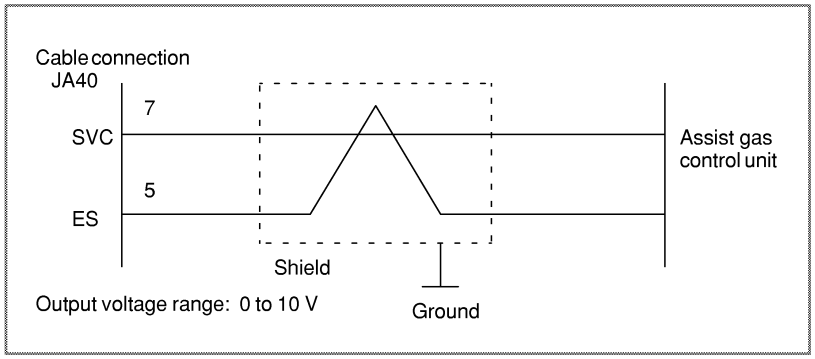
7.3 ASSIST GAS PRESSURE ANALOG OUTPUT

Assist gas pressure analog output signals are output from either the analog spindle interface on the main board or the analog output interface on the analog option board.
Which interface to use can be specified with the appropriate parameter.
For details, see Section 4.1 "ASSIST GAS CONTROL" in Part II "LASER FUNCTION".

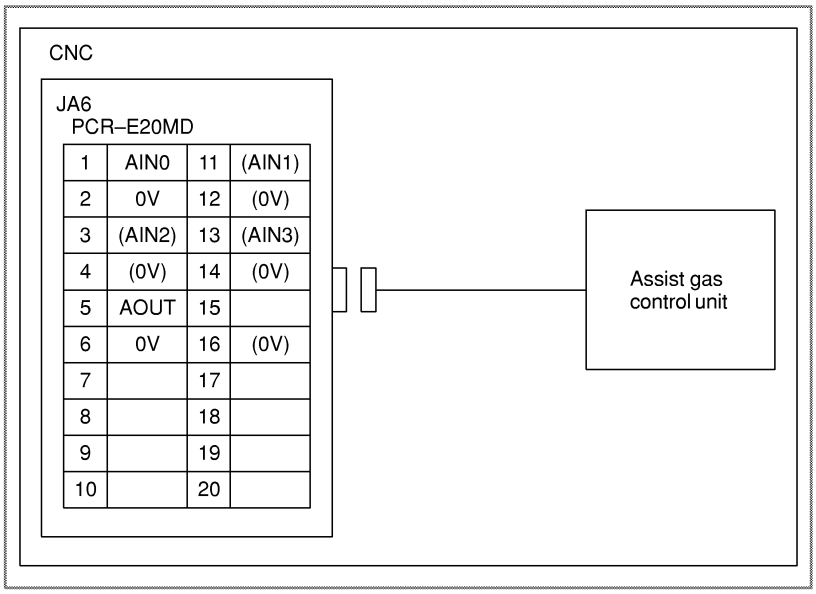
To output signals from the main board



⚠ CAUTION
1 SVC, ES: Common lines are used for the SVC, ES, and assist gas pressure analog output signals.
2 The signals in parentheses are high-speed DI input signals.
3 For details of the output voltage, see Section 4.1 "ASSIST GAS CONTROL" in Part II "LASER FUNCTION".



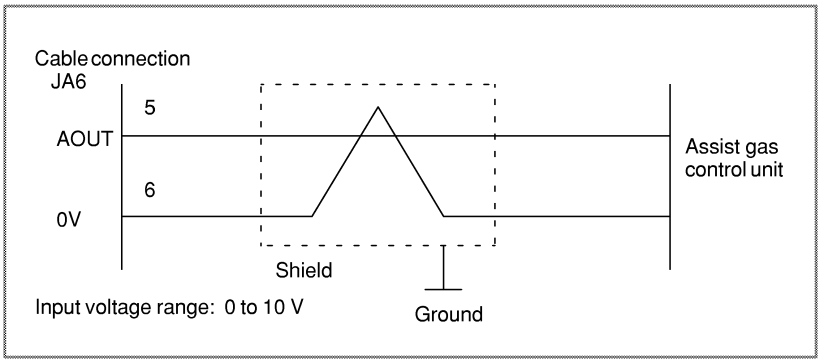
To output signals from the analog option board



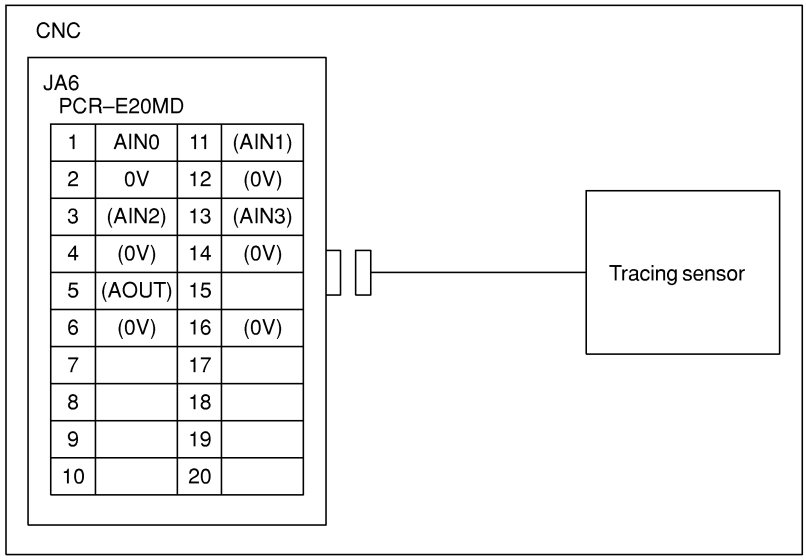
1	AIN0	11	(AIN1)
2	0V	12	(0V)
3	(AIN2)	13	(AIN3)
4	(0V)	14	(0V)
5	AOUT	15	
6	0V	16	(0V)
7		17	
8		18	
9		19	
10		20	

⚠ CAUTION

1 AOUT, 0V: Common lines are used for the AOUT, 0V, and assist gas pressure analog output signals.
2 The signals in parentheses cannot be used.
3 For details of the output voltage, see Section 4.1 "ASSIST GAS CONTROL" in Part II "LASER FUNCTION".

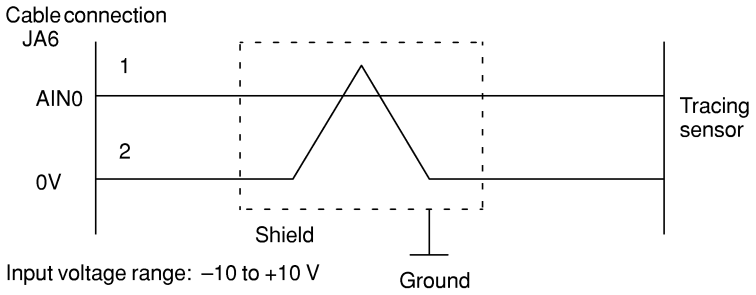


7.4 CONNECTION OF THE TRACING SENSOR



⚠ CAUTION

1 AIN0, 0V: Common lines are used for the AIN0, 0V, and analog input signals.
2 The signals in parentheses cannot be used.
2 For details of the input voltage, see the section on tracing control in the function description.



II. LASER FUNCTION

1 FUNCTIONS

Overview

For information about connections other than the laser functions, refer to the "16*i*/160*i*-MODEL B Connection Manual (Function) (B-63523EN-1)".
Most of the functions described in manual (B-63523EN-1) can be used with the 16*i*-LB. Note, however, that some functions cannot be used with the 16*i*-LB, while others require a different specification for use with the 16*i*-LB.
Whether the functions described in manual (B-63523EN-1) can be used with the 16*i*-LB is listed below.
For details of those functions for which a different specification is necessary, see Chapter 2. The functions are listed below.

Functions

CNCs which can be combined with a oscillator are Series16*i*-LB and Series160*i*-LB.

Legends used in the following table
○ : Standard
● : Standard option
☆ : Option
* : Function included in another option

Axis control

Item		Specifications	16*i*-LB	160*i*-LB
Maximum total controlled axes (machine controlled axes + loader controlled axes)		12 axes (macine 8 axes + loader 4 axes)	☆	☆
Machine controlled axes	Controlled paths	1 path	○	○
	Controlled axes	3 axes	○	○
	Controlled axes expansion	Max. 8 axes	☆	☆
	Simultaneously controlled axes	3 axes	○	○
	Simultaneously controlled axes expansion	Max. 6 axes	☆	☆
	Axis control by PMC	Max. simultaneous 4 axes	☆	☆
Loader controlled axes	Controlled paths	1 path	○	○
	Controlled axes	Max. 4 axes	☆	☆
	Simultaneously controlled axes	Max. 4 axes	☆	☆
	Axis control by PMC	Max. 4 axes	☆	☆
Axis name		3 basic axes: X, Y, Z; Additional axes: U, V, W, A, B, or C	○	○
Simple synchronous control		4 pairs	☆	☆
Twin table control			☆	☆
Tandem control			☆	☆
Torque control		PMC axis control required	*	*
Controlled axes detach			☆	☆

Item	Specifications	16*i*-LB	160*i*-LB
Least input increment	0.001mm, 0.001deg, 0.0001inch	○	○
Flexible feed gear	Optional DMR	○	○
Dual position feedback		☆	☆
Fine acceleration/deceleration		○	○
HRV control		○	○
High-speed HRV control		○	○
Inch/metric conversion		☆	☆
Interlock	All axes/each axis/each axial direction/start block/cutting block start	○	○
Machine lock	All axes/each axis	○	○
Emergency stop		○	○
Overtravel		○	○
Stored stroke check 1		○	○
Stored stroke limit external setting		☆	☆
Stored stroke check 2		☆	☆
Stored stroke check 3		☆	☆
Stroke limit check before move		○	○
Mirror image	Each axis	○	○
Follow-up		○	○
Servo-off/mechanical handle		○	○
Backlash compensation		○	○
Backlash compensation for each rapid traverse and cutting feed		○	○
Stored pitch error compensation		☆	☆
Inclination compensation		☆	☆
Straightness compensation		☆	☆
Position switch		☆	☆
Unexpected disturbance torque detection function		☆	☆
Fine torque sensing		☆	☆
High-speed position switch		☆	☆
Direction-dependent type high-speed position switch		☆	☆

Operation

Item	Specifications	16*i*-LB	160*i*-LB
Automatic operation (memory)		○	○
DNC operation	Reader/puncher interface required	*	*
MDI operation		○	○
Scheduling function		*	*
Program number search		○	○
Sequence number search		○	○
Sequence number comparison and stop		☆	☆
Program restart		☆	☆
Manual intervention and return		○	○
Buffer register		○	○
Dry run		○	○
Single block		○	○
Jog feed		○	○
Manual reference position return		○	○
Reference position setting without DOG		○	○
Reference position setting with mechanical stopper		☆	☆
Reference position shift		☆	☆

Item	Specifications	16*i*-LB	160*i*-LB
Manual handle feed	1 unit	☆	☆
	2 or 3 units	☆	☆
Manual handle feed rate	×1, ×10, ×m, ×n	*	*
Manual handle interruption		☆	☆
Incremental feed	×1, ×10, ×100, ×1000	○	○
Jog and handle simultaneous mode		○	○

Interpolation

Item	Specifications	16*i*-LB	160*i*-LB
Positioning	G00 (linear interpolation type positioning is possible)	○	○
Single direction positioning	G60	☆	☆
Exact stop mode	G61	○	○
Exact stop	G09	○	○
Linear interpolation		○	○
Circular interpolation	Supported for multiple quadrants	○	○
Dwell	In seconds	○	○
Polar coordinate interpolation		☆	☆
Cylindrical interpolation		☆	☆
Helical interpolation	(Circular interpolation) + (Linear interpolation for up to 2 axes)	☆	☆
Helical interpolation B	(Circular interpolation) + (Linear interpolation for up to 4 axes)	☆	☆
Hypothetical axis interpolation		☆	☆
Skip	G31	○	○
Reference position return	G28	○	○
Reference position return check	G27	○	○
2nd reference position return		○	○
3rd/4th reference position return		☆	☆
Floating reference position return		☆	☆
Normal-direction control		☆	☆
High-speed linear interpolation		☆	☆

Feed function

Item	Specifications	16*i*-LB	160*i*-LB
Rapid traverse rate	Max. 240 m/min (1μm)	○	○
Rapid traverse override	F0, 25, 50, 100%	○	○
Feed per minute		○	○
Tangential speed constant control		○	○
Cutting feedrate clamp		○	○
Automatic acceleration/deceleration	Rapid traverse : linear Cutting feed : exponential	○	○
Rapid traverse bell-shaped acceleration/deceleration		☆	☆
Positioning by optimal acceleration		☆	☆
Linear acceleration/deceleration after cutting feed interpolation		☆	☆
Bell-shaped acceleration/deceleration after cutting feed interpolation		☆	☆
Linear acceleration/deceleration before cutting feed interpolation		☆	☆
Feedrate override	0% to 254%	○	○

Item	Specifications	16*i*-LB	160*i*-LB
2nd feedrate override	0% to 254%	☆	☆
One-digit F code feed		☆	☆
Jog override	0% to 655.34%	○	○
Override cancel		○	○
External deceleration		☆	☆
Feed stop		☆	☆
Advanced preview control		☆	☆
AI contour control		☆	☆
Bell–shaped acceleration/deceleration before look–ahead interpolation		☆	☆
High-precision contour control	A 64-bit RISC engine is used.	☆	☆

Program input

Item	Specifications	16*i*-LB	160*i*-LB
Tape code	EIA RS244/ISO840 automatic recognition	○	○
Label skip		○	○
Parity check	Horizontal parity, vertical parity	○	○
Control in/out		○	○
Optional block skip	1 block	○	○
	9 blocks	☆	☆
Maximum value	±8-digit	○	○
Program number	O4-digit	○	○
	O8-digit	☆	☆
Sequence number	N5-digit	○	○
Absolute/incremental programming	Combined use in the same block	○	○
Decimal point programming/ pocket calculator type decimal point programming		○	○
Input unit 10 time multiply		○	○
Plane selection	G17, G18, G19	○	○
Rotary axis designation		○	○
Rotary axis roll-over		○	○
Polar coordinate command		☆	☆
Coordinate system setting		○	○
Automatic coordinate system setting		○	○
Workpiece coordinate system	G52 to G59	☆	☆
Workpiece coordinate system preset		☆	☆
Addition of workpiece coordinate system pair	48 pairs	☆	☆
	300 pairs	☆	☆
Manual absolute on/off		○	○
Optional chamfering/corner R		☆	☆
Programmable data input	G10	☆	☆
Subprogram call	Four folds nested	○	○
Custom macro B		☆	☆
Addition of custom macro common variables	#100 to #199, #500 to #999	☆	☆
Interruption type custom macro		☆	☆
Embedded macro		☆	☆
Circular interpolation by R programming		○	○
Circular interpolation by 9-digit R designation		☆	☆
Automatic corner override		☆	☆
Automatic corner deceleration		☆	☆
Feedrate clamp based on arc radius		☆	☆

Item	Specifications	16*i*-LB	160*i*-LB
Scaling		☆	☆
Coordinate system rotation		☆	☆
Programmable mirror image		☆	☆
Figure copy		☆	☆
Retrace		☆	☆
Tape format for FANUC Series 15		☆	☆
Macro executor	Max. 6MB	☆	☆
C language executor	Max. 6MB	☆	☆

Auxiliary function

Item	Specifications	16*i*-LB	160*i*-LB
Auxiliary function	M with 8 digits	○	○
2nd auxiliary function	B with 8 digits	☆	☆
Auxiliary function lock		○	○
High-speed M/T/B interface		○	○
Multiple command of auxiliary function	3	○	○
M code group check		☆	☆

Tool functions/Tool compensation functions

Item	Specifications	16*i*-LB	160*i*-LB
Tool function	T with 8 digits	○	○
Tool offset pairs	± with 6 digits, 32 pairs	○	○
	± with 6 digits, 64 pairs	☆	☆
	± with 6 digits, 99 pairs	☆	☆
	± with 6 digits, 200 pairs	☆	☆
	± with 6 digits, 400 pairs	☆	☆
	± with 6 digits, 499 pairs	☆	☆
	± with 6 digits, 999 pairs	☆	☆
Tool offset memory B	Geometry/wear memory	☆	☆
Tool offset memory C	Distinction between geometry and wear, or between cutter and tool length compensation.	☆	☆
Tool length compensation		○	○
Tool offset		☆	☆
Cutter compensation C		○	○

Editing operation

Item	Specifications	16*i*-LB	160*i*-LB
Part program storage length	160m (64Kbyte)	○	○
	320m (128Kbyte)	☆	☆
	640m (256Kbyte)	☆	☆
	1280m (512Kbyte)	☆	☆
	2560m (1024Kbyte)	☆	☆
	5120m (2056Kbyte)	☆	☆
Number of registerable programs	125	○	○
	200	☆	☆
	400	☆	☆
	1000	☆	☆
Part program editing		○	○
Program protect		○	○

Item	Specifications	16*i*-LB	160*i*-LB
Background editing		☆	☆
Extended part program editing		☆	☆
Playback		☆	☆
Machining time stamp		☆	☆

Setting and display

Item	Specifications	16*i*-LB	160*i*-LB
Status display		○	○
Clock function		○	○
Current position display		○	○
Program display	31-character program name	○	○
Parameter setting and display		○	○
Self-diagnosis function		○	○
Alarm display		○	○
Alarm history display		○	○
Operator message history display		*	*
Operation history display		○	○
Help function		○	○
FACTOLINK		☆	☆
Remote diagnosis	Reading information for mounted printed circuit board, CNC data such as parameters, alarm status, etc.	*	*
Run hour and parts count display		☆	☆
Actual cutting feedrate display		○	○
Directory display of floppy cassette		☆	☆
Directory display and punch for each group		○	○
Graphic function		☆	☆
Dynamic graphic display		☆	☆
Servo setting screen		○	○
Servo waveform display	Graphic display circuit is required	*	*
Display of hardware and software configuration		○	○
Periodic maintenance screen		○	○
Maintenance information screen		○	○
Software operator’s panel		☆	☆
Software operator's panel general purpose switch		☆	☆
Software operator's panel general purpose switch expansion		☆	☆
Touch panel		☆	☆
External touch panel interface		☆	☆
Multi-language display	English	○	○
	Japanese (Chinese characters)	☆	☆
	German/French	☆	☆
	Italian	☆	☆
	Spanish	☆	☆
	Korean	☆	☆
Data protection key	Four types	○	○
Erase CRT screen display		○	○

Data input/output

Item	Specifications	16*i*-LB	160*i*-LB
Reader/puncher interface	Reader/puncher (channel 1) interface	☆	☆
	Reader/puncher (channel 2) interface	☆	☆
Input/output simultaneous operation		☆	☆
Remote buffer		☆	☆
High-speed remote buffer A		☆	☆
Data server		☆	☆
External I/O device control		☆	☆
DNC1 control		☆	☆
DCN2 control		☆	☆
Modem card control		○	○
External tool offset		☆	☆
External message		☆	☆
External machine zero point shift		☆	☆
External data input	Including above three items	☆	☆
External key input		○	○
External program input		○	○
External workpiece number search	9999	○	○
External program number search	1 to 9999	*	*
Memory card input/output		○	○
Screen hard copy		○	○
Power mate CNC manager		☆	☆

Communication function

Item	Specifications	16*i*-LB	160*i*-LB
Embedded Ethernet		○	○
Ethernet		☆	☆
PROFIBUS-DP		☆	☆
DeviceNet		☆	☆
FOCAS1/HSSB PORT2 function		☆	☆

Laser control function

Item	Specifications	16*i*-LB	160*i*-LB
Output power command		○	○
Pulse frequency command	5 to 2000Hz	○	○
Pulse duty command	0 to 100%	○	○
Piercing command	G24	○	○
High-speed piercing command	Including the piercing command	○	○
Assist gas command	G32	○	○
Power override	0 to 200%	○	○
Duty override	0 to 150%	○	○
Frequency override	0 to 200%	○	○
Assist gas pressure override	0 to 200%	○	○
Power control		○	○
Laser screen display		○	○
Pulse enhanced function		○	○
Oscillator control using an M code		○	○
External alteration of piercing time		○	○
Return light monitoring function		○	○
Beam output delay function		○	○

Item	Specifications	16*i*-LB	160*i*-LB
Laser status output signal	Purge completed, gas pressure under control, base discharging, discharge start ready, etc.	○	○
Tracing control	G13, G14	☆	☆
Tracing interlock function		*	*
Cutting condition setting function		☆	☆
Edge machine function		☆	☆
Start-up function		*	*
Step control		☆	☆
Optical path length compensation		☆	☆
Retry processing function		☆	☆
High-speed machining function		☆	☆

Three-dimensional machining tool function

Item	Specifications	16*i*-LB	160*i*-LB
Attitude control A		☆	☆
Attitude control B		☆	☆
Interaction control		☆	☆
Manual operation in hand coordinate system		☆	☆
W-axis tracing control		☆	☆
Spatial circular interpolation	G12	☆	☆
Three-dimensional coordinate conversion	G68、G69	☆	☆
Proximity point search		☆	☆
Spatial corner R insertion	G33, G34	☆	☆
Three-dimensional conversion function	G98, G99	☆	☆
Teaching function		☆	☆
Step feed return		☆	☆
Bevel cutting compensation function		☆	☆

Others

Item	Specifications	16*i*-LB	160*i*-LB
Status output signal	NC ready, servo ready, automatic operation, reset, alarm, etc.	○	○
Control unit built-in display	7.2″ monochrome LCD	●	●
	9.5″ monochrome LCD	●	●
	8.4″ color LCD	●	●
	10.4″ color LCD	●	●
	12.1″ color LCD	●	●
	15.0″ color LCD	-	●
Control unit optional slots (depth)	Without optional slot (60 mm)	●	●
	With 2 optional slots (110 mm)	●	●
	With 3 optional slots (125 mm)	●	●
	With 4 optional slots (170 mm)	●	●
MDI unit	Separate MDI (standard vertical type, standard horizontal type)	●	●
	Separate MDI (standard vertical type, standard horizontal type)	●	●
	Separate MDI (61–key vertical type, 61–key horizontal type)	●	●
	Separate MDI(PC key, vertical type)	●	●

Item		Specifications	16*i*-LB	160*i*-LB
Touch panel		Only for 10.4″ LCD or 12.1″ LCD	●	●
PMC system	PMC-SB7	Basic instruction : 0.033 μsec/step Max. step number ladder: 64,000	○	○
		Step sequence function	☆	☆
	C language	Max. 2MB	☆	☆
		Nonvolatile memory expansion	☆	☆
	I/O Link expansion	DI/DO : 1792/1792 points	☆	☆
Standard operator's panel		I/O Unit-MODEL A	☆	☆
Machine interface (I/O Link) Max. DI/DO points: 2048/2048 points		Operator's panel I/O module	●	●
		Connection panel I/O module (DI/DO module, 2A output module, Analog input module)	●	●
		Power magnetics control I/O module	●	●
		I/O Unit-MODEL A	●	●
		I/O Unit-MODEL B	●	●
Manual pulse generator			☆	☆
Pendant type manual pulse generator		With axis selection and magnification switches	☆	☆
Codeless manual pulse generator		Restricted use in Japan	☆	☆
Connectable servo motor		FANUC AC SERVO MOTOR α series FANUC AC SERVO MOTOR β series	○	○
Connectable servo amplifier		FANUC SERVO AMPLIFIER α series FANUC SERVO AMPLIFIER β series	○	○
Position detector unit for full-closed control (for full-closed control)		Pulse coder/optical scale (2-phase pulse interface)	☆	☆
		Pulse coder/optical scale (serial interface)	☆	☆
Linear scale interface with absolute addressing reference mark			☆	☆
Control unit supply voltage		24VDC ±10%	●	●
Ambient temperature around the unit		LCD–mounted type control unit, Operating: 0°C to 58°C Non–operating: –20°C to 60°C	●	●
Ambient relative humidity		Normal: 75% or less (no condensation) Short period (within one month):95% or less (no condensation)	○	○
Vibration		Operating: 0.5G or less Non–operating: 1G or less	○	○

2 FUNCTIONS DIFFERING FROM THE M SERIES SPECIFICATIONS

Overview

The specifications of some functions of the 16*i*-LB differ from those of the functions explained in "16*i*-MODEL B Connection Manual: (Function) (B-63523EN-1)". This chapter explains these differences.

2.1 EMERGENCY STOP

Difference

When the emergency stop signal (*ESP) is set to 0 while the oscillator is in the oscillation state (LSTR=1), the beam is turned off, and none of the assist gas select signals (AG1 to AG3) is selected. Then, the high frequency power supply is turned off, discharging stops, and the discharge ready state (LRDY=1) is entered.
In this case, release emergency stop (emergency stop signal *ESP=1), then set the discharge start signal (HVON) to 0 then to 1. The reference discharge operation starts, and oscillation is resumed.
To connect the emergency stop signal to the oscillator directly, see the description of the connection to the laser oscillator.

2.2 FEED HOLD

Difference

When the automatic operation stop signal (*SP) is set to 0 during laser output, the beam is turned off, the shutter is closed, and none of the assist gas select signals (AG1 to AG3) is selected.
In this case, setting the automatic operation stop signal (*SP) to 1 does not cause automatic operation to be resumed. To resume the operation, set the automatic operation stop signal (*SP) to 1, then set the automatic operation start signal (ST) to 1, then to 0 again.
If a feed hold is specified in the middle of a block in which the beam is output, restarting automatic operation places the assist gas select signals in the state existing immediately before the feed hold state was entered. The shutter is opened, the beam is turned on, then machine movement starts.

2.3 TEST OPERATION

2.3.1 Machine Lock

Difference

When beam output is programmed, all commands relating to beam output are ignored. Instead, only machine move commands are executed (the beam remains off) and the current position indication is updated.
When piercing command G24 is executed, no beam is output. In this case, that block may be skipped with no operation performed. Or, a dwell may be performed. Either option can be selected with a parameter.

Parameter

	#7	#6	#5	#4	#3	#2	#1	#0
15001						PES		

[Data type] Bit

PES Specifies how a piercing command (G24) is to be treated when the machine lock or dry run is set to ON.

0: Dwell is performed.
1: The block of the piercing command is skipped.

2.3.2 Dry Run

Difference

When beam output is programmed, all commands relating to beam output are ignored. Instead, only machine move commands are executed by means of dry run. The beam remains off.
When piercing command G24 is executed, no beam is output. In this case, that block may be skipped with no operation performed. Or, a dwell may be performed. Either option can be selected with a parameter.

Parameter

	#7	#6	#5	#4	#3	#2	#1	#0
15001						PES		

[Data type] Bit

PES Specifies how a piercing command (G24) is to be treated when the machine lock or dry run is set to ON.

0: Dwell is performed.
1: The block of the piercing command is skipped.

2.3.3 Single Block

Difference

When a beam output command block is executed and terminated, feed stops, the beam is turned off, the shutter is closed, and none of the assist gas select signals (AG1 to AG3) is selected.
When the automatic operation start signal (ST) is set to 1, then to 0 again, execution of the next block starts.
If this block specifies beam output, the assist gas select signals (AG1 to AG3) are placed in the state existing before the single block stop occurred. The shutter is opened, the beam is turned on, and machine movement starts.

2.4 PROGRAM RESTART (LASER SPECIFICATIONS)

Overview

If machining is stopped during automatic operation, machining can be resumed from a specified block.

Signal

- Program restart signal REST2<G226#1>

[Classification] Input signal

[Function] This signal selects program restart (laser specifications).

[Operation] <1> Select EDIT mode, and display the program. Position the cursor to the block from which you want to restart the program.

<2> Select memory mode, set the program restart signal (REST2) to 1, and perform cycle start. Then, search starts, and the automatic operation started signal (STL) and the proximity point search in progress signal (LNSR) are set to

<3> During search, M codes and other auxiliary functions are all sent to the PMC. Every time such a auxiliary function code is sent, the completion signal (FIN) should be returned.

<4> During search, dwell commands are not executed.

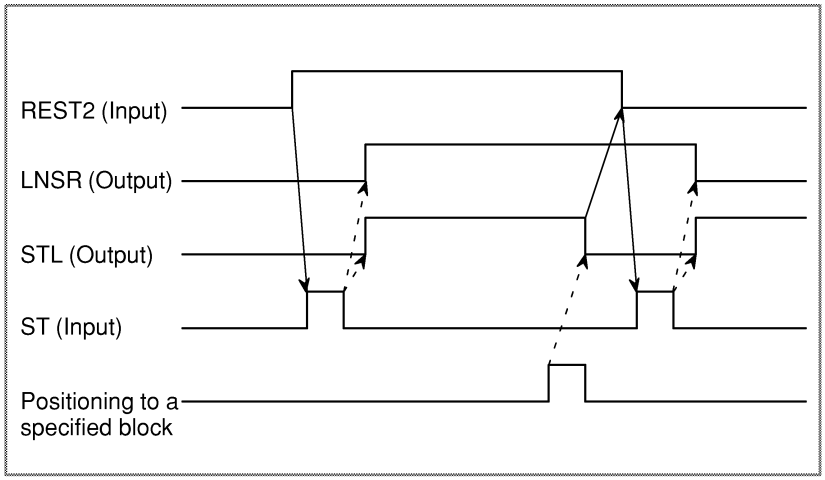
<5> During search, laser output is not performed.

<6> When a block immediately before a specified block is found, positioning to the end point of that block is performed, after which the search operation terminates.

<7> Upon the completion of the search, the feed hold state is entered, and the automatic operation started signal (STL) is set to 0.

<8> Check that the proximity point search in progress signal (LNSR) is 1, and that the automatic operation started signal (STL) is 0 on the PMC side. Then, set the program restart signal (REST2) to 0.

<9> Set the automatic operation start signal (ST) to 1 then to 0. Then, automatic operation restarts from the specified block.



- Proximity point search in progress signal LNSR<F225#1>

[Classification] Output signal

[Function] This signal posts that the end point of the block immediately before a specified block is being searched for.

[Output condition] This signal becomes 1 under the following condition:

- When the automatic operation started signal (STL) is set to 1 while the program restart signal (REST2) is 1

This signal becomes 0 under the following condition:

- When positioning to the end point of the block immediately before the specified block is performed, after which the automatic operation start signal (ST) is changed from 1 to 0 while the program restart signal (REST2) is 0

Signal address

	#7	#6	#5	#4	#3	#2	#1	#0
G226						REST2		
F225						LNSR		

Parameter

	#7	#6	#5	#4	#3	#2	#1	#0
15630		NMC	NSC	PRT		NSR	PRZ	PRS

[Data type] Bit

PRS Selects the following specifications as the program restart function:
- 0: Standard specifications
- 1: Laser specifications

PRZ During program restart, the command for performing movement to the restart position along the Z-axis is:
- 0: Executed
- 1: Ignored

NSR During search for a block, the automatic operation signal (OP)
- 0: Posted
- 1: Not posted

PRT When an attempt is made to execute the program restart function on a Z-axis tracing program using G13:
- 0: Alarm 4001 is raised. (Current specifications)
- 1: The alarm is not raised. Search is possible. At the restart, turn on/off the Z-axis machine lock (G108#2, MLK3) at the same time as the program restart signal REST2. Note that the program must be specified in absolute mode.

NSC If, with the program restart function conforming to the laser specifications and the proximity point search function, a program is to restart in a spatial corner R insertion block:
- 0: The program restarts at the program-specified point at which a corner R is not inserted.
- 1: The program restarts at the end of the inserted corner R.

NMC With the proximity point search of the offset type and the program restart function, positioning to the restart point is:

0: Executed for all axes at the same time.

1: Executed for the fourth and fifth axes first, then for the remaining axes. (Note: Executed in non-interpolation mode.)

NOTE

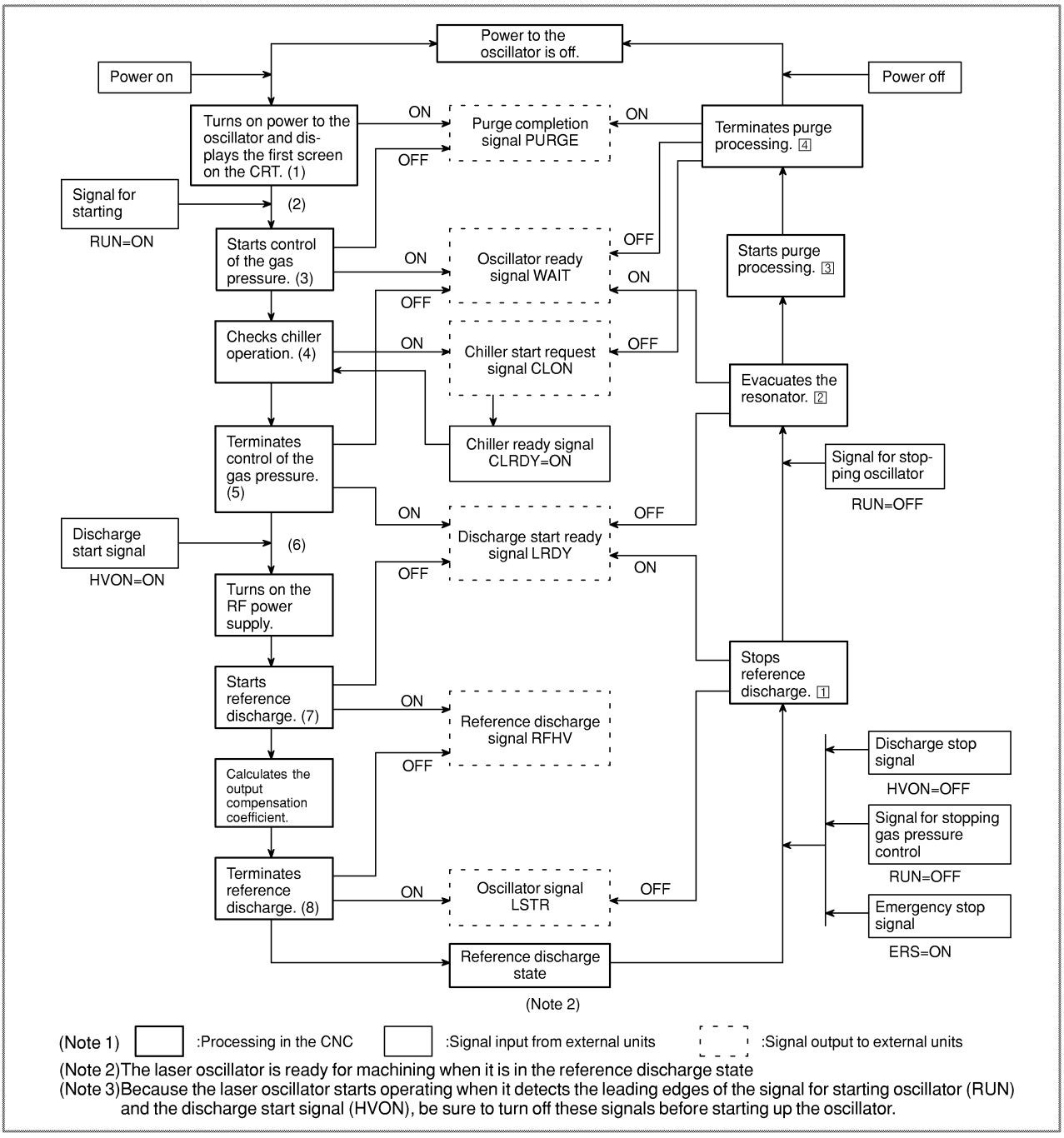
When G13 and G14 are specified, the program restart function (laser or standard mode) cannot be used. To enable the use of the program restart function, specify tracing control by using the corresponding external signal.

3 LASER SEQUENCE CONTROL

3.1 SEQUENCE CONTROL OF THE C SERIES AND Y SERIES LASER OSCILLATORS

Overview

The C series (CO_2 Laser) and Y series (continuously output type YAG) laser oscillators are activated and stopped according to the following sequence chart.



Oscillator start sequence

The sequence of operations from when the power to the oscillator is turned on to when the oscillator starts oscillation and the response of the CNC to these actions are described below.

(1) When the power to the oscillator is turned on, the CPU in the CNC becomes operational and the relevant screen is displayed. At this point, the CNC is ready for operation. The CNC then sets purge completion signal PURGE to 1.

(2) When the PURGE signal is set to 1, the CNC receives the signal for starting oscillator (RUN).

(3) When the CNC receives the RUN signal, it starts controlling the gas pressure and clears the PURGE signal to 0. Then the CNC sets oscillator ready signal (WAIT) to 1 and chiller start request signal CLON to 1.
Then, the CNC sets the chiller start request signal (CLON) to 1 to start the chiller unit. For the Y series oscillator, gas pressure control is not performed; signal processing is performed immediately.

(4) When the chiller start request signal (CLON) is set to 1, the machine tool starts the external chiller to supply cooling water to the oscillator. While supplying cooling water to the oscillator, the machine tool sets the chiller ready signal (CLRDY) to 1 and inputs it to the CNC.
The CNC monitors the chiller ready signal (CLRDY). If the CNC detects that the signal has been set to 0, the CNC issues an alarm, assuming that an abnormality has occurred in the chiller.

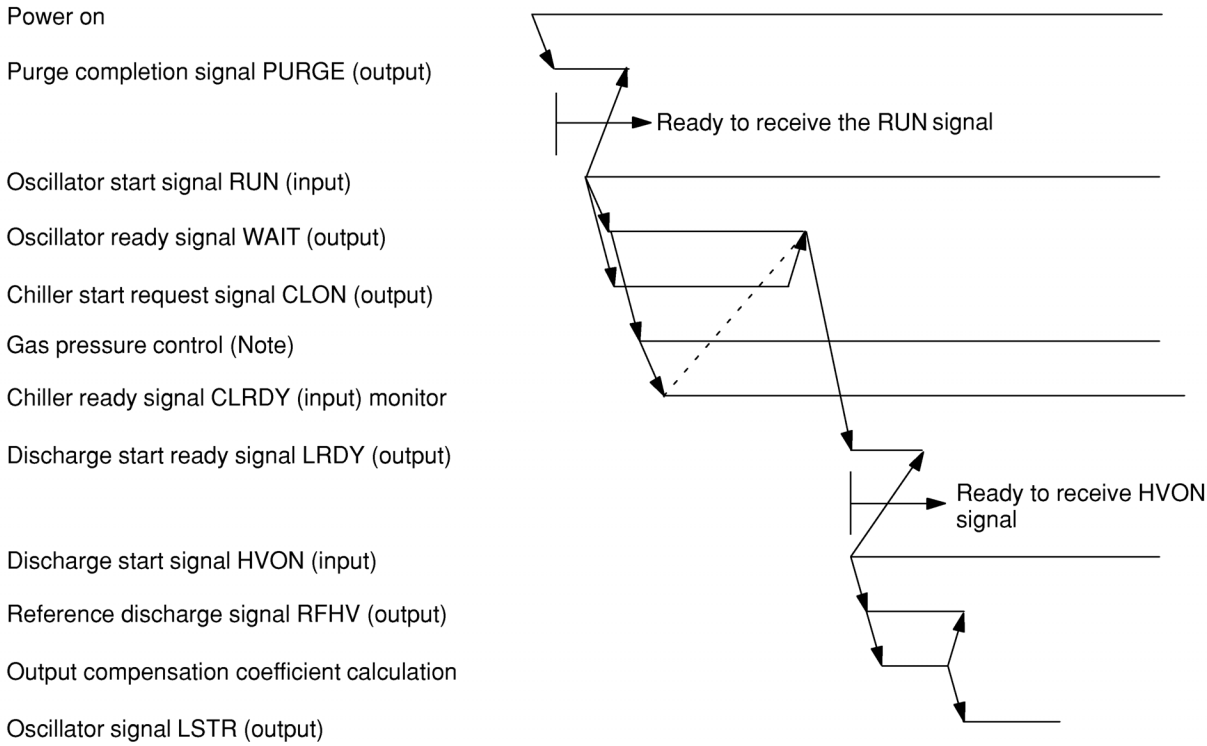
(5) When control of the gas pressure has terminated, the CNC clears the oscillator ready signal (WAIT) to 0 and sets discharge start ready signal LRDY to 1.

(6) When the LRDY signal is set to 1, the CNC receives discharge start signal (HVON).

(7) When the CNC receives the HVON signal, it turns on the RF power supply and clears the LRDY signal to 0, in preparation for reference discharge. Then the CNC sets reference discharge signal RFHV to 1. The output compensation coefficient is calculated by measuring the ratio of power drop according to internal oscillation.

(8) After the output compensation coefficient is calculated, the reference discharge state is resumed. The oscillator is ready for machining when the LSTR signal is 1.

The timing chart for operations after the power is turned on is shown below. In the figure, a solid line indicates the time during which a signal is on or 1.



(Note) Gas pressure control is performed only for the C series. For the Y series, gas pressure control is not performed. Therefore, the sequence indicated by the broken line is used.

Oscillator stop sequence

To turn off the power to the laser oscillator, follow the procedure below.

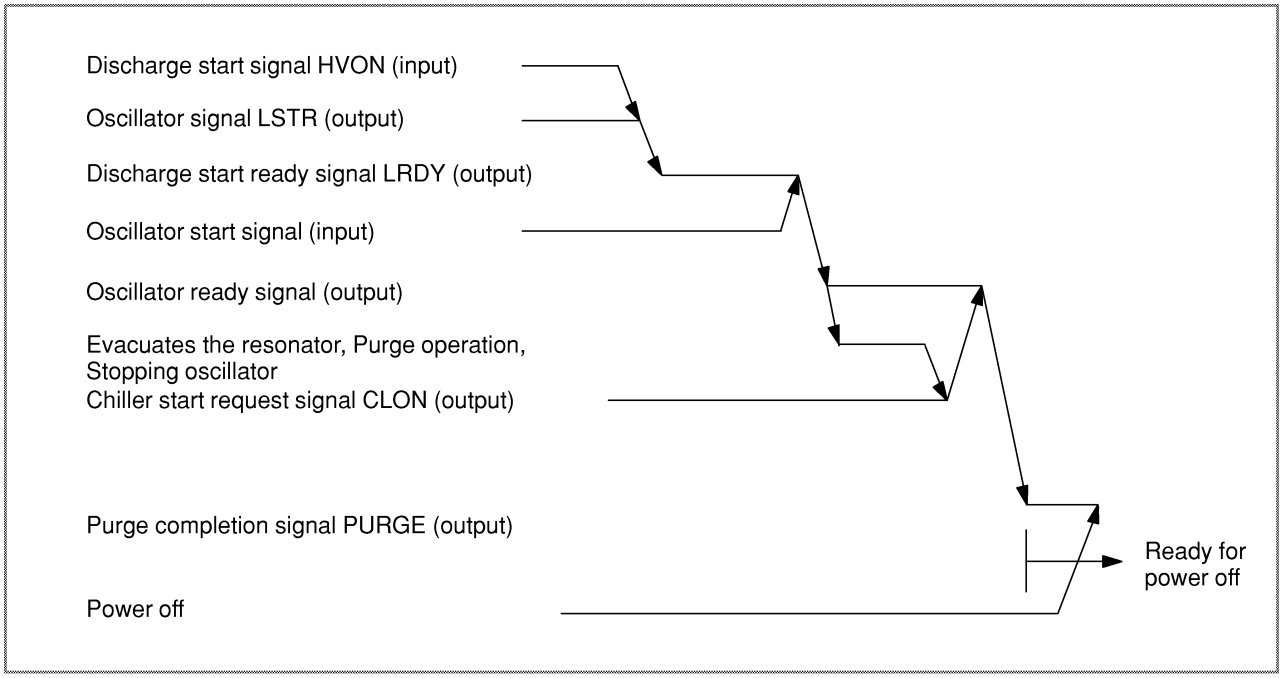
(1) When the discharge start signal (HVON) is set to 0 while the oscillator is in the reference discharge state, the CNC stops discharge, sets the oscillator signal (LSTR) to 0, and sets the discharge start ready signal (LRDY) to 1.

(2) When the signal for starting oscillator (RUN) is set to 0 with the LRDY signal set to 1, the CNC evacuates the fan system by closing the laser gas supply valve and opening the exhaust valve. At the same time, the CNC clears the LRDY signal to 0, and sets the WAIT signal to 1.

(3) On completion of evacuation, the CNC starts purge processing. For the Y series, since gas control is not performed, evacuation and purge processing are omitted, and oscillator stop processing is performed.

(4) When purge processing is completed, the CNC clears the chiller start request signal CLON to 0, and sets purge completion signal PURGE to 1.
When the PURGE signal is set 1, the power to the oscillator can be turned off.

The timing chart for operations before the power is turned off is shown below.



Signal

- Purge completion signal PURGE<F221#2>

[Classification] Output signal

[Function] This signal notifies the PMC of the time when the oscillator can be started and when the power to the unit can be turned off.

[Output] The CNC can accept the oscillator start signal (RUN) when the purge completion signal (PURGE) is 1. When the purge completion signal (PURGE) is 1, the power to the unit can be turned off.

The purge completion signal becomes 1 under the following conditions:

- When the power to the unit is turned on, initial clear processing is completed, after which the CNC becomes ready for operation
- When the oscillator start signal (RUN) is set to 0 during operation, oscillator stop processing is performed, then purge processing is completed

The signal becomes 0 under the following condition:

- When the oscillator start signal (RUN) is set to 1

- Oscillator start signal RUN<G222#6>

[Classification] Input signal

[Function] This signal starts or stops the oscillator.

[Operation] Starting the oscillator

When the oscillator start signal (RUN) is set to 1 with the purge completion signal (PURGE) set to 1, the CNC starts gas pressure control, sets the purge completion signal (PURGE) to 0, and sets the oscillator ready signal (WAIT) to 1.

Stopping the oscillator

When the oscillator start signal (RUN) is set to 0 during operation, if discharge is being performed, the CNC stops discharge. If discharge is not being performed, the CNC immediately closes the laser gas supply valve, and opens the exhaust valve to evacuate the fan system for the period specified in parameter No.15256.

At this time, the discharge start ready signal (LRDY) is set to 0, and the oscillator ready signal (WAIT) is set to 1.

Upon the completion of evacuation, the CNC starts purge processing to supply new laser gas, up to atmospheric pressure. Once purge processing has been completed, the oscillator ready signal (WAIT) is set to 0, and the purge completion signal (PURGE) is set to 1.

For the Y series oscillator, the laser gas is not controlled. Hence, evacuation is not performed.

⚠ CAUTION

Safety standards for laser application devices (e.g., FDA Part 1040 PERFORMANCE STANDARDS FOR LIGHTEMITTING PRODUCTS, Sec 1040.10 Laser Products, (f), (4) Key control) specify that a key switch shall be used as the start and stop switch of an oscillator and that it shall not be possible to remove the key during operation of the oscillator.

To maintain compliance with these safety standards, always use a key switch as the oscillator start signal (RUN) switch.

- Oscillator ready signal WAIT<F221#3>

[Classification] Output signal

[Function] This signal notifies the PMC that oscillator start processing or stop processing is being performed.

[Output] The signal becomes 1 under the following conditions:

- When the oscillator start signal (RUN) is set to 1 while the purge completion signal (PURGE) is set to 1
- When the oscillator start signal (RUN) is set to 0 while the discharge start ready signal (LRDY) is set to 1

The signal becomes 0 under the following conditions:

- When the CNC is ready for discharge in the oscillator start sequence
- When purge processing has been completed in the oscillator stop sequence

- Chiller start request signal CLON<F221#4>

[Classification] Output signal

[Function] This signal notifies the PMC that cooling water must be supplied to the oscillator.

[Output] Before the oscillator can be operated, cooling water must be supplied from the external chiller unit. When a supply of cooling water is needed, the CNC sets the chiller start request signal (CLON) to 1. When the cooling water becomes unnecessary, the CNC sets the signal to 0. Therefore, the supply of cooling water to the oscillator should be started or stopped according to this signal.

The signal becomes 1 under the following condition:

- When the oscillator start signal (RUN) is set to 1 while the purge completion signal (PURGE) is set to 1

The signal becomes 0 under the following condition:

- When the oscillator start signal (RUN) is set to 0 while the discharge start ready signal (LRDY) is set to 1, oscillator stop processing is performed, then purge processing is completed

- Chiller ready signal CLRDY <G221#6>

[Classification] Input signal

[Function] This signal is used to monitor the supply of cooling water to the oscillator.

[Operation] When the CNC sets the chiller start request signal (CLON) to 1 to request the supply of cooling water, the machine should supply cooling water to the oscillator, provided the chiller unit is normal. At the same time, the machine should set the chiller ready signal (CLRDY) to 1 and input it to the CNC. When the machine stops supplying cooling water to the oscillator, the machine should set the chiller ready signal (CLRDY) to 0.

If the chiller ready signal (CLRDY) is set to 0 while the CNC is outputting 1 for the chiller start request signal (CLON), the CNC issues an alarm, assuming that an abnormality has occurred in the external chiller unit.

- Discharge start ready signal LRDY<F221#1>

[Classification] Output signal

[Function] This signal notifies the PMC that the CNC is ready for discharge for the oscillator.

[Output condition] When the discharge start ready signal (LRDY) is set to 1, the CNC can accept the discharge start signal (HVON).

The discharge start ready signal becomes 1 under the following conditions:

- When the oscillator start signal (RUN) is set to 1, and the CNC is ready for discharge
- When the discharge start signal (HVON) is set to 0 during oscillation
- When the oscillator start signal (RUN) is set to 0 during oscillation
- When emergency stop is performed during oscillation

The signal becomes 0 under the following conditions:
- When the discharge start signal (HVON) is set to 1 while the discharge start ready signal (LRDY) is set to 1
- When the oscillator start signal (RUN) is set to 0 while the discharge start ready signal (LRDY) is set to 1

- Discharge start signal HVON<G222#7>

[Classification] Input signal

[Function] This signal starts discharge for the oscillator, thus readying the oscillator for operation.

[Operation] When starting the oscillator

When the discharge start signal (HVON) is set to 1 while the discharge start ready signal (LRDY) is set to 1, the CNC turns on the laser power supply to achieve the reference discharge state (simmer discharge for the Y series).

When stopping the oscillator

When the discharge start signal (HVON) is set to 0 while the oscillator is operating, the CNC turns off the laser power supply to stop discharge, and sets the discharge start ready signal (LRDY) to 1.

- Reference discharge signal RFHV<F221#5>

[Classification] Output signal

[Function] This signal notifies the PMC that discharge by the oscillator has been started to achieve the reference discharge state (simmer discharge state for the Y series).

[Output condition] The reference discharge signal becomes 1 under the following condition:
- When the discharge start signal (HVON) is set to 1 while the discharge start ready signal (LRDY) is set to 1

The reference discharge signal becomes 0 under the following condition:
- When the RF power supply is turned on, reference discharge start processing is performed, then calculation of the output compensation coefficient is completed

- Oscillator signal LSTR<F221#6>

[Classification] Output signal

[Function] This signal notifies the PMC that the oscillator is ready for output.

[Output condition] When the oscillator signal (LSTR) is set to 1, laser output can be specified for machining.

The LSTR signal becomes "1" under the following condition.
- When the oscillator enters the reference discharge state (for the C series) or the simmer discharge state (for the Y series)

The LSTR signal becomes "0" under the following conditions.
- When the discharge start signal (HVON) becomes 0.
- When the oscillator start signal (RUN) becomes 0.
- When a laser alarm occurs.
- When an emergency stop occurs.

Signal address

	#7	#6	#5	#4	#3	#2	#1	#0
G221		CLRDY						
G222	HVON	RUN						
F221		LSTR	RFHV	CLON	WAIT	PURGE	LRDY	

Parameter

	#7	#6	#5	#4	#3	#2	#1	#0
15004	CWY							

[Data type] Bit

CWY Specifies the type of laser oscillator to be connected.

0: CO_2 laser

1: CW-YAG laser

#7	#6	#5	#4	#3	#2	#1	#0
15003						GVW		

[Data type] Bit

GVW 0: Evacuation is not performed before the oscillator stops. (for maintenance)

1: Evacuation is performed before the oscillator stops. (Normal use) The duration for which evacuation is to be performed is set in parameter No.15256.

15256	RUN-OFF evacuation time

[Data type] Word

[Unit of data] Seconds

[Valid data range] 600 to 32767

[Standard setting value] 900

If bit 2 (GVW) of parameter No.15003 is 1, evacuation is performed for the set duration when the oscillator start signal (RUN) is set to 0.

Alarm and message

No.	Message	Contents
4066	DISCHARGING	Discharging could not be started normally.
4070	CHILLER NOT READY	No ready signal is sent from the external chiller.
4072	CHILL FLOW	Cooling water flow is insufficient.
4073	LASER GAS PRES.	The laser gas pressure is low.
4075	CHILLER TEMP.	Condensation was detected.
4081	GAS PRES. CONTROL	The actual gas pressure did not fall within ±2.0 (1 = 133 Pa) of the setting of parameter No. 15241, within 45 seconds after gas control started.
4099	GAS PRES. NOT REACH	With bit 3 of parameter No. 15001 being set to 1, the actual gas pressure was insufficient when the gas pressure at the start of discharging was raised to the gas pressure at the time of oscillation. The actual gas pressure was not raised to the value obtained by subtracting the setting of parameter No. 15248 from the setting of parameter No. 15242 or No.15243 within 15 seconds after the gas pressure goal reached the gas pressure at the time of oscillation.

4 ASSIST GAS

4.1 ASSIST GAS CONTROL

Overview

When bit 6 (LHC) of parameter No.15001 is set to 0, assist gas control described below can be performed. Assist gas control can be specified in either of the following two ways:

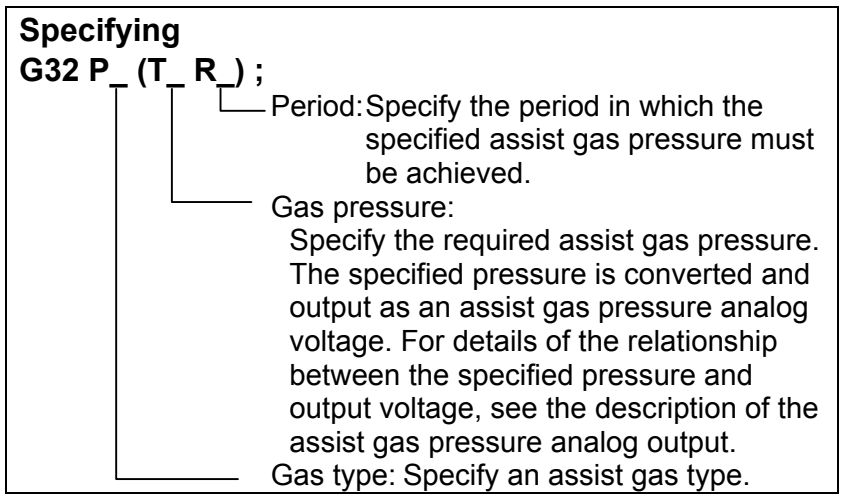
<1> Directly specifying gas pressure control (when bit 0 (AGC) of parameter No.15004 is set to 1)
- Specifying G32 P_ (T_ R_);
- Specifying G32 L_; with the optional function to set machining conditions

<2> Specifying a flow pattern (when bit 0 (AGC) of parameter No.15004 is set to 0)
- Specifying G32 P_ (Q_);
- Performing manual operation

Directly specifying gas pressure control

When bit 0 (AGC) of parameter No.15004 is set to 1, gas pressure control can be specified directly.
G32, for which a non-zero value has been specified for address P or L, opens the shutter and outputs an assist gas select signal (AG1, AG2, or AG3) and assist gas pressure analog signal (see Section 4.2). G32, for which 0 has been specified for address P or L, closes the shutter, selects none of the assist gas select signals (AG1, AG2, AG3), and sets the assist gas pressure analog signal to 0.

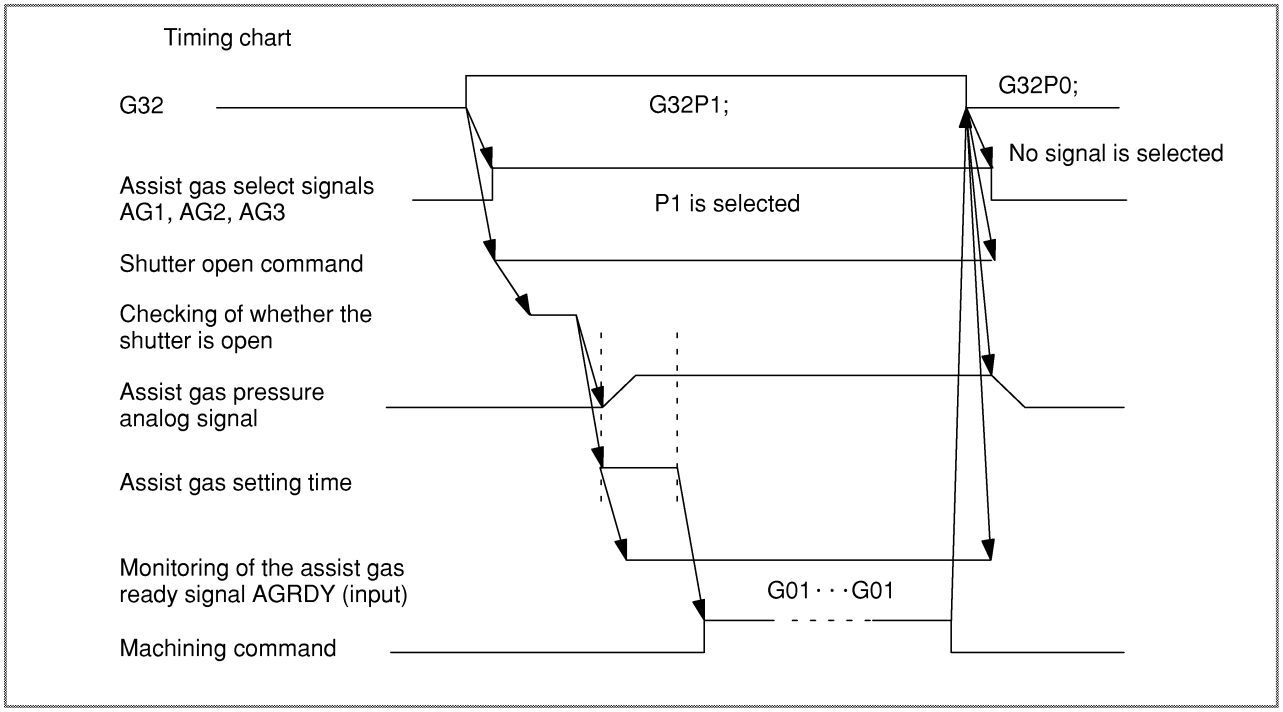
(a) Specifying G32 P_ (T_ R_);



When the following sample program is executed, G32 causes the operation shown in the timing diagram below:

Sample program

```
G32P1T-R-;          Shutter open, Assist gas on command
G01X-Y-F-S-;
G01X-Y-;
G01X-Y-;
G32P0;              Shutter close, Assist gas off command
```



(b) Specifying assist gas control using the machining condition setting function

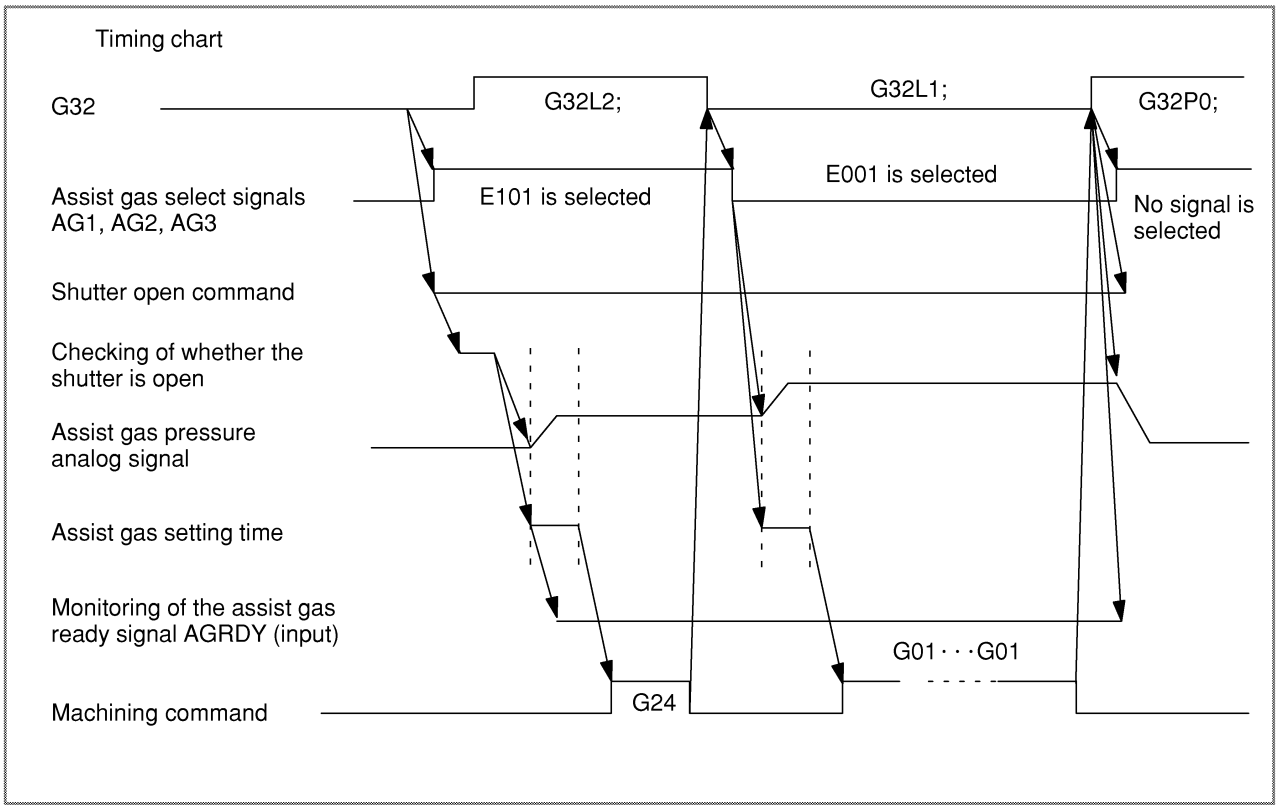
G32L - ;

- 0: Shutter closed, assist gas stopped
- 1: Shutter opened, assist gas flow started according to the machining data
- 2: Shutter opened, assist gas flow started according to the piercing data

When the following sample program is executed, G32 causes the operation shown in the timing diagram below:

Sample program

```
E101;
E001;
G32L2;          Shutter open, Assist gas on command
G24;
G32L1;
G01X-Y-;
G01X-Y-;
G01X-Y-;
G32L0;          Shutter close, Assist gas off command
```



Specifying a flow pattern

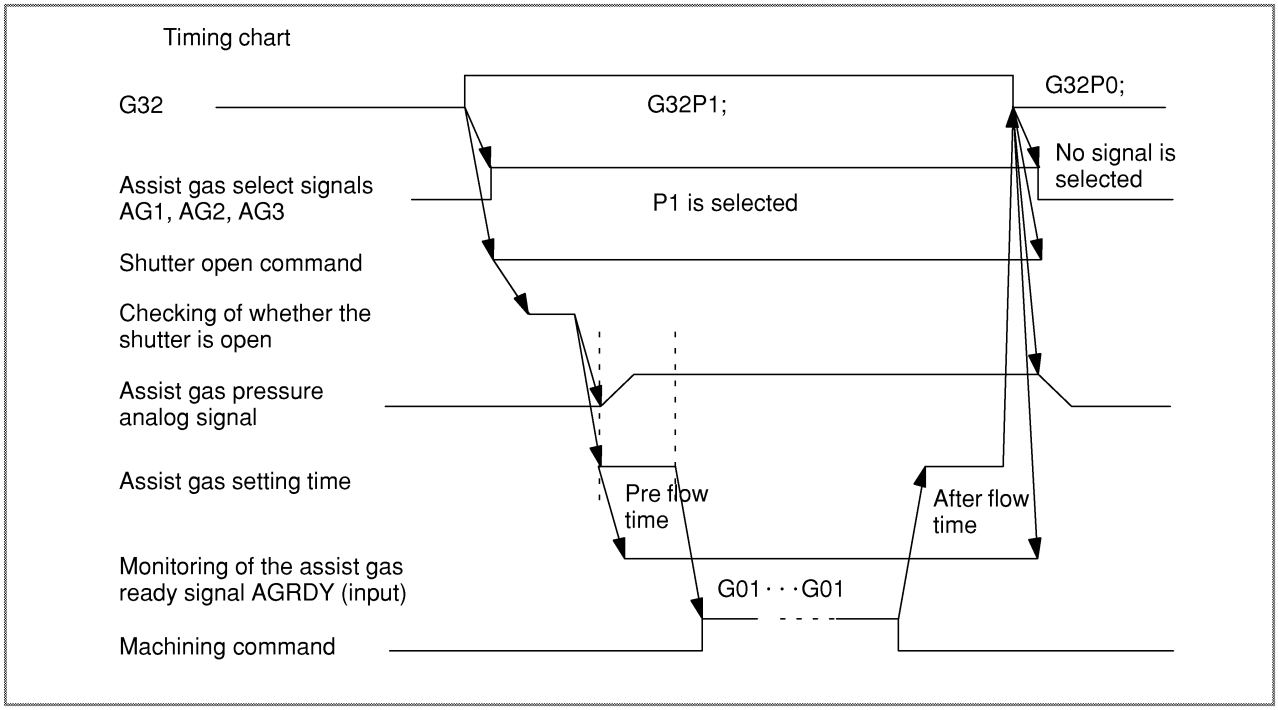
When bit 0 (AGC) of parameter No.15004 is set to 0, a flow pattern can be specified.
G32, for which a non-zero value has been specified for address P, opens the shutter and outputs an assist gas select signal (AG1, AG2, or AG3) and assist gas pressure analog signal.
G32, for which 0 has been specified for address P, closes the shutter, selects none of the assist gas select signals (AG1, AG2, AG3), and sets the assist gas pressure analog signal to 0.

G32P - (Q -);
Pattern: Specify a flow pattern number.
Gas type: Specify an assist gas type.

When the following sample program is executed, G32 causes the operation shown in the timing diagram below:

Sample program

G32P1Q-;	Shutter open, Assist gas on command
G01X-Y-F-S-;	
G01X-Y-;	
G01X-Y-;	
G32P0;	Shutter close, Assist gas off command



Switching between direct gas pressure control specification and flow pattern specification

The G32 command does not necessarily require that T, R, and Q be specified. If none is specified, however, the system cannot decide whether gas pressure control is specified directly or a flow pattern is specified. In this case, the system follows the setting of bit 0 of parameter No. 15004. This is true for output with the external signal AGST.

⚠ CAUTION

1 The assist gas and the shutter are basically controlled synchronously. Keep in mind, therefore, that the shutter is open when the assist gas is output, and never place your hand under the nozzle.
2 The assist gas is not output if:
   1) A machine lock or dry run is applied.
   2) Both a beam lock and shutter lock are applied.
   3) No assist gas type is specified.
   4) A proximity point search or machining restart is in progress.
   5) The assist gas ready signal is 0.
   6) No oscillator is connected.

Signal

- Assist gas select signals AG1,AG2,AG3 <F222#0,#1,#2>

[Classification] Output signal

[Function] Notifies the PMC of the assist gas type to be selected.

[Output condition] When the specified G32 is executed, the CNC outputs an assist gas select signal (AG1, AG2, or AG3).

When G32 P_; is specified, the signal corresponding to the number specified in address P is set to 1. When P2 is specified, for example, assist gas select signal AG2 is set to 1.

When G32 L_; is specified, the value set in the data area for setting the machining conditions is read and the corresponding signal is output as described above.

The PMC should read the assist gas select signal (AG1, AG2, AG3) and open and close the assist gas valve corresponding to the output signal.

The assist gas select signals (AG1, AG2, AG3) can be used to output codes when bit 0 of parameter No.15001 is set accordingly. When code output is selected, a choice of up to seven gas types becomes available.

Assist gas selection number	Signals		
	AG3	AG2	AG1
0: Non selection	0	0	0
1	0	0	1
2	0	1	0
3	0	1	1
4	1	0	0
5	1	0	1
6	1	1	0
7	1	1	1

- Assist gas ready signals AGRDY <G221#7>

[Classification] Input signal

[Function] Monitors whether the external assist gas control unit operates normally.

[Operation] After an interval corresponding to the assist gas setting time, starting from the output of an assist gas select signal (AG1, AG2, or AG3), the CNC starts monitoring the assist gas ready signal (AGRDY).

The assist gas ready signal (AGRDY) should be set to 1 before the CNC starts monitoring it. If the signal is not set to 1 before monitoring starts, the assist gas not ready alarm is issued.

If an error occurs in the assist gas control unit during operation, set the assist gas ready signal (AGRDY) to 0. This generates an alarm and stops the operation.

- Assist gas start signal AGST <G222#5>

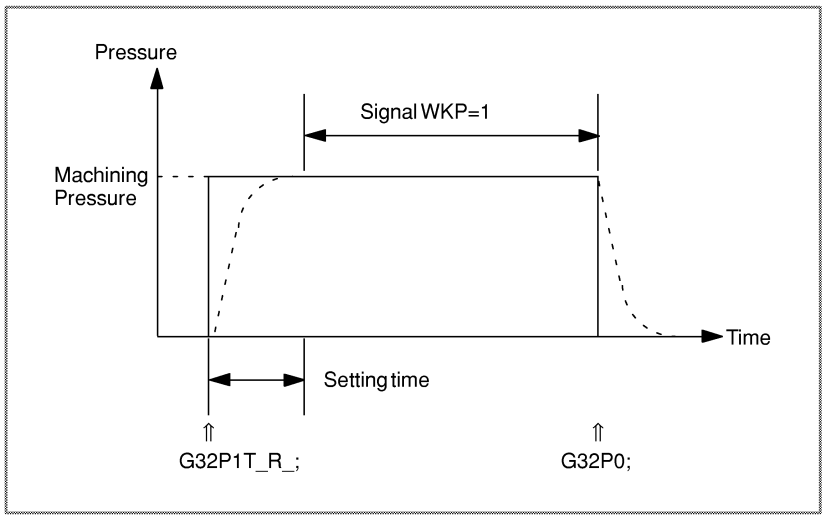
[Classification] Input signal
[Function] Allows the PMC to start the assist gas.
[Operation] When a flow pattern can be specified (bit 0 (AGC) of parameter No.15004 is 0), setting the assist gas start signal (AGST) to 1 in manual operation mode causes assist gas control to be started according to the data specified in the assist gas select field of the laser setting screen.
When the assist gas start signal (AGST) is set to 0, none of the assist gas select signals (AG1, AG2, AG3) is selected.

- Assist gas selection signal AGSLT <F220#1>

[Classification] Output signal
[Function] Notifies the PMC that an assist gas select signal is set to a non-zero value.
[Output condition] When an assist gas select signal (AG1, AG2, AG3) is set to a non-zero value, the assist gas selection signal (AGSLT) is set to 1. This signal can be used to determine whether none of the assist gas select signals is selected by the PMC.

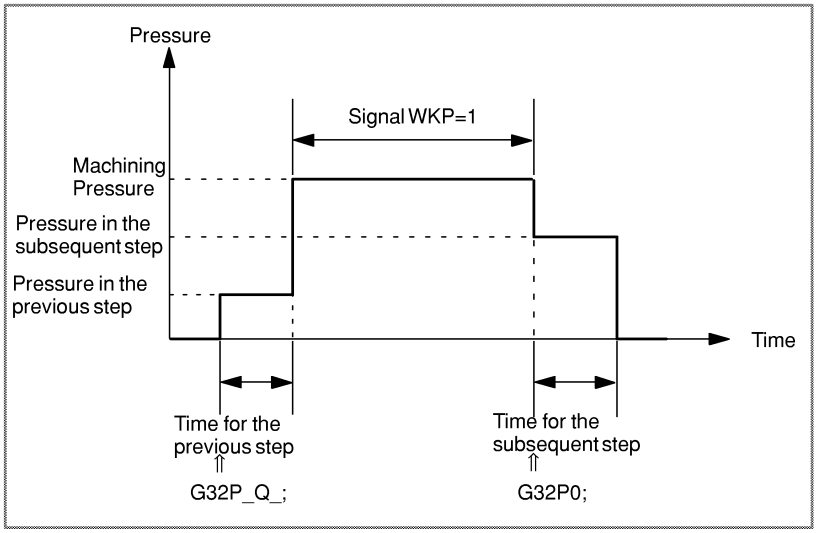
- Machining pressure signal WKP <F220#5>

[Classification] Output signal
[Function] Notifies the PMC that the assist gas has reached the specified machining pressure.
[Output condition] When gas pressure control is specified directly
G32 P_; (or L_;) starts assist gas control. After the set interval elapses, the machining pressure signal (WKP) is set to 1.
G32 P0; (or L0;) stops assist gas control, returning the machining pressure signal (WKP) to 0.



When a flow pattern is specified

If the gas flow pattern data is set in the gas flow field of the laser setting screen, assist gas control is performed as described below:
G32 P_ Q_; (non-zero values for P and Q) starts assist gas control, causing the specified pressure to be output during the specified period, as the previous step. When the specified period elapses, the machining pressure is output, rather than the pressure in the previous step. The machining pressure signal (WKP) is set to 1.
When G32 P0; is specified, the pressure specified for the subsequent step is output, instead of the machining pressure, and the machining pressure signal (WKP) is reset to 0.
Once the period for the subsequent step elapses, the pressure is reduced to 0.



Signal address

	#7	#6	#5	#4	#3	#2	#1	#0
G221	AGRDY							
G222			AGST					
F220			WKP				AGSLT	
F222						AG3	AG2	AG1

Parameter

	#7	#6	#5	#4	#3	#2	#1	#0
15001		LHC						EXA

[Data type] Bit

EXA The assist gas select signals offer a choice of:
0: Three types. (normal)
1: Seven types. (code output)

LHC Oscillator control (shutter open/close, beam on/off, assist gas control) is:
0: Not performed by external signals. Assist gas control is specified by G32. (standard setting)
1: Performed by external signals. The PMC performs assist gas control.

	#7	#6	#5	#4	#3	#2	#1	#0
15004								AGC

[Data type] Bit

AGC G32 P_; specifies:
0: A flow pattern.
1: Direct Gas pressure control.

Alarm and message

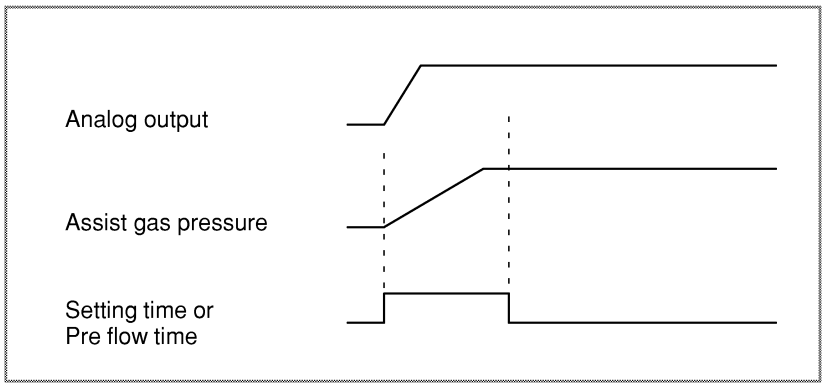
No.	Message	Contents
4051	DATA ERROR	An illegal value is specified with G32.
4071	ASSIST GAS NOT READY	The assist gas supply unit does not set the assist gas ready signal (G221#7) to 1.
4089	ASSIST GAS NO SELECT	The laser output command is executed while assist gas control is not performed.

4.2 ASSIST GAS PRESSURE ANALOG OUTPUT

Overview

When assist gas control is specified, the CNC outputs the specified assist gas pressure as an analog voltage signal. As the destination of the signal, either the analog spindle interface on the main board or the analog output on the analog option board can be selected.
Which to use can be specified with bit 4 of parameter No. 15011.
For details of how to connect the voltage signal, see the explanation of the hardware.
The relationship between the specified assist gas pressure and the voltage level of an analog output signal can be specified in parameter No.15132.
Upon receiving the assist gas pressure analog output signal from the CNC, the assist gas control unit should operate the control valve and automatically adjust the assist gas pressure.
When the control valve operation contains a delay time that cannot be ignored, the CNC operation can be delayed by adjusting the gas pressure setting time or pre-flow time.

- When gas pressure control is to be specified directly, adjust the gas pressure setting time.
- When a flow pattern is specified, adjust the pre-flow time.



Parameter

	#7	#6	#5	#4	#3	#2	#1	#0
15011				AOC				

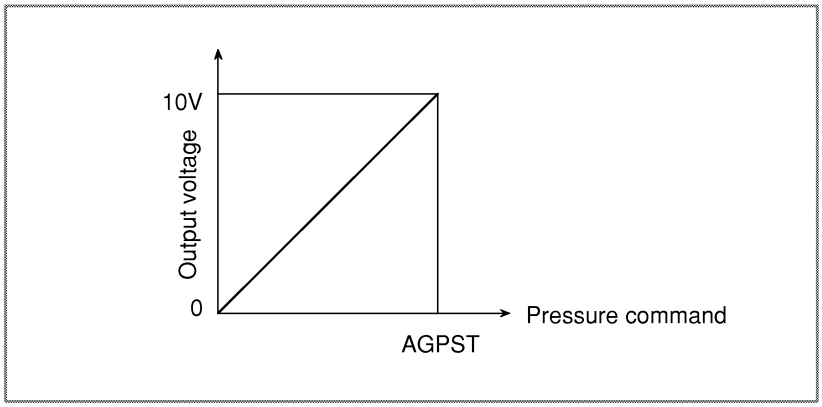
[Data type] Bit

AOC The analog output of the assist gas pressure command is output from:
0: The connector (JA40) on the main board.
1: The connector (JA6) on the analog option board.

15132	Maximum assist gas pressure (AGPST)

[Data type] Word
[Unit of data] 0.1kg/cm^2 or 0.01MPa
[Valid data range] 0 to 255
[Standard setting value] 99

Specify a gas pressure (kg/cm^2 or MPa) that corresponds to 10 V when converted to assist gas pressure analog output.



Limitations

- If no analog option board is not installed

If no analog option board is installed although the connector (JA6) on the analog option board is selected, the assist gas pressure command is not output.

- If using actual-speed analog output B

To use actual-speed analog output B, be sure to set bit 4 of parameter No. 15011 to 1. Otherwise, neither will be output properly.

4.3 ASSIST GAS PRESSURE OVERRIDE

Overview

It is possible to override the assist gas pressure analog output with 0 to 200% of it in units of 1%.

Signal

- Assist gas pressure override signals *AOV0 to *AOV7<G229#0 to #7>

[Classification] Input signal

[Function] Overrides the assist gas pressure analog output.
The eight signals represent a binary code. The override value is given by the expression below:

$$0\text{verride value} = \sum_{i=0}^{7} \left| 2^{i} \times \mathrm{Vi} \right| \ \%$$

Vi is 0 while *AOVi is 1. Vi is 1 while *AOVi is 0.

[Operation] The assist gas pressure analog output is overridden by 0% to 200% (in units of 1%).
When a value exceeding 200% is specified, the value is reduced to 100%. When the overridden value exceeds the upper limit for the analog output voltage, the value is reduced to the upper limit.

Override %	Override signal							
	*AOV7	*AOV6	*AOV5	*AOV4	*AOV3	*AOV2	*AOV1	*AOV0
0	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	0
2	1	1	1	1	1	1	0	1
:	:	:	:	:	:	:	:	:
:	:	:	:	:	:	:	:	:
100	1	0	0	1	1	0	1	1
:	:	:	:	:	:	:	:	:
:	:	:	:	:	:	:	:	:
200	0	0	1	1	0	1	1	1

Signal address

	#7	#6	#5	#4	#3	#2	#1	#0
G229	*AOV7	*AOV6	*AOV5	*AOV4	*AOV3	*AOV2	*AOV1	*AOV0

5 LASER OUTPUT CONTROL

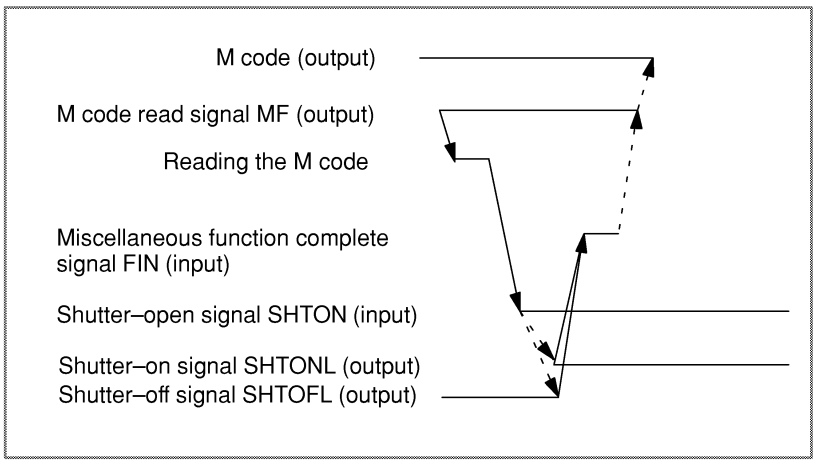
5.1 SHUTTER OPENING/CLOSING CONTROL

Overview

The output section of the oscillator contains a shutter that mechanically shuts off the laser beam output. This shutter is provided as a safety device. The laser can be output only after the shutter has been opened.
In automatic operation, the shutter can be opened in either of the following two ways. A parameter is provided to enable the selection of the method to be used.

(1) Specifying a G code (when bit 6 (LHC) of parameter No.15001 is set to 0)
In automatic operation mode, G32 P_; or G32 L_; opens and closes the shutter. When a non-zero value is specified for address P or L, the shutter opens. When zero is specified for address P or L, the shutter closes.
In manual mode, the shutter open signal (SHTON) from the PMC can be used to open and close the shutter.

(2) Specifying an external signal (when bit 6 (LHC) of parameter No.15001 is set to 1)
When bit 6 (LHC) of parameter No.15001 is set to 1, setting the shutter open signal (SHTON) to 1 causes the shutter to open in both automatic and manual operation mode. To close the shutter, set the signal to 0.
The shutter open signal (SHTON) can be used when the PMC receives an M code specified in a program. Instead of G32, the M code can open and close the shutter.



Shutter interlock

A shutter lock signal (*SHTLC) is provided as a safety feature, making it impossible to open the shutter.
When the shutter lock signal (*SHTLC) is set to 0, the shutter open/close command cannot be used to open the shutter.
To open or close the shutter with the shutter open/close command, first set the shutter lock signal (*SHTLC) to 1.

Signal

- Shutter lock signal *SHTLC<G222#0>

[Classification] Input signal
[Function] Interlocks the shutter open/close command so that the shutter will not open.
[Operation] Set the shutter lock signal (*SHTLC) to 0 to prevent the shutter from being opened or closed by an invalid shutter open/close command.
To open or close the shutter with the shutter open/close command, first set the shutter lock signal (*SHTLC) to 1.

- Shutter open signal SHTON<G222#3>

[Classification] Input signal
[Function] Opens and closes the shutter.
[Operation] When bit 6 (LHC) of parameter No.15001 is set to 0 and the shutter lock signal (*SHTLC) is set to 1, setting the shutter open signal (SHTON) to 1 in manual operation mode opens the shutter.

- Shutter ON/OFF signal SHTONL,SHTOFL<F220#4,F220#3>

[Classification] Output signal
[Function] Notifies the PMC whether the oscillator shutter is open or closed.
[Output condition] The SHTONL and SHTOFL signals indicate whether the shutter is open or closed. The relationship between the shutter statuses and signal statuses is indicated below. The PMC should judge the shutter status from both the SHTONL and SHTOFL signals.
The shutter transient state generally lasts for 500 to 600 msec. If the transient state continues for one second or longer, it indicates that the shutter has not opened or closed normally.

State of the shutter	Signal	
	SHTONL	SHTOFL
Shutter open	1	0
Shutter closed	0	1
Shutter transient state	1	1
	0	0

Signal address

	#7	#6	#5	#4	#3	#2	#1	#0
G222					SHTON			*SHTLC
F220				SHTONL	SHTOFL			

Parameter

	#7	#6	#5	#4	#3	#2	#1	#0
15001		LHC						

[Data type] Bit

LHC Oscillator control (shutter open/close, beam on/off, assist gas control) is:

0: Not performed by external signals. The shutter is opened and closed by G32. (standard setting)

1: Performed by external signals. The shutter is opened and closed using the shutter open signal (SHTON).

	#7	#6	#5	#4	#3	#2	#1	#0
15004							STC	

[Data type] Bit

STC Shutter control is performed by:

0: G32. (standard setting)

1: The shutter open signal (SHTON). (G32 is effective only for assist gas control.)

With the standard setting, G32 can open and close the shutter and can perform assist gas control. Use this parameter to make G32 valid only for assist gas control (the shutter is opened and closed by the PMC.) This parameter differs from bit 6 (LHC) of parameter No.15001. When LHC is set, the PMC must perform both beam control and assist gas control.

Alarm and message

No.	Message	Contents
4065	SHUTTER ACTION	The operation of the shutter is abnormal.
4087	SHTTER OH	The shutter has overheated.

NOTE

For the C series, the shutter cannot be opened unless the oscillator is in the LSTR state.
For the Y series, the shutter can be opened even if the oscillator is in the PURGE state. The oscillator cannot, however, be started when the shutter is open. An attempt to do this results in an alarm.

5.2 BEAM ON/OFF CONTROL

Overview

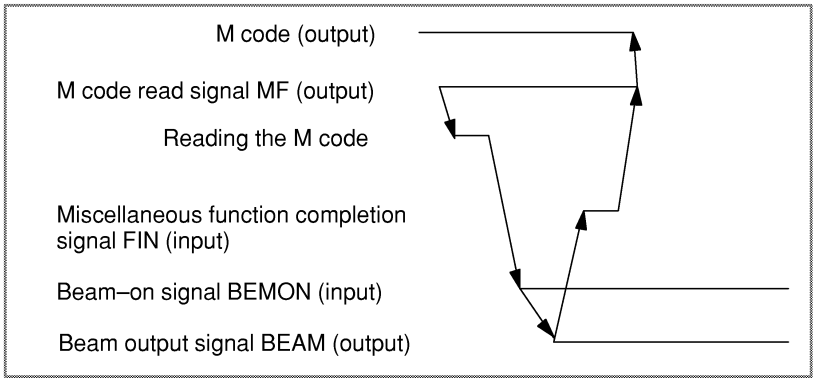
When the shutter is open, executing a beam output command causes the oscillator to radiate the laser beam to the outside.
The beam output command can be issued by either of the following methods, according to the bit 6 (LHC) of parameter No. 15001.

Using a G code

(1) Using a G code (bit 6 (LHC) of parameter No.15001 is 0)
When the piercing command (G24) or cutting feed command (G01, G02, G03, G12) is executed, the beam is turned on. When the command terminates, the beam is turned off. In manual operation mode, the beam on signal (BEMON) from the PMC can be used to turn the laser beam on or off.

Using the beam on signal

(2) Using the beam on signal (BEMON) (bit 6 (LHC) of parameter No.15001 is set to 1)
When bit 6 (LHC) of parameter No.15001 is set to 1, the PMC can turn the beam on or off in both automatic and manual operation mode. The beam on signal (BEMON) can be set to 1 when the PMC receives an M code specified in a program. The M code can turn the beam on or off, instead of the G code. This method controls the beam through the PMC, causing a delay relative to beam control with the G code.



Beam lock signal

A beam lock signal (*BEMLC) is supported to ensure safe operation. This signal can be used to allow specified beam output only when a key-operated switch is activated.
0: Beam lock status
1: Beam lock released
When the beam lock signal (*BEMLC) is set to 1, the beam lock is released. When a machining program is executed in this state, the laser beam is output as specified in the program.

To execute a machining program without outputting the laser beam, set both the beam lock signal (*BEMLC) and shutter lock signal (*SHTLC) to 0. This setting can also be used to operate the machine while the oscillator is not connected or not adjusted, or to check a machining program (movements only).
When the beam on state is selected, the beam output signal (BEAM) is set to 1. The PMC can check this state.

Signal

- Beam on signal BEMON<G222#4>

[Classification] Input signal
[Function] The beam can be turned on and off by an external signal.
[Operation] When the oscillator is in the oscillation state (oscillation signal LSTR is set to 1), while when the shutter is opened, the external signal turns the beam on or off.

(1) When bit 6 (LHC) of parameter No.15001 is set to 0
The beam is output by setting the beam on signal (BEMON) to 1 in manual operation mode.

(2) When bit 6 (LHC) of parameter No.15001 is set to 1
The beam is output by setting the beam on signal (BEMON) to 1 in automatic or manual operation mode.
Instead of the G code, an M code can be used to turn the beam on or off.
This method controls the beam through the PMC, causing a delay relative to beam control with the G code.

- Beam lock signal *BEMLC<G222#1>

[Classification] Input signal
[Function] This external signal can interlock the beam on command. The signal can be used for safety check or for automatic operation in which the motion of the machine is checked without activating or connecting the oscillator.
[Operation] When the beam lock signal (*BEMLC) is set to 0, the CNC enters the beam lock state. In this state, the beam on command (G32 or beam on signal (BEMON)) cannot be used to output the beam.
To output the beam, set the beam lock signal (*BEMLC) to 1.
0: Beam lock state
1: Beam lock released

- Beam output signal BEAM<F221#7>

[Classification] Output signal
[Function] Notifies the PMC that the beam is output.
[Output condition] The signal is set to 1 when:
- The beam is turned on.

The signal is set to 0 when:
- The beam is turned off.

- Mode output signal CW<F222#6>

[Classification] Output signal

[Function] Notifies the PMC that the beam is output in continuous (CW) mode. In continuous mode, the pulse duty ratio of the output command, multiplied by the duty override, is 100%. Power control is not performed.

[Output condition] The signal is set to 1 when:

- The beam is output in continuous (CW) mode.

The signal is set to 0 when:

- The beam is not output.
- The beam is output in pulse mode.

- Mode output signal PULSE<F222#5>

[Classification] Output signal

[Function] Notifies the PMC that the beam is output in pulse mode. In pulse mode, the pulse duty ratio of the output command, multiplied by the duty override, is less than 100%. Or, power control is used to select the pulse output state.

[Output condition] The signal is set to 1 when:

- The beam is output in pulse mode.

The signal is set to 0 when:

- The beam is not output.
- The beam is output in continuous (CW) mode.

Signal address

	#7	#6	#5	#4	#3	#2	#1	#0
G222				BEMON	SHTON		*BEMLC	*SHTLC
F220				SHTONL	SHTOFL			
F221	BEAM							
F222		CW	PULSE					

Parameter

	#7	#6	#5	#4	#3	#2	#1	#0
15001		LHC						

[Data type] Bit

LHC Oscillator control (shutter open/close, beam on/off, assist gas control) is:

0: Not performed by external signals. The beam is turned on and off by a G code. (standard setting)

1: Performed by external signals. The beam is turned on and off by the beam on signal (BEMON).

Alarm and message

No.	Message	Contents
4068	BEAM REFLECTION	Beam reflection from the workpiece is greater than or equal to the specified standard level.

No.	Message	Contents
4076	LASER POWER DOWN	The actual output is lower than the specified average power by a predetermined value or greater.
4089	ASSIST GAS NO SELECT	Assist gas signals were not output. Assist gas signals AG1 to AG3 (F0222#0 to F0222#2)
4090	LASER NOT GENERATE	Before the oscillator is activated, the beam output command is specified.

5.3 OUTPUT OVERRIDE

5.3.1 Power Override Signal

Overview

When the C-series or Y-series oscillator is being used, the currently set output power can be overridden. The override value can be specified within a range of 0% to 200%, in units of 1%.

Signal

- Power override signals
POV0 to POV7<G223#0 to #7>

[Classification] Input signal
[Function] Overrides the currently set output power.
[Operation] When the C-series or Y-series oscillator is being used, the currently set output power can be overridden. The override value can be specified within a range of 0% to 200%, in units of 1%.
If the overridden power falls outside the range specified for the system, it is rounded up or down to the upper or lower limit of the range.

Override %	Signal							
	POV7	POV6	POV5	POV4	POV3	POV2	POV6	POV0
0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	1
:	:	:	:	:	:	:	:	:
100	0	1	1	0	0	1	0	0
:	:	:	:	:	:	:	:	:
200	1	1	0	0	1	0	0	0

Signal address

	#7	#6	#5	#4	#3	#2	#1	#0
G223	POV7	POV6	POV5	POV4	POV3	POV2	POV1	POV0

NOTE
During high-speed piercing, this function is disabled.

5.3.2 Frequency Override Signal

Overview

The currently set pulse frequency of the laser oscillator can be overridden.

Signal

- Frequency override signals
***FOV0 to *FOV7<G228#0 to #7>**

[Classification] Input signal

[Function] It is possible to override the output pulse frequency of the laser oscillator.

[Operation] When the C-series or Y-series oscillator is used, the frequency override signals (*FOV0 to *FOV7) can be used to override the currently set pulse frequency of the laser oscillator.
The override value can be specified within a range of 0% to 200%, in units of 1%. If the overridden frequency falls outside the range specified for the system, it is rounded up or down to the upper or lower limit of the range.
When the specified override value exceeds 200%, it is reduced to 100%.

Override %	Signal							
	*FOV7	*FOV6	*FOV5	*FOV4	*FOV3	*FOV2	*FOV1	*FOV0
0	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	0
:	:	:	:	:	:	:	:	:
100	1	0	0	1	1	0	1	1
:	:	:	:	:	:	:	:	:
200	0	0	1	1	0	1	1	1

Signal address

(1) For C series and Y series laser oscillator

	#7	#6	#5	#4	#3	#2	#1	#0
G228	*FOV7	*FOV6	*FOV5	*FOV4	*FOV3	*FOV2	*FOV1	*FOV0

NOTE
During high-speed piercing, this function is disabled.

5.3.3 Duty Override

Overview

When the C-series or Y-series oscillator is being used, the currently set laser output pulse duty can be overridden.

Signal

- Duty override signals *DU1 to *DU16<G220#0 to #4>

[Classification] Input signal

[Function] Overrides the currently set pulse duty ratio of the laser oscillator.

[Operation] When the C-series or Y-series oscillator is used, the duty override signals (*DU1 to *DU16) can be used to override the current pulse duty ratio of the laser oscillator.

The override value can be specified within a range of 0% to 150%, in units of 10%. Note that specifying an override value of 0% makes the duty ratio 0%, resulting in the beam off state.

Override %	Signal				
	*DU16	*DU8	*DU4	*DU2	*DU1
0	1	1	1	1	1
10	1	1	1	1	0
20	1	1	1	0	1
30	1	1	1	0	0
40	1	1	0	1	1
50	1	1	0	1	0
60	1	1	0	0	1
70	1	1	0	0	0
80	1	0	1	1	1
90	1	0	1	1	0
100	1	0	1	0	1
110	1	0	1	0	0
120	1	0	0	1	1
130	1	0	0	1	0
140	1	0	0	0	1
150	1	0	0	0	0

Signal address

	#7	#6	#5	#4	#3	#2	#1	#0
G220				*DU16	*DU8	*DU4	*DU2	*DU1

NOTE
During high-speed piercing, this function is disabled.

5.4 CHANGING THE PIERCING TIME

Overview

When the C-series or Y-series oscillator is used, external signals can be used to change the piercing time specified by G24.
When the CNC executes G24, it presets the timer to the specified piercing time. While the timer is counting down, piercing is executed.

Reducing the piercing time

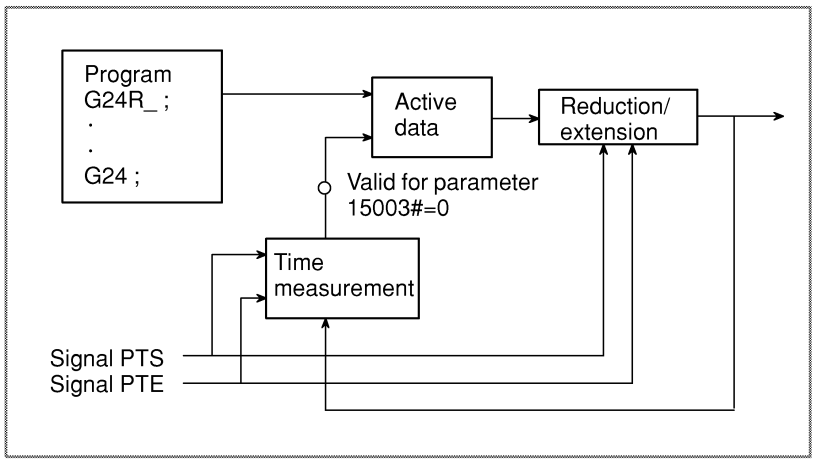
When the piercing time reduction signal (PTS) is set to 1 during piercing, the timer set for the piercing time stops counting down at the rising edge of the signal and piercing stops.

Extending the piercing time

When the piercing time extension signal (PTE) is set to 1 during piercing, piercing does not stop when down-counting by the timer ends. The piercing continues until the piercing time extension signal (PTE) is set to 0.
The following block diagram indicates the piercing operation.

Updating the piercing time

The piercing time can be updated to an extended or reduced value. As shown in the block diagram, piercing time R, specified by G24 R_; is stored as active data. When the piercing time is changed by the piercing time reduction signal (PTS) or piercing time extension signal (PTE), the update data is prepared by means of time measurement. When bit 1 (HPT) of parameter No.15003 is set to 0, the update data replaces the active data.
To execute piercing with the updated time, specify the next G24 command without R. If G24 is specified with R, the updated time is replaced with the value for R.
If cutting conditions have been specified using the cutting condition setting function, the piercing time stored in the data area for the cutting condition setting function is valid at all times and, therefore, the active data cannot be changed.



Signal

- Piercing time reduction signal PTS<G221#2>

[Classification] Input signal

[Function] This external signal can abort the piercing specified by G24 and can reduce the piercing time.

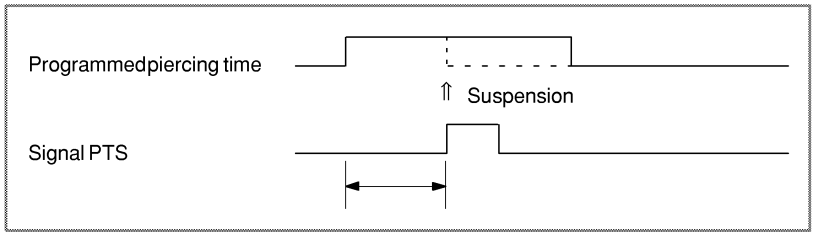
[Operation] When the C-series or Y-series oscillator is used, an external signal can be used to change the piercing time specified with G24.

When the CNC executes G24, it stores the specified piercing time and presets the timer to the piercing time. While the timer is counting down, piercing is executed.

When the piercing time reduction signal (PTS) is set to 1 during piercing, the timer set for the piercing time stops counting down at the rising edge of the signal and piercing stops.

The time from when piercing starts until it stops is measured. This value can replace the piercing time.

Bit 1 (HPT) of parameter No.15003 specifies whether this value is used to replace the piercing time.



- Piercing time extension signal PTE<G221#3>

[Classification] Input signal

[Function] This external signal can abort the piercing specified by G24 and can extend the piercing time.

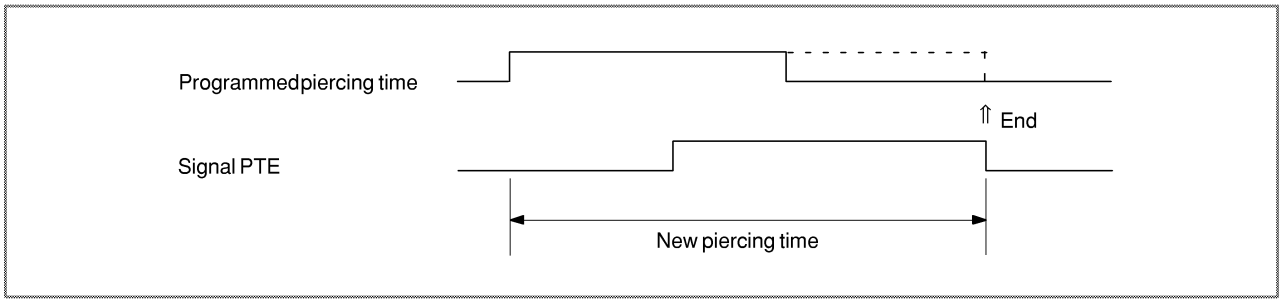
[Operation] When the C-series or Y-series oscillator is used, an external signal can be used to change the piercing time specified with G24.

When the CNC executes G24, it stores the specified piercing time and presets the timer to the piercing time. While the timer is counting down, piercing is executed.

When the piercing time extension signal (PTE) is set to 1 during piercing, piercing does not stop when counting-down ends. Instead, piercing continues until the piercing time extension signal (PTE) is set to 0.

The time from when piercing starts until it ends is measured. This value can replace the piercing time.

Bit 1 (HPT) of parameter No.15003 specifies whether this value is used to replace the piercing time.



Signal address

	#7	#6	#5	#4	#3	#2	#1	#0
G221					PTE	PTS		

Parameter

	#7	#6	#5	#4	#3	#2	#1	#0
15003							HPT	

[Data type] Bit

HPT When the function for changing the piercing time is executed, the newly specified piercing time:

0: Replaces the current data.

1: Does not replace the current data.

5.5 GUIDE LIGHT ON SIGNAL

Overview

If the laser oscillator contains an optional guide light unit (semiconductor laser), an external signal can be used to turn the guide light laser unit on or off.

> ⚠ **CAUTION**
> The external guide light on signal (SCLON) must be used with a key-operated switch, the key of which cannot be removed while the guide light is turned on.

Signal

- Guide light on signal SCLON<G222#2>

[Classification] Input signal

[Function] Turns on the laser unit for the laser oscillator guide light.

[Operation] (1) C-series oscillator

If the laser oscillator contains an optional guide light unit (semiconductor laser), setting the guide light on signal (SCLON) to 1 turns on the guide light laser unit.

In this state, the oscillator outputs the guide light when the shutter is closed. When the shutter is open, the oscillator outputs carbon dioxide gas laser instead of the guide light.

The external guide light on signal (SCLON) must be used with a key-operated switch, the key of which cannot be removed while the guide light is turned on.

(2) Y-series oscillator

Each YAG laser oscillator contains a guide light unit (semiconductor laser). When the guide light on signal (SCLON) is set to 1, the guide light laser unit is turned on.

When the shutter is opened in this condition, the oscillator outputs the guide light, either together with or without the YAG laser. When the shutter is closed, the oscillator outputs neither the guide light nor the YAG laser.

The external guide light on signal (SCLON) must be used with a key-operated switch, the key of which cannot be removed while the guide light is turned on.

Signal address

	#7	#6	#5	#4	#3	#2	#1	#0
G222						SCLON		

5.6 STATE OUTPUT SIGNAL

5.6.1 Piercing Signal

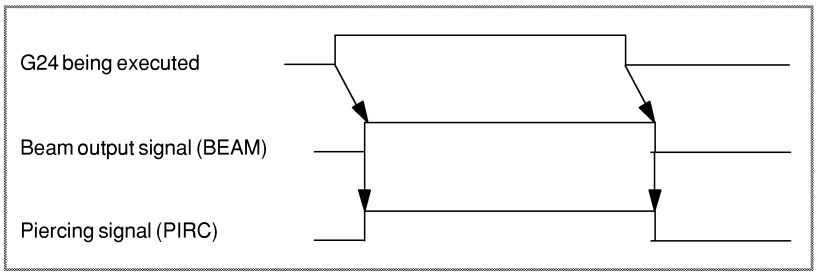
Overview

A signal is output to indicate that piercing specified by G24 is in progress.

Signal

- Piercing signal
PIRC<F222#7>

[Classification] Output signal
[Function] Notifies the PMC that piercing specified by G24 is in progress.
[Output condition] When the C-series or Y-series oscillator is used, the piercing signal (PIRC) remains set to 1 while the piercing specified by G24 is being performed.



⚠ CAUTION
1 When beam lock, machine lock, or dry run is enabled or the pulse duty cycle is set to "0", executing the G24 command does not set the piercing signal (PIRC) to "1".
2 If an alarm occurs during execution of G24, the piercing signal (PIRC) becomes "0".
3 If feeding is placed on hold during execution of G24, the piercing signal (PIRC) becomes "0". When feeding is released from hold and the beam is tuned on, the piercing signal (PIRC) is back to "1".

Signal address

	#7	#6	#5	#4	#3	#2	#1	#0
F222	PIRC							

5.6.2 Laser Processing Signal

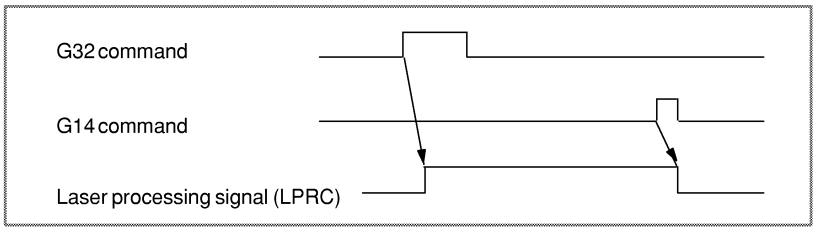
Overview

The laser processing signal is output for the time between assist gas output being started and tracing control being cancelled.

Signal

- Laser processing signal
LPRC<F222#4>

[Classification] Output signal
[Function] Notifies the PMC of the time between assist gas output being started and tracing control being cancelled.
[Output condition] When assist gas output is turned on by G32, the CNC sets the laser processing signal (LPRC) to 1. When tracing is cancelled by G14, the CNC sets the laser processing signal (LPRC) to 0.



⚠ CAUTION
1 If feeding is placed on hold during laser processing, the laser processing signal (LPRC) remains to be "1".
2 The laser processing signal (LPRC) remains to be "1" during single-block operation.
3 If the program is terminated without issuing G14, the laser processing signal (LPRC) remains to be "1".
4 A reset turns the laser processing signal (LPRC) to "0".
5 If the assist gas is not output when G32 is executed (during machine locked state, dry run, or simultaneous occurrence of shutter locked and beam locked states), the laser processing signals (LPRC) becomes "0".
6 If an alarm occurs, the laser processing signal (LPRC) becomes "0".

Signal address

	#7	#6	#5	#4	#3	#2	#1	#0
F222				LPRC				

5.6.3 Output Drop Alarm Signal

Overview

As the mirror of the resonator becomes dirty, laser output will drop. When the laser oscillator is activated, the power compensation coefficient is automatically calculated. By specifying this coefficient for the values specified for output, the reduction in the laser output can be compensated for.
When the output drops to such a degree that the compensation exceeds the maximum permissible value, an output drop alarm is displayed on the CRT screen. The output drop alarm signal (MWRN) is also set to 1.
Pressing the reset key clears the alarm on the screen but does not clear the output drop alarm signal (MWRN). The signal returns to 0 only when the mirror is cleaned, such that the output rises to a satisfactory level.

Signal

- Output drop alarm signal MWRN<F220#6>

[Classification] Output signal
[Function] Notifies the PMC that the reduction in the laser output exceeds the maximum permissible value.
[Output condition] The signal is set to 1 when:
- The power compensation coefficient calculated upon activation of the laser oscillator exceeds the maximum permissible value.

The signal is set to 0 when:
- The power compensation coefficient calculated upon activation of the laser oscillator is within the permissible range.

Signal address

	#7	#6	#5	#4	#3	#2	#1	#0
F220		MWRN						

5.6.4 Laser Alarm Signal

Overview

When a laser oscillator error is detected, a laser alarm occurs.

Signal

- Laser alarm signal LARM<F221#0>

[Classification] Output signal

[Function] Notifies the PMC that the laser oscillator or laser control has developed a fault.

[Output condition] The signal is set to 1 when the following occurs:

- No. 4061 Illegal A/D convert-1
- No. 4062 Illegal A/D convert-2
- No. 4063 R/F power supply error
- No. 4065 Shutter operation error
- No. 4066 Discharge start error
- No. 4067 Laser cabinet temperature error
- No. 4069 Laser IF unconnected/error
- No. 4070 Chiller not ready
- No. 4072 Chiller water amount error
- No. 4073 Laser gas pressure error
- No. 4074 Roots flower temperature error
- No. 4075 Chiller water temperature error
- No. 4076 Laser power low
- No. 4077 Absorber temperature error
- No. 4078 Laser tube pressure error
- No. 4079 Press the reset key.
- No. 4080 Laser tube exhaust error
- No. 4081 Gas pressure control error
- No. 4082 Negative pressure sensor error
- No. 4087 Shutter temperature error
- No. 4088 Discharge voltage low
- No. 4091 Inverter error
- No. 4093 Vibration detected
- No. 4094 Vacuum pump error
- No. 4099 Gas pressure not reached
- No. 4100 Inverter error 1
- No. 4101 Inverter arrival signal 1
- No. 4102 Vibration error 1
- No. 4103 Blower not stopped 1
- No. 4104 Turbo overcurrent 1
- No. 4105 Turbo temperature error 1
- No. 4106 Insufficient turbo lubricant
- No. 4107 Return mirror not mounted
- No. 4110 Inverter error 2
- No. 4111 Inverter arrival signal 2
- No. 4112 Vibration error 2
- No. 4113 Blower not stopped 2
- No. 4114 Turbo overcurrent 2
- No. 4115 Turbo temp. 2
- No. 4132 A parameter was changed.
- No. 4136 Too much internal pressure
- No. 4137 Mixer power supply error
- No. 4138 Improper degree of vacuum
- No. 4139 Mixer pressure switch error

The signal is set to 0 when:

- None of the alarms listed above occurs.
- The reset key is pressed after the causes of the alarms listed above have been removed.

Signal address

	#7	#6	#5	#4	#3	#2	#1	#0
F221								LARM

5.6.5 Laser Oscillator Not Connected Signal

Overview

This signal is output if no laser oscillator is connected.

Signal

- Laser oscillator not connected signal
LONC<F223#7>

[Classification] Output signal
[Function] Notifies the PMC that no laser oscillator is connected to the CNC.
[Output condition] The signal is set to "1" if the power is turned on with no laser oscillator connected.

> ⚠ **CAUTION**
> This signal is output if the system determines that no laser oscillator is connected when the power is turned on. The state of the signal does not, therefore, change if a laser oscillator is connected or disconnected after the power is turned on.

Signal address

	#7	#6	#5	#4	#3	#2	#1	#0
F223	LONC							

6 TRACING CONTROL

6.1 TRACING CONTROL

6.1.1 Tracing Function

Overview

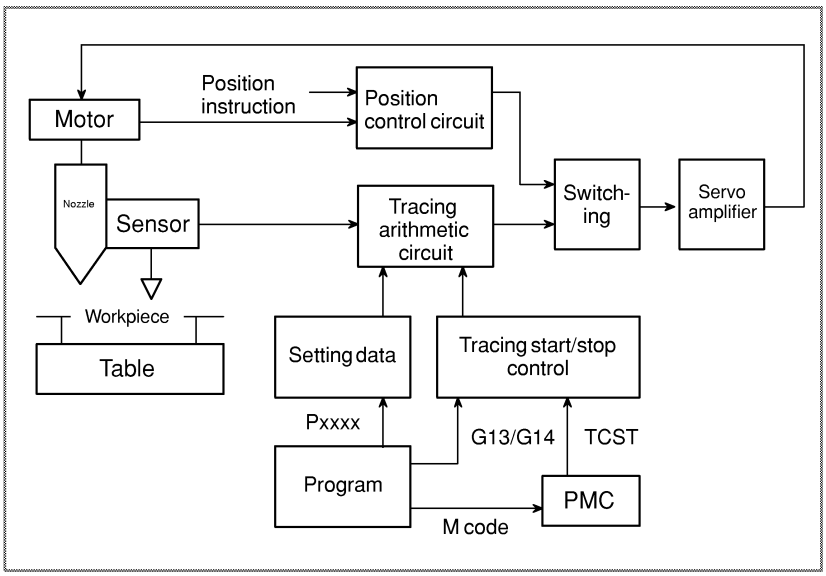
When a sensor for detecting the distance to a workpiece is mounted on the Z-axis, and a signal from this sensor is sent to the CNC, the CNC outputs a Z-axis (W-axis) move command to establish a specified distance between the sensor and workpiece.

Commands

Both G codes and an external signal are available as tracing commands.
The G codes (G13 and G14) and the external signal (TCST) cannot be used at the same time.

Block diagram of tracing control

A block diagram of the tracing control system is shown below.



Controlled axes

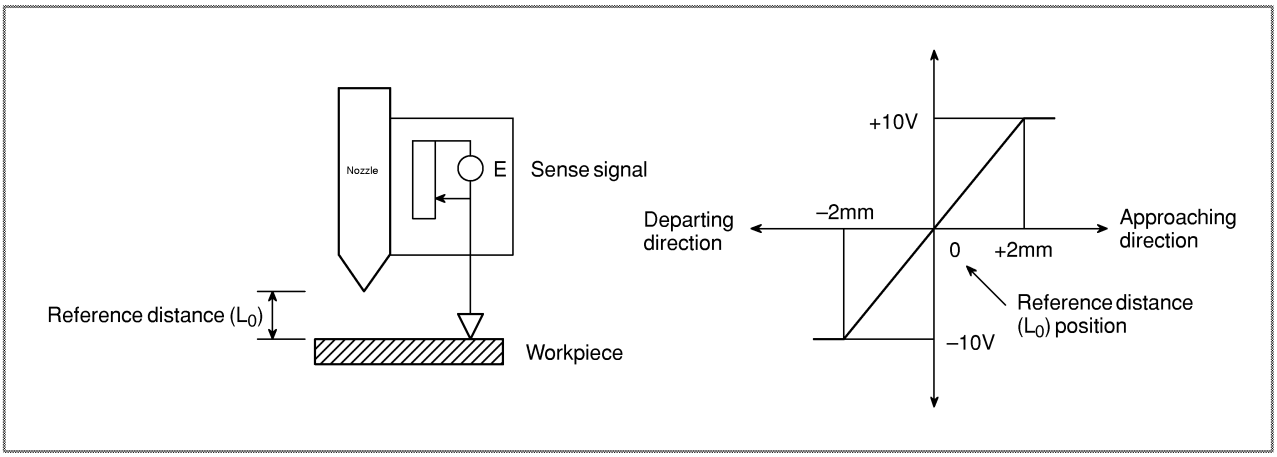
For facing machines
Z axis (The third axis is fixed.)
For three-dimensional machining machines
W and Z axes (The sixth and third axes are fixed. They can be switched by using the corresponding external signal or G13L_.)

Polarity

Configure the mechanical system so that the nozzle moves away from the workpiece in response to a positive direction command, and approaches the workpiece in response to a negative direction command along the Z-axis and W-axis.

Polarity of the sense signal

The sensor should be designed to send a 0-V sense signal when the nozzle is at the reference distance (L_0) position and then output voltage in proportion to any shift from the reference position. Positive voltage should be output when the nozzle approaches the workpiece from the reference distance position.
Negative voltage should be output when the nozzle leaves from the reference distance position.



Level of the sense signal

As a sense signal, +10 VDC or -10 VDC must be sent to the CNC when the nozzle has moved away from the reference position by 2 mm in either the approach or retreat directions.
When the signal output by the sensor is not of the required level, a gain adjustment circuit must be provided.
Clamp the output of the sensor so that the voltage applied to the CNC does not exceed ±10 V.

Resolution of the sense signal

When a voltage of ±10V is input for shifts of ±2mm, CNC reads the shift with a minimum resolution of 0.001 mm with the aid of an A/D converter.

Selection of the sense signal level

The standard shift is ±2mm, for which as voltage of ±10 is output. However, for applications where a larger sensing stroke is required, the parameter No. 15504 is provided:

Shift	Sense signal voltage	Resolution
±2mm	±10V	0.001mm
±4mm	±10V	0.002mm
±6mm	±10V	0.003mm
±8mm	±10V	0.004mm
±10mm	±10V	0.005mm

Sensor performance

Tracking accuracy depends on the linearity of the sensor. So, use only a sensor having extremely high linearity.
The frequency characteristics of the amplifier and sensor greatly affect the response of the tracing control system. So, use only a sensor and amplifier having extremely good frequency characteristics (with a frequency band of 30 Hz or wider).
Mount the sensor such that it is mechanically secure, and not subject to vibration.
Also pay attention to the rigidity, lost motion, and resonance of the drive system of the tracing axis.

Tracking speed

The tracking speed of tracing is equal to the loop gain multiplied by a shift.

$Vz=60\times K\times (\Delta E-E0)$

where,

Vz : Tracking speed (mm/min)
K: Tracking speed voltage conversion coefficient
ΔE: Amount of shift (mm)
E0: Standard shift (mm)

When the nozzle is lifted away the workpiece, the amount of shift assumes the maximum negative value, such that the value of Vz becomes extremely high.
In this case, the nozzle approaches the workpiece at high speed. Parameter No. 15553 can be used to clamp this speed.

> ⚠ **CAUTION**
> While an axis is assumed a tracing axis, do not issue move commands using a program or manually.

Signal

- Tracing start signal TCST<G225#3>

[Classification] Input signal
[Function] Tracing is started and stopped using an external signal.
[Operation] Tracing is performed while this signal is 1.
To set this signal to 0 using an M code, set this M code as an M code without buffering.

- Tracing motion signal TRCL<F220#2>

[Classification] Output signal
[Function] This signal informs the PMC that tracing is in progress.
[Output condition] This signal is set to 1 in the following case:

- When nozzle approach is assumed to have been completed, with the nozzle having approached to within a certain distance from the workpiece after the start of tracing

This signal is set to 0 in the following case:

- When a tracing stop condition is accepted

When an M code is used to start and stop tracing, the tracing motion signal (TRCL) set to 1 must be confirmed after the tracing start signal (TCST) is set to 1. Then, FIN must be returned.

> ⚠ **CAUTION**
> Set TCST ON when TRCL is equal to 0 and OFF when TRCL is equal to 1. For example, do not set TCST to 0 when TRCL is equal to 1 and set TCST to 1 again before TRCL is set to 0.

Signal address

	#7	#6	#5	#4	#3	#2	#1	#0
G225					TCST			
F220						TRCL		

Parameter

	#7	#6	#5	#4	#3	#2	#1	#0
15003								TIV

[Data type] Bit

TIV When a tracing shift is read, the polarity is

0: Not modified.

1: Inverted.

> ⚠ **CAUTION**
> The following functions cannot be used with the tracing axis:
> 1 Advanced preview feed forward
> Set bit 7 of parameter No. 1819 to "1."
> 2 Fine acceleration/deceleration for cutting and rapid traverse each
> Set bit 0 of parameter No. 2202 to "0."

6.1.2 Tracing Control Adjustment

Overview

After connecting the signal from the sensor to the CNC, make the adjustments described below.

Sensor adjustment

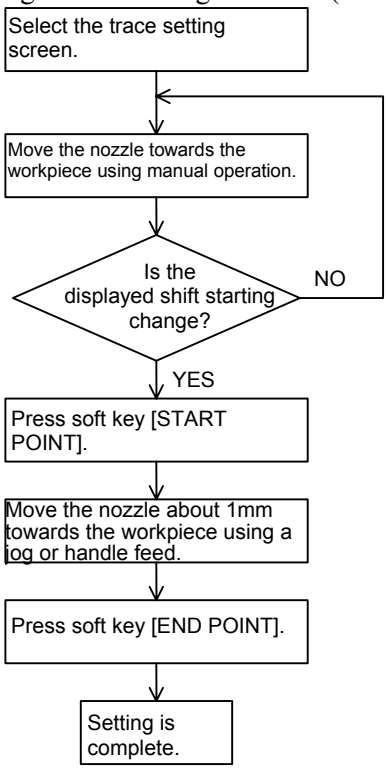
Position the sensor so that the distance between the sensor and workpiece is equal to the sensor stroke + α (standard value: 2 mm + α). (α is between about 0.1 mm and 0.2 mm.)
At this position, adjust the zero point of the sensor amplifier so that the sensor outputs a sense signal of about 0 V.
Move the sensor toward the workpiece by an amount equal to the positive stroke (standard value: 2 mm) of the sensor, then adjust the sensor amplifier so that the sensor outputs a sense signal of +10 V.
Similarly, move the sensor away from the workpiece by an amount equal to negative stroke (standard value: -2 mm) of the sensor, then adjust the sensor amplifier so that the sensor outputs a sense signal of -10 V.

Sensor adjustment on the CNC

Select a sensing stroke by specifying parameter No. 15504. If the sense signal polarity of the sensor is inverted, set bit 0 (TIV) of parameter No. 15503 to 1.

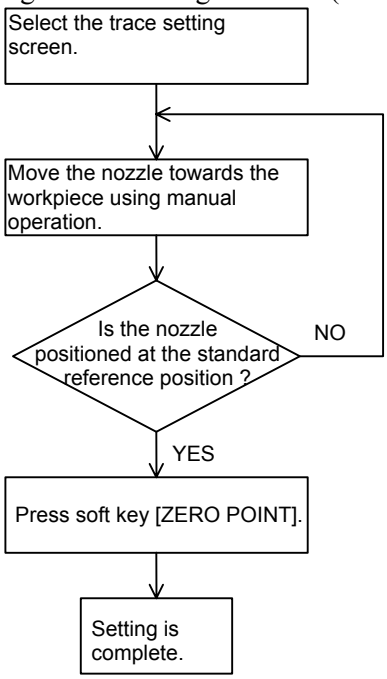
Sensing gain setting

Set a sensing gain coefficient with the trace setting screen.
Repeat the following operation a few times to check that there is no significant setting variation (within about ±20).



Zero point adjustment

Set a zero point with the trace setting screen.
Repeat the following operation a few times to check that there is no significant setting variation (within about ±320).



Shift calculation formula

When the above adjustments are made, the CNC calculates the amount of shift DE by means of the following formula.

$$\Delta E = (Ke \times E - Ezr) \times Emul$$

where,

- ΔE: Calculated amount of shift
- Ke: Sensing gain coefficient (determined by the above operation and set in parameter No. 15500)
- E: Sense level read from the A/D converter
- Ezr: Amount of zero adjustment (determined by the above operation and set in parameter No. 15502)
- Emul: Value set in parameter No. 15504

- Tracing gain adjustment procedure

Tracing gain is a parameter that determines the tracking capability of tracing. The tracking speed (Vz) of tracing is determined from the formula below.

$$Vz = 60 \times K \times (\Delta E - E0)$$

where,

- Vz: Tracking speed (mm/min)
- K: Tracking speed voltage conversion coefficient
- ΔE: Amount of shift (mm)
- E0: Standard shift (mm)

The higher the tracing gain, the better the tracking capability. However, too great a gain results in unstable operation, causing oscillation within the system. So, a gain that ensures stable operation must be determined and set.

Gain setting procedure
<1> Set the standard tracing gain.
<2> Move the nozzle away from the workpiece by at least 100 mm.
<3> Start tracing. The nozzle approaches the workpiece, and stops where the amount of shift is 0.
<4> The nozzle will stop smoothly provided the operation is stable. The nozzle will vibrate upon stopping if the operation is unstable.
<5> If the operation is stable, gradually increase the setting to find a value where oscillation starts when the nozzle stops.
<6> Set the value obtained in the above step, multiplied by 0.8, and again check that the operation is stable.

Set a tracing gain value in parameter No. 15540 for the Z-axis, in parameter No. 15541 for the W-axis.

Parameter

	#7	#6	#5	#4	#3	#2	#1	#0
15003								TIV

[Data type] Bit
TIV When a tracing shift is read, the polarity is
0: Not modified.
1: Inverted.

15006							TRM	

[Data type] Bit
TRM On the trace setting screen, the soft keys are:
0: Enabled.
1: Disabled.

15500	Sensing gain coefficient (Ke)

[Data type] Word
[Unit of data]
[Valid data range] 0 to 65535
[Setting] The trace setting screen is used for setting.

15502	Sense zero point (Ezr)

[Data type] Word
[Unit of data] mm
[Valid data range] -32768 to 32767
[Setting] The trace setting screen is used for setting.

15503	Filter time constant

[Data type] Word
[Unit of data] msec
[Valid data range] 0 to 32767 (except 1)
[Standard setting value] 0

If tracing becomes unstable as a result of a disturbance such as mechanical vibration superimposed on the sense signal, set this parameter to reduce the disturbance.
As a guideline, set a value of no more than 16. If a greater value is set, the tracing speed response will be lost, thus resulting in problems such as the nozzle hitting the workpiece upon its approach.

15504	Shift multiplier (EMUL)

[Data type] Word
[Unit of data]
[Valid data range] 1 to 5
[Standard setting value] 1

A multiplier can be applied to the tracing sense signal.

Set value	Max. shift	Resolution
1	±2 mm	0.001 mm
2	±4 mm	0.002 mm
3	±6 mm	0.003 mm
4	±8 mm	0.004 mm
5	±10mm	0.005 mm

15505								
			TRA					

[Data type] Bit
TRA On the trace setting screen, the current position is displayed:
0: In the relative coordinate system.
1: In the absolute coordinate system.

15540	Voltage conversion coefficient of the Z-axis tracing feedrate control

[Data type] Word
[Unit of data]
[Valid data range] 0 to 32767
[Setting] Calculate a conversion coefficient using the following formula, and set the value thus found.

$$\text{Conversion coefficient} = G \times \frac{P \times 4}{1000 \times Le} \times 2 \times 10^{-3} \times 4096$$

where,
G: Tracing gain (sec^{-1}). Standard value = 30 sec^{-1}
Le: Machine travel per motor revolution (mm/rev)
P: Number of detected pulse coder pulses per motor revolution (p/rev).
Set 2048 when using a serial A or α motor.

The parameters listed below are supported. Usually, set the standard values.

15510	Integral time constant : standard setting value=300
15511	Integral compensation zero width : standard setting value=30000 (Not required)
15512	Integral clamp value : standard setting value=0 (Not required)
15520	Phase compensation time constant : standard setting value=0 (Not required)
15521	Phase compensation gain : standard setting value=0 (Not required)

6.1.3 Standard Shift

Standard Shift

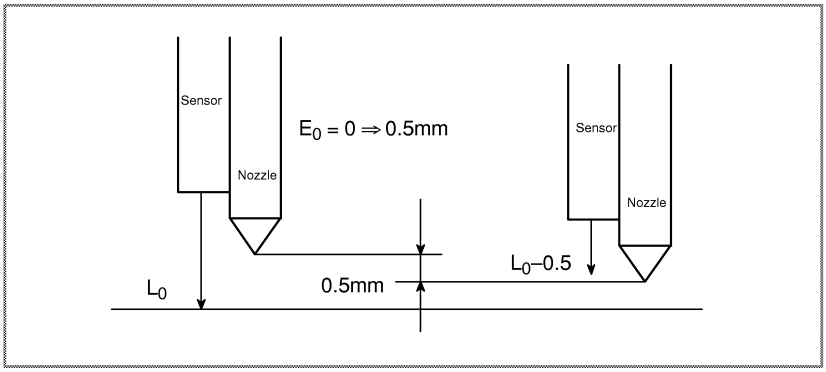
A standard shift is used to change the gap between the nozzle and workpiece. The following formula is used to calculate the feedrate along a tracing axis.

$$Vz=K\times(\Delta E-E0) \quad (1)$$

where,

- Vz: Feed rate of tracing axis (mm/sec)
- K: Tracking speed voltage conversion coefficient
- ΔE: Amount of shift (mm)
- E_0: Standard shift (mm)

As is obvious from formula (1) above, the amount of shift (DE) that produces Vz = 0 depends on the standard shift (E_0). When the value of E_0 is changed from 0 to 0.5 mm, for example, the positional relationship between the nozzle and workpiece changes as shown below.



Standard shift setting range

Controlled by the amount of shift, the standard shift setting range is restricted to within the range of the sense signal. So, use a standard shift to enable fine adjustment. The lower and upper limits imposed on the standard shift values can be specified using parameter Nos. 15531 and 15532.

How to specify the standard shift

The standard shift can be specify as follows:

<1> In program
G13P_ ; Specify the value in address P.

<2> By means of setting data
Changes can be made in the trace setting screen.

<3> By means of the machining condition setting function
Set a desired standard shift value as part of the machining condition setting data, then start tracing. The standard shift data is read.

<4> By means of a macro executor
Use system variable #6020.

Parameter

	#7	#6	#5	#4	#3	#2	#1	#0
15006						PIN		

[Data type] Bit

PIN A standard shift to be specified with address P of G13 must be entered in:
0: Metric input.
1: Inch input.

15530 **Standard shift**

[Data type] Word
[Unit of data] 0.001mm
[Valid data range] -32768 to 32767
[Standard setting value] 0

The most-recently specified standard shift is written. The standard shift is rewritten by specifying G13, trace screen setting, or executing the machining condition setting function.

15531 **Setting the lower limit of standard shift**

[Data type] Word
[Unit of data] 0.001mm
[Valid data range] -32768 to 32767
[Standard setting value] 0

Set a lower limit for the specifiable standard shift values for tracing control. An alarm is issued if a standard shift value of less than this lower limit is specified.

15531 **Setting the upper limit of standard shift**

[Data type] Word
[Unit of data] 0.001mm
[Valid data range] -32768 to 32767
[Standard setting value] 1000

Set an upper limit for the specifiable standard shift values for tracing control. An alarm is issued if a standard shift value of more than this upper limit is specified.

Alarm and message

No.	Message	Contents
4052	G13 DATA ERROR	An out-of-range value was specified in a tracing command.

6.1.4 Approach

Approach

If tracing is started when the nozzle is raised from the workpiece, the nozzle will start moving towards the workpiece. This operation is referred to as approach.

Approach speed

The speed of the approach motion is calculated using the folmula below.

$Vz=60\times K\times(\Delta E-E_0)$ ———— (1)

where,

Vz: Approach speed (mm/min)
K: Tracking speed voltage conversion coefficient
ΔE: Amount of shift (mm)
Eo: Standard shift (mm)

The upper limit of the speed is controlled by parameter No. 15553.

Approach completion

When tracing is started by G13, the approach state is set, and the nozzle continues its approach until the amount of shift satisfies the formula shown below.
Upon reaching this point, approach completion is assumed, and operation proceeds to the next block.

$-A_{PRCH}\leq\Delta E-E_0\leq A_{PRCH}$

where,

ΔE: Amount of shift (mm)
E_0: Standard shift (mm)
A_{PRCH}: Approach-completion-sensing band width (parameter No. 15550) mm

When the machine does not move to the approach sensing position because of an excessive load torque in the drive system, set an approach-completion-sensing bandwidth in parameter No. 15550. If approach completion is not detected with the standard setting value, check the load torque in the drive system for abnormalities. When there are no abnormalities, increase the setting.

When tracing is started, approach completion may be detected even while the nozzle is lifted away from the workpiece. In such a case, change the approach completion interval, set with parameter No. 15551. This problem occurs because a transient sense signal variation caused by a disturbance (such as mechanical vibration) when tracing is started does not lie within the specified interval.

Parameter

15550 **Approach-completion-sensing band width (A_{PRCH})**

[Data type] Word
[Unit of data] 0.001mm
[Valid data range] 0 to 32767
[Standard setting value] 50

Set the amount of shift used to assume approach completion. Approach completion is assumed when the state where the amount of shift is within a specified approach-completion-sensing bandwidth has existed for the approach completion interval, set in parameter No. 15551, or longer.

15551 **Approach completion interval time**

[Data type] Word
[Unit of data] msec
[Valid data range] 0 to 32767
[Standard setting value] 500

Upon detecting the state where the tracing shift is within the approach-completion-sensing bandwidth, the timer is started. The amount of shift is checked when the timer times out. If this check finds that the amount of shift is within the approach-completion-sensing bandwidth, approach completion is assumed.

15553 **Approach side feedrate upper limit**

[Data type] Word
[Unit of data] mm/min
[Valid data range] 0 to 32767
[Standard setting value] 1200

Set an upper limit for the approach speed. A calculated approach speed is clamped to this upper limit.

15554 **Constant for approach side feedrate clamping**

[Data type] Word
[Unit of data] mm/min
[Valid data range] 0 to 32767

Calculate the constant used for approach side feedrate clamping using the formula below, then set the found value.

$$\text{Constant for approach side feedrate clamping} = \frac{4 \times P}{Le}$$

where,

P: Number of detected pulse coder pulses per motor revolution (p/rev) (Set 2048 when using a serial A or motor.)
Le: Machine travel per motor revolution (mm/rev)

6.1.5 Tracing Alarm

Overview

Two check functions are provided for tracing.

Over-shift alarm

If, during approach, the nozzle comes too close to the workpiece, the nozzle is stopped by means of the over-shift alarm, and the alarm signal (TRALM) is sent to the PMC.
The level at which the over-shift alarm is issued can be set in parameter No. 15533. Set a value within the range of the sensor, and consider the overrun that occurs when the nozzle is stopped in the event of an alarm.
Reset this alarm, if issued, by moving the nozzle away from the workpiece in the +Z (+W) direction by jog feed or handle feed, then pressing the reset button.

Tracing range-over alarm

If the absolute value of a shift exceeds a specified value, the status is reported to the PMC.

<1> When the trace check mode signal TRCKM=0
When $|\Delta E| \geq E_{OVRS}$ is sensed, the system stops with an alarm and the signal TRALM becomes 1.
The value for E_{OVRS} is set in parameter No. 15534.
<2> When trace check mode signal TRCKM=1
When $|\Delta E| \geq E_{OVRS}$ is sensed, the system continues operation without issuing an alarm, and signal TRERS become and is maintained at 1 until the amount of shift becomes smaller than E_{OVRS}.

Signal

- Alarm signal TRALM<F220#7>

[Classification] Output signal
[Function] This signal reports the detection of a tracing over-shift alarm or tracing range-over alarm to the PMC.
[Output condition] This signal is set to 1 in the following cases:
- When a tracing over-shift alarm is detected
- When a tracing over-range alarm is detected while trace check mode is off

This signal is set to 0 in the following case:
- When an alarm is reset by pressing the reset button

- Trace check mode signal
TRCKM<G225#2>

[Classification] Input signal
[Function] This signal detects whether the tracing shift exceeds a specified tracing range-over alarm value.
[Operation] (1) When the trace check mode signal (TRCKM) is set to 0
When the tracing shift exceeds a tracing range-over alarm value (set in parameter No. 15537), tracing is stopped, and the alarm signal (TRALM) is set to 1.
(2) When the trace check mode signal (TRCKM) is set to 1
While the tracing shift exceeds the tracing range-over alarm value (set in parameter No. 15537), the tracing disabled state signal (TRERS) is set to 1.

- Tracing disabled state signal
TRERS<F220#0>

[Classification] Output signal
[Function] This signal informs the PMC that the tracing shift exceeds the specified tracing range-over alarm value.
[Output condition] This signal is set to 1 in the following case:
- When the trace check mode signal is set to 1, and the tracing shift exceeds the tracing range-over alarm value (set in parameter No. 15537)

This signal is set to 0 in the following cases:
- When the trace check mode signal is set to 0
- When the trace check mode signal is set to 1, and the tracing shift is within the tracing range-over alarm value (set in parameter No. 15537)

Signal address

	#7	#6	#5	#4	#3	#2	#1	#0
G225						TRCKM		
F220	TRALM							TRERS

Parameter

15533	Tracing over-shift alarm

[Data type] Word
[Unit of data] 0.001mm
[Valid data range] 0 to 32767
[Standard setting value] 1200
If the tracing shift exceeds the tracing over-shift alarm value, set in this parameter, an alarm is issued and operation is stopped, with the occurrence of an abnormal approach assumed.

15537 **Tracing range-over alarm (E_{OVRS})**

[Data type] Word
[Unit of data] 0.001mm
[Valid data range] 0 to 32767
[Standard setting value] 1000

When the absolute value of a tracing shift exceeds the value set in this parameter, an alarm, or a signal indicating that the value set in this parameter has been exceeded, is output.

15538 **Tracing range-over alarm mask**

[Data type] Word
[Unit of data] msec
[Valid data range] 0 to 32767
[Standard setting value] 1000

When the standard shift is rewritten during tracing, the tracing range-over alarm is detected in the transient state. In this case, tracing range-over alarm detection is masked for the period set in this parameter.

15539 **Tracing range-over alarm offset (E_{OVRD})**

[Data type] Word
[Unit of data] 0.001mm
[Valid data range] 0 to 32767
[Standard setting value] 0

An offset for the value set in parameter No. 15537 can be added to an approach
side sense value. As a result, the sensing range is:
$-E_{OVRS} \geq \Delta E$, $\Delta E \geq E_{OVRS} + E_{OVRD}$

6.1.6 Tracing Gain Override

Overview

Tracing gain can be overridden in steps of 12.5%.

Signal

- Tracing gain override GAPG0 to GAPG2<G225#4 to #6>

[Classification] Input signal
[Function] Tracing gain can be overridden using these signals.
[Operation] Tracing gain can be overridden in steps of 12.5%.

Override %	GAPG2	GAPG1	GAPG0
100	0	0	0
87.5	0	0	1
75	0	1	0
62.5	0	1	1
50	1	0	0
37.5	1	0	1
25	1	1	0
12.5	1	1	1

Signal address

	#7	#6	#5	#4	#3	#2	#1	#0
G225		GAPG2	GAPG1	GAPG0				

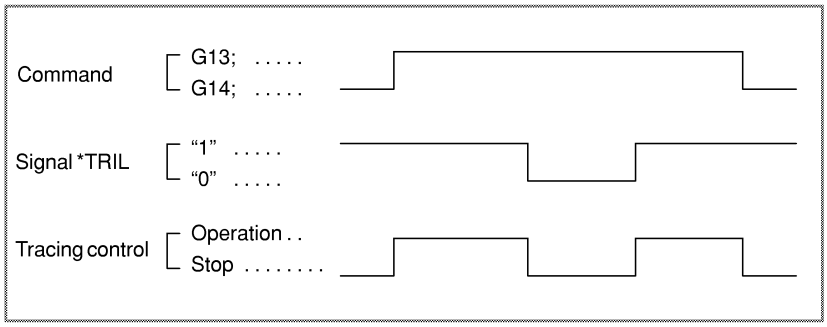
6.2 TRACING INTERLOCK FUNCTION

Overview

Once this external signal has been turned on during tracing control, interlock is applied to tracing control while the signal is on, thus stopping tracing control. While tracing control is enabled, the nozzle may be moved through space where no workpiece exists during machining. This signal can be used to, for example, continue machining without lowering the nozzle by externally stopping tracing control along the Z-axis.

Operation during tracing control

During tracing control, setting tracing interlock signal (*TRIL) to 0 stops tracing control. While the *TRIL signal is set to 0, machining along the X-axis and Y-axis continues without tracing control. Subsequently setting the *TRIL signal to 1 causes tracing control along the Z-axis to be restarted. When the *TRIL signal is set to 0, position control is applied to the Z-axis but automatic operation commands can not be specified for the Z-axis. Manual operation is, however, possible by halting automatic operation.



Operation prior to execution of tracing command (G13)

If the *TRIL signal has already been set to 0 before the G13 command is executed, the program proceeds by ignoring G13. Subsequently setting the *TRIL signal to 1 causes tracing control to be started and program execution to be resumed.

Operation during execution of tracing command (G13)

If the *TRIL signal is set to 0 during approach with tracing control applied according to the G13 command, tracing control is stopped, then program execution advances to next block. Subsequently setting the *TRIL signal to 1 causes approach to be restarted and program execution to be resumed.

Operation after execution of tracing stop command (G14)

The *TRIL signal has no effect once tracing control has stopped after execution of the G14 command. In this state, tracing control mode is canceled regardless of the state of the *TRIL signal.

Reset processing

When interlock is applied to tracing control with the *TRIL signal set to 0, a reset operation cancels tracing control mode as well as interlock.

Signal

- Tracing interlock signal *TRIL<G227#6>

[Classification] Input signal

[Function] By means of the external signal, Z-axis tracing can be stopped and clamped.

[Operation] When the tracing interlock signal *TRIL is set to 0 during tracing control, tracing is interlocked and stopped while the signal is set to 0.
When tracing control is enabled, and the nozzle is to move through a region where no workpiece is located, for example, this function can be used to enable machining to continue by temporarily stopping Z-axis tracing externally without lowering the nozzle.

Signal address

	#7	#6	#5	#4	#3	#2	#1	#0
G227		*TRIL						

Parameter

	#7	#6	#5	#4	#3	#2	#1	#0
15005		ITR						

[Data type] Bit

ITR The tracing interlock function is:
0: Disabled.
1: Enabled.

6.3 TRACING AXIS MACHINE LOCK

Overview

In tracing mode, the tracing axis can be stopped by changing its speed to 0. This does not cause the system to leave tracing mode. The axis can therefore be stopped before tracing mode is canceled.

Signal

- Tracing axis machine lock signal TRMLK<G227#7>

[Classification] Input signal

[Function] Changes the tracing axis speed to 0, so that the system enters the machine lock state.

Signal address

	#7	#6	#5	#4	#3	#2	#1	#0
G227	TRMLK							

NOTE

1 Turning the tracing axis machine lock signal on or off in tracing mode
In tracing mode, as soon as the tracing axis machine lock signal is set to 1, a tracing axis machine lock is applied. As a result, the tracing speed is changed to 0, causing the axis to stop. Note that acceleration/deceleration is not performed. Thus, do not set the tracing axis machine lock signal to 1 when tracing occurs at high speed (immediately after an approach is started, for example).
Also in the tracing axis machine lock state, care should be taken when setting the tracing axis machine lock signal to 0; for example, do not set the signal to 0 when the tracing axis is away from a workpiece.

2 When G13 is specified in the tracing axis machine lock state, the approach is not completed with the block containing G13, and the next block is executed. Then, the tracing mode signal is set to 1.

7 THREE-DIMENSIONAL MACHINING SYSTEM

7.1 ATTITUDE CONTROL

Overview

Specifying five or more control axes as well as attitude control allows attitude control of a nozzle with the fourth and fifth axes as rotation axes, enabling a three-dimensional machine to be configured.
Two types of attitude control are provided according to the shape of the nozzle head.
<1> Attitude control A (zero-offset head)
<2> Attitude control B (offset head)

> ⚠ **CAUTION**
> The following restrictions are imposed if the attitude control function is attached. The meanings of the terms used in the explanation are as follows:
> 1) The term three-dimensional machine refers to machines performing attitude control.
> 2) The term three-dimensional machining refers to machining by specifying linear axes plus rotation axes.
> 3) The term two-dimensional machining refers to machining by specifying linear axes.

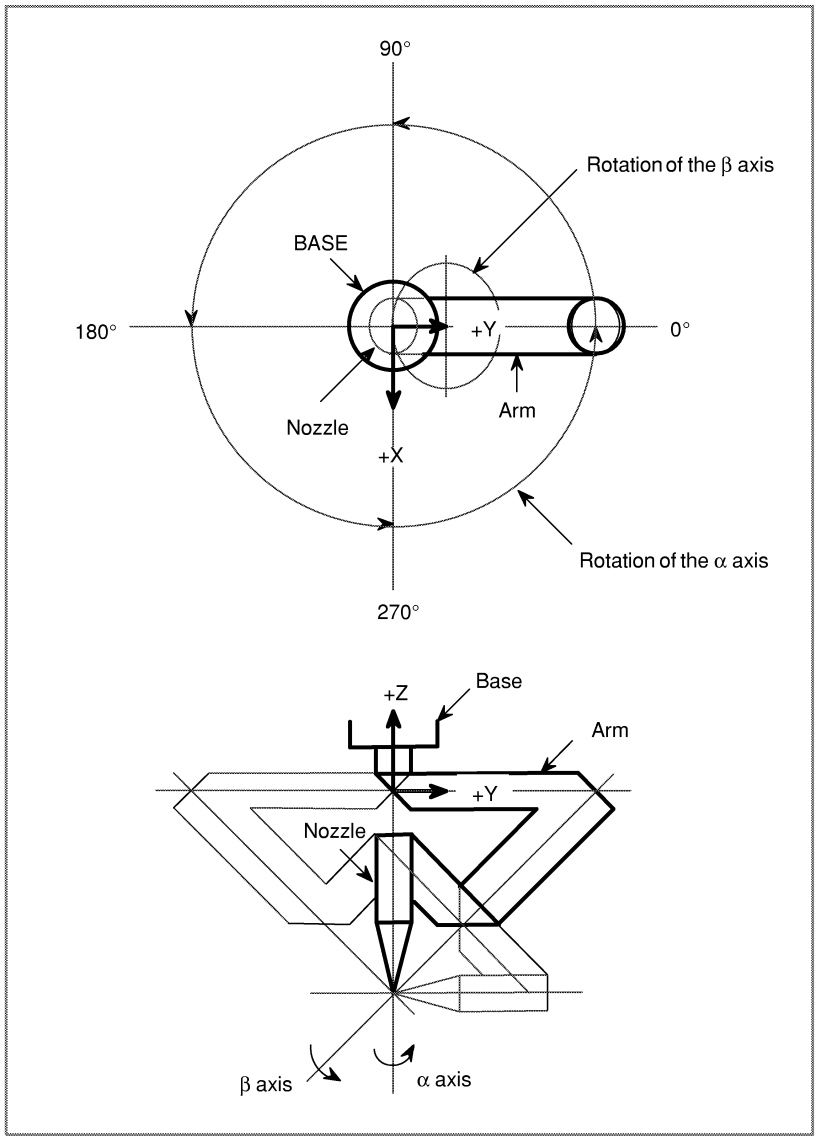
1 The following functions cannot be used in three-dimensional machining. Use them in two-dimensional machining programs.
- Advanced preview control
- AI contour control
- Laser power control
- Step control
- Edge machine function
- Start-up machining function
- Retry processing function7

2 The following functions cannot be used with three-dimensional machines:
- High-precision contour control and its related functions
- High-speed laser machining

7.1.1 Attitude Control A (Zero-offset Head)

Overview

The nozzle-head position fixing (zero-offset) mechanism consists of the α (4th) axis, that rotates around the Z-axis, and the β (5th) rotation axis, that is associated with the α axis. By means of this structure, the nozzle head is positioned to the point where the center lines of α-axis rotation and β-axis rotation intersect.



Reference positions

The reference positions of the α and β axes are indicated by their zero-degree positions and rotation directions shown in the above figure.

Reference position of the α axis

When the α axis is viewed from the +Z direction, the position where the arm faces in the +Y direction is 0°. When +90° rotation from that position is commanded, the α axis rotates counterclockwise and matches the -X direction.

Reference position of the β axis

When the α axis is set to 0° and the β axis is viewed from the +X direction, the position where the nozzle faces in the -Z direction is 0°. When +90° rotation from that position is commanded, the β axis rotates counterclockwise.

Setting differences if the α and β axes are not in their reference positions

If the axes are not in their reference positions, specify the differences in the appropriate parameters.
By specifying them in the parameters, the CNC performs attitude control by considering the differences from the reference positions.
The rotation directions can be selected with parameter No. 15601.
The machine zero-degree positions can be offset with parameters Nos. 15601 and 15611.

Axis names

Specify the names of the α (4th) and β (5th) axes using parameter No. 1020.

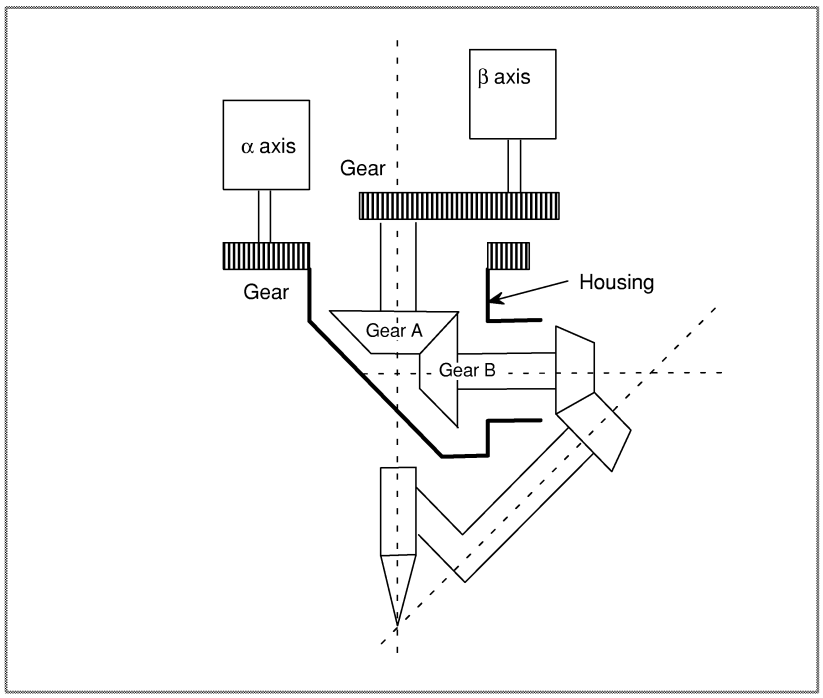
Setting the maximum speed for the α and β axes

When a command causes the nozzle to perform a large rotational movement about the α or β axis, while movement along the X-, Y- and Z-axes is small, the rotation speed may exceed the limit. In such a case, when the maximum speed for the α and β axes is set in parameters No. 15612 and 15613, the nozzle is moved along the X-, Y-, and Z- axes at a lower speed that is calculated according to the set maximum speed (automatic deceleration).

Interaction control

The following figure shows the configuration of axes for the nozzle head.
As shown in the figure, interaction control is as follows. The motor for the β axis is located around the Z axis, and gears transmit rotational power to the nozzle under the attitude control of the nozzle. In this case, when a command specifying the α axis is issued, the housing rotates, and the nozzle rotates on the Z axis. At the same time, gear B must rotate on gear A. This movement means that the nozzle is rotated by the β axis.

Namely, the α axis is rotated by the command specifying the α axis at the same time the β axis is rotated.
The interaction control function automatically issues the same command as the command specifying the α axis for the β axis to cancel the rotation of the β axis in the nozzle head whose axes are configured so that the β axis is rotated by the command specifying the α axis. Polarity is selected by the parameter No. 15602:



W-axis tracing control

The W axis can be added to the 6th axis as a tracing axis.

Parameter

1020	Axis names used in the program

[Data type] Byte axis

Select the names of the 4th and 5th axes from A, B, C, U, and V, and set the relevant values. When W-axis tracing is selected, select W as the name of the 6th axis.

Axis name	Setting value	Axis name	Setting value
A	65	U	85
B	66	V	86
C	67	W	87

	#7	#6	#5	#4	#3	#2	#1	#0
15601							PA5	PA4

[Data type] Bit

PA4 The α axis rotates:
- 0: In the same direction as that defined for the reference position.
- 1: In the opposite direction to that defined for the reference position.

PA5 The β axis rotates:
- 0: In the same direction as that defined for the reference position.
- 1: In the opposite direction to that defined for the reference position.

	#7	#6	#5	#4	#3	#2	#1	#0
15602								TGC

[Data type] Bit

TGC For interaction control, the rotation of the α axis is specified in a command:
- 0: Using a sign different from that used for the β axis rotation command.
- 1: Using the same sign as that used for the β axis rotation command.

15610	Mechanical zero-degree position offset of the α axis
15611	Mechanical zero-degree position offset of the β axis

[Data type] 2-word
[Unit of data] 0.001deg
[Valid data range] 0, 90000, 180000, 270000
[Standard setting value] 0

Set the mechanical zero-degree position offset for the α and β axes.

15612	Maximum speed for machining feed about the α axis
15613	Maximum speed for machining feed about the β axis

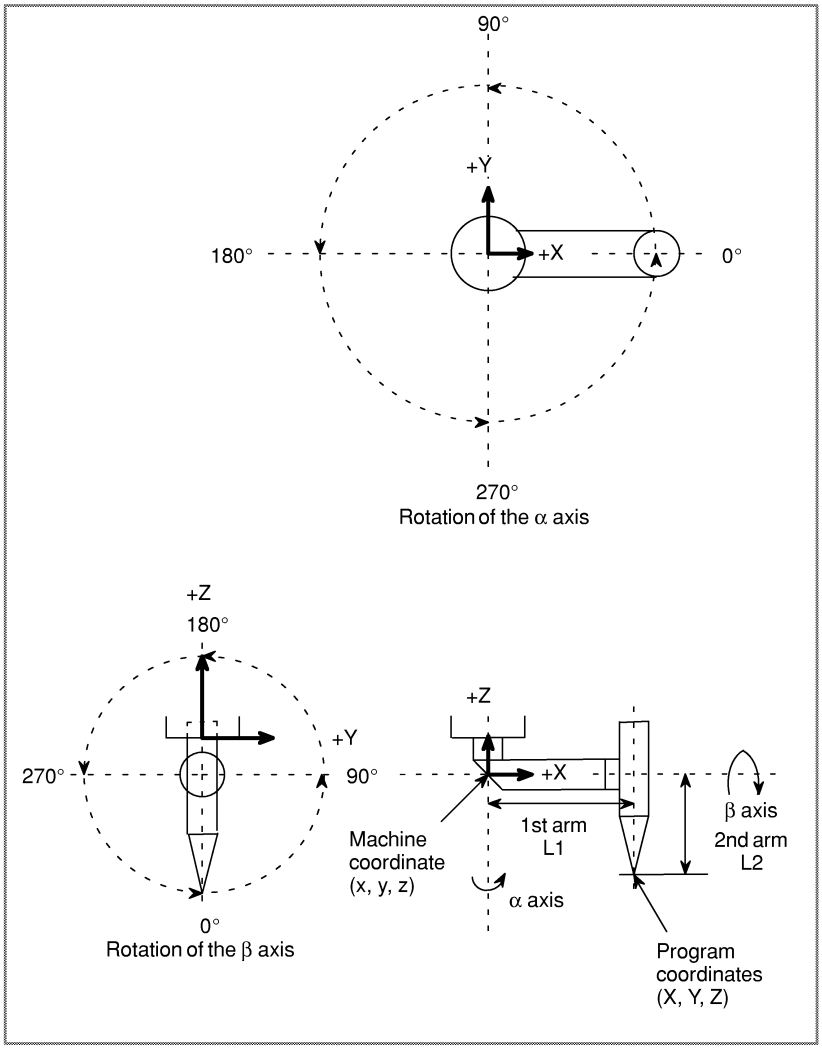
[Data type] 2-word
[Unit of data] deg/min
[Valid data range] 6 to 15000

Set the maximum speed for machining feed about the α and β axes. When attitude control is performed in synchronization with the move command along the X-, Y-, and Z-axes, the nozzle is moved along the X-, Y-, and Z- axes at a lower speed corresponding to that when the rotation speed about the α or β axis is clamped to the maximum speed. When interaction control is specified, the same value must be set for the α and β axes.

7.1.2 Attitude Control B (Offset Nozzle)

Overview

The offset mechanism consists of the α (4th) axis that rotates on the Z axis and the β (5th) rotation axis associated with the α axis. In this structure, the nozzle head is positioned at the point of intersection of the center lines of α-axis rotation and β-axis rotation, and the center lines of α-axis rotation and the nozzle do not intersect.



Reference positions

The reference attitudes of the α and β axes are indicated by their zero-degree positions and rotation directions shown in the above figure.

Reference position of the α axis

When the α axis is viewed from the +Z direction, the position where the arm faces in the +Y direction is 0°. When +90° rotation from that position is commanded, the α axis rotates counterclockwise and matches the -X direction.

Reference attitude of the β axis

When the α axis is set to 0° and the β axis is viewed from the +X direction, the position where the nozzle faces in the -Z direction is 0°. When +90° rotation from that position is commanded, the β axis rotates counterclockwise.

Setting differences if the α and β axes are not in their reference positions

If the axes are not in their reference positions, specify the differences in the appropriate parameters.
By specifying them in the parameters, the CNC performs attitude control by considering the differences from the reference positions.
The rotation directions can be selected with parameter No. 15601.
The machine zero-degree positions can be offset with parameters Nos. 15601 and 15611.

Coordinate system

The machine coordinates refer to the coordinates (x, y, z) of the fixed section of the nozzle.
The program coordinates refer to the coordinates (X, Y, Z) of the nozzle head.
The length of the 1st arm, L1, and the length of the 2nd arm, required to convert the machine coordinates to program coordinates. Specify them using the parameters No. 15615 and 15616.

Axis names

Specify the names of the α (4th) and β (5th) axes using parameter No. 1020.

Attitude control mode

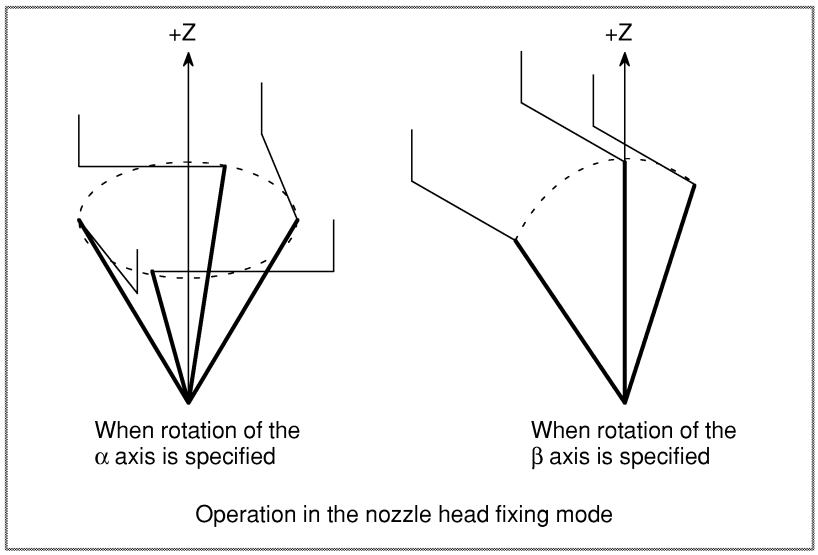
In manual operation, mode select signal ALNAXS can be used to switch between the nozzle head fixing mode and the independent axis mode. When the ALNAXS signal is set to 0, the machine tool enters the nozzle head fixing mode. When the ALNAXS signal is set to 1, the machine tool enters the independent axis mode.
In automatic operation, the machine tool automatically enters the nozzle head fixing mode regardless of the mode select signal.
In manual reference position return, the machine tool automatically enters the independent axis mode regardless of the mode select signal. After reference position return is completed, the attitude control function is enabled.
In automatic reference position return, the machine tool automatically operates in the independent axis mode.

Independent axis mode

When the command specifying the α or β axis is issued, only the specified axis rotates. When the α or β axis is rotated by this command, the position of the nozzle head is changed. The coordinates in the incremental coordinate system and workpiece coordinate system are then changed according to changed coordinates (X, Y, Z) to make the position of the nozzle head match the coordinate systems.

Nozzle head fixing mode

When the command specifying the α or β axis is issued, the specified axis is rotated at the same time linear axes X, Y, and Z are moved. This allows the specified axis to rotate around the nozzle head position.
When the α or β axis is rotated by the command, the position of the nozzle head is changed. The X, Y, and X axes are then moved according to changed coordinates (X, Y, Z) to return the nozzle head to the original position.
This operation does not affect the incremental coordinate system and workpiece coordinate system of the X, Y, and Z axes, but affects their machine coordinate system.



Operation in the nozzle head fixing mode

Setting the maximum speed for the α and β axes

When a command causes the nozzle to perform a large rotational movement about the α or β axis, while movement along the X-, Y- and Z-axes is small, the rotation speed may exceed the limit. In such a case, when the maximum speed for the α and β axes is set in parameters Nos. 15612 and 15613, the nozzle is moved along the X-, Y-, and Z- axes at a lower speed that is calculated according to the set maximum speed (automatic deceleration).

Feedrate clamp function

If the fourth and fifth axes are specified together with the X, Y, and Z axes, the speeds on the X, Y, and Z axes that have been compensated for by attitude control B may be very high. This function is intended to clamp the specified feedrate so that the speeds on the X, Y, and Z axes that have been compensated for do not exceed the rapid traverse rate (parameter No. 1420). This function is effective to the G01, G02, G03, and G12 commands, as well as the interpolation-type G00 command.
The clamp speed in the "G91 G01 Xx Yy Zz Aa Bb Ff" block is determined as described below.

In the following description, the axis names A and B represent the fourth and fifth axes, respectively.
The maximum feedrate on the X axis that has been compensated for by attitude control B can be estimated with the following formula:

$Fxmax = [f \times x/L] + [f \times a/L \times (\pi \times R/180)] + [f \times b/L \times (\pi \times P/180)]$

$L = \sqrt{(x^2+y^2+z^2)}$: Travel distance of the nozzle head

$R = \sqrt{[(\text{Length of the first arm})^2 + (\text{Length of the second arm})^2]}$

P : Length of the second arm

$F \times x/L$: Speed on the X axis that is generated with the Xx command

$F \times a/L \times (\pi \times R/180)$: Maximum speed on the X axis that is generated by Aa command compensation

$F \times b/L \times (\pi \times P/180)$: Maximum speed on the X axis that is generated by Bb command compensation

The value of "f" that does not cause Fxmax to exceed the rapid traverse rate on the X axis (parameter No. 1420) is calculated.

$fx = Rpdx / \{ [x/L] + [a/L \times (\pi \times R/180)] + [b/L \times (\pi \times P/180)] \}$

fx : "f" determined from the X axis

Rpdx : Rapid traverse rate on the X axis (parameter No. 1420)

Similarly, the clamp speed is determined from the maximum feedrate on the Y axis.

$Fymax = [f \times y/L] + [f \times a/L \times (\pi \times R/180)] + [f \times b/L \times (\pi \times P/180)]$

$fy = Rpdy / \{ [y/L] + [a/L \times (\pi \times R/180)] + [b/L \times (\pi \times P/180)] \}$

fy : "f" determined from the Y axis

Rpdy : Rapid traverse rate on the Y axis (parameter No. 1420)

For the Z axis, no compensation with the Aa command will be performed. Thus,

$Fzmax = [f \times z/L] + [f \times b/L \times (\pi \times P/180)]$

$fz = Rpdz / \{ [z/L] + [b/L \times (\pi \times P/180)] \}$

fz : "f" determined from the Z axis

Rpdz : Rapid traverse rate on the Z axis (parameter No. 1420)

The smallest value of the determined "fx," "fy," and "fz" will be assumed the cutting feedrate clamp value.

Remark)

In reality, $[f \times a/L \times (\pi \times R/180)]$ and $[f \times b/L \times (\pi \times P/180)]$ are not generated at the same time. For this reason, the speed on each axis after clamping will be slightly lower than the rapid traverse rate.

In "G91 G02 Xx Yy Zz Aa Bb Ff," the maximum speeds on the X, Y, and Z axes are estimated as described below.

$Fxmax = f + [f \times a/L \times (\pi \times R/180)] + [f \times b/L \times (\pi \times P/180)]$

$Fymax = f + [f \times a/L \times (\pi \times R/180)] + [f \times b/L \times (\pi \times P/180)]$

$Fzmax = [f \times y/L] + [f \times b/L * (\pi * P/180)]$

Thus, the speed clamp value is determined with the following formulas:

$fx = Rpdx / \{ 1 + [a/L \times (\pi \times R/180)] + [b/L \times (\pi \times P/180)] \}$

$fy = Rpdy / \{ 1 + [a/L \times (\pi \times R/180)] + [b/L \times (\pi \times P/180)] \}$

$fz = Rpdz / \{ [z/L] + [b/L \times (\pi \times P/180)] \}$

Sample

Assume the following:
Length of the first arm: 130mm
Length of the second arm: 145mm
Rapid traverse rates on the respective axes: 24000 for X, 24000 for Y, 20000 for Z, 4000 for A, and 8000 for B
Upper speed limits during machining feed along the A and B axes: 4000 for A and 8000 for B
The clamp speed in the next command block is calculated.
G91 G01 X10. Y20. Z30. A45. B90. F5000;

The travel distance of the nozzle head is $L=\sqrt{(10^2+20^2+30^2)}=37.416$
Assuming the nozzle head speed after clamping to be f,

The speed for the X axis command is $F_{XL} = f \times 10 / L = 0.267 \times f$
The speed for the Y axis command is $F_{YL} = f \times 20 / L = 0.535 \times f$
The speed for the Z axis command is $F_{ZL} = f \times 30 / L = 0.802 \times f$
The speed on the A axis is $F_{AL} = f \times 45 / L = 1.203 \times f$
The speed on the B axis is $F_{BL} = f \times 90 / L = 2.405 \times f$

Assuming that operation is performed on the A axis when the position on the B axis is at 90°,

The maximum speed on the X axis by A axis attitude control is
$F_{XA} = F_{AL} \times \pi \times \sqrt{(130^2+145^2) / 180} = 4.089 \times f$
The maximum speed on the Y axis by A axis attitude control is
$F_{YA} = F_{AL} \times \pi \times \sqrt{(130^2+145^2) / 180} = 4.089 \times f$
The maximum speed on the Z axis by A axis attitude control is
$F_{ZA} = 0$

Assuming that operation is performed on the B axis when the position on the A axis is at 0°,

The maximum speed on the X axis by B axis attitude control is
$F_{XB} = F_{BL} \times \pi \times 145 / 180 = 6.086 \times f$

Assuming that operation is performed on the B axis when the position on the A axis is at 90°,

The maximum speed on the Y axis by B axis attitude control is
$F_{YB} = F_{BL} \times \pi \times 145 / 180 = 6.086 \times f$
The maximum speed on the Z axis by B axis attitude control is
$F_{XB} = F_{BL} \times \pi \times 145 / 180 = 6.086 \times f$

Totaling the speeds for the X, Y, and Z axis commands and the speeds on the X, Y, and Z axes by A and B axis attitude control,

The estimated maximum speed on the X axis is
$F_{XMAX} = F_{XL} + F_{XA} + F_{XB} = 10.442 \times f$
The estimated maximum speed on the Y axis is
$F_{YMAX} = F_{YL} + F_{YA} + F_{YB} = 10.71 \times f$
The estimated maximum speed on the Z axis is
$F_{ZMAX} = F_{ZL} + 0 + F_{ZB} = 6.888 \times f$

Let us find the value of f that does not cause F_{XMAX}, F_{YMAX}, and F_{ZMAX} to exceed the rapid traverse rates on the X, Y, and Z axes,

$F_{XMAX} = 10.442 \times f \leq 24000$, thus f = 2298
$F_{YMAX} = 10.71 \times f \leq 24000$, thus f = 2241
$F_{ZMAX} = 6.888 \times f \leq 20000$, thus f = 2904

The nozzle head speed that does not cause the rapid traverse rates on the X, Y, and Z axes to be exceeded is 2241 mm/min.

Automatic feedrate override function

If the speed specified for the motor for each axis exceeds the speed specified in the corresponding parameter, this function immediately and automatically overrides that speed so that it does not exceed the setting of the parameter. This means that the speeds on the X, Y, and Z axes that have been compensated for by the attitude control B function can be clamped at the execution level.

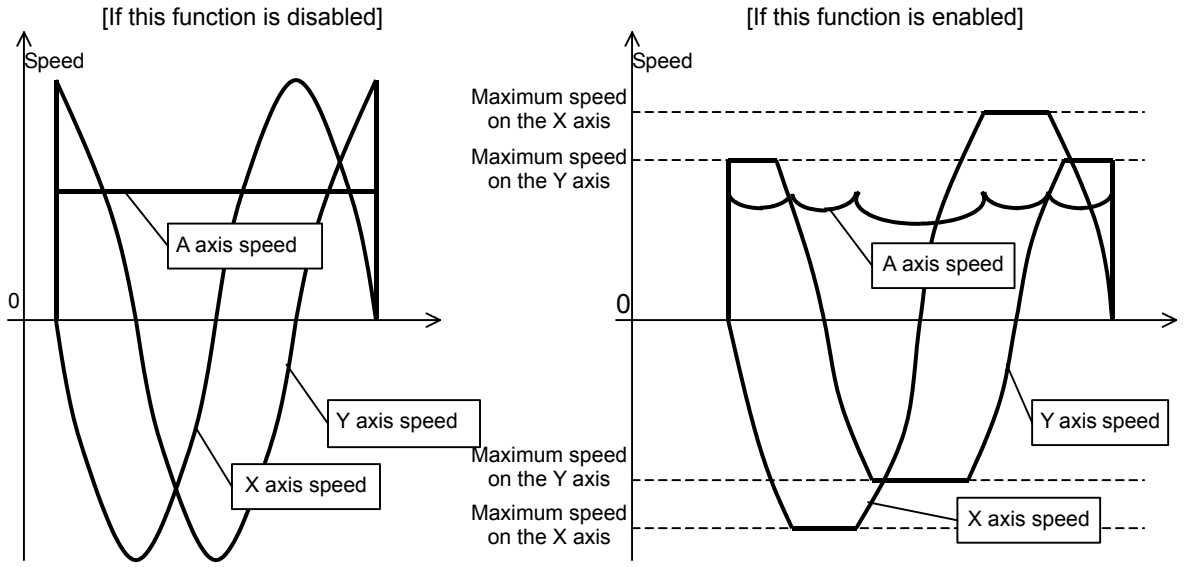
If, during axial movement, the speed on any axis exceeds the speed specified in parameter No. 15621, this function immediately and automatically overrides that speed so that it does not exceed the setting of the parameter. The override is applied to all axes and, therefore, there will occur no deviations from the path under interpolation. In addition, the override automatically increases so that the speed will not decrease more than necessary. The override can never exceed 100%, so that a speed exceeding the specified value will never be generated.

This automatic override function overrides a speed in the cycle following the one in which an excessive speed is detected and, therefore, the parameter value will be slightly exceeded.

If a command that causes the setting of parameter No. 15621 to be exceeded is issued, the override constantly changes and, therefore, the feedrate of the nozzle head will not be constant even in the same command block. In normal machining, specify parameter No. 15621 so that no override is applied.

This function is effective to not only automatic operation but also feed in all modes such as jog and handle feed.

With the "G91 G01 X4. A360. F10000" command, the override is applied as shown below. The axis name A represents the fourth axis.



Interaction control

For interaction control of the offset nozzle, the interaction ratio can be set using parameters even when compensation of the β axis does not apply to the command specifying the α axis.
Assume that the number of gear teeth of the α axis is specified in parameter No. 15617 and that the number of gear teeth of the β axis is specified in parameter No. 15618. The interaction ratio is obtained by dividing the value of parameter No. 15617 by the value of parameter No. 15618. The direction of rotation in interaction compensation can be set by parameter No. 15602.

Reference position return order

When an offset nozzle is used, first return the α and β axes to their respective reference positions, then return the X, Y, and Z axes. If the X, Y, and Z axes are returned before the fourth (α) and fifth (β) axes are returned, the absolute coordinates for the X, Y, and Z axes deviate.

Arm length compensation

When nozzles are changed to suit the workpiece to be machined, the length of the second arm varies. Therefore, reference position return is required before nozzle head fixing can be controlled properly. In such a case, by using G71 (arm length compensation) to reset a new nozzle length, nozzle head fixing can be controlled without the need for a reference position return. For details, refer to the FS16*i*-LB operator's manual.

Position display

- Displaying relative and absolute positions

In the nozzle head fixing mode, the displayed position of the X, Y, and Z axes is not affected by the distance of movement of the α and β axes. In the independent axis mode, the displayed position of the X, Y, and Z axes are updated according to the distance of movement of the X, Y, and Z axes as changed by the α and β axes.

- Displaying the position of the machine

In the nozzle head fixing mode, the displayed position of the X, Y, and Z axes are updated according to the distance of movement of the X, Y, and Z axes as changed by the α and β axes.
In the independent axis mode, the displayed position of the X, Y, and Z axes is not affected by the α and β axes.

- Position display in servo off

The displayed incremental and absolute positions of the X, Y, and Z axes are updated according to the follow-up values of the α and β axes. The displayed machine position of the X, Y, and Z axes is not affected by the follow-up values of the α and β axes.

- W-axis tracing

The W axis can be added to the 6th axis as a tracing axis.

Cautions

Consider the length of the arm when specifying overtravel because overtravel is monitored with the machine coordinates.

In the nozzle head fixing mode, the distances of movement along the X, Y, and Z axes caused by the rotation about the α and β axes are added to those of the X, Y, and Z axis move commands. The speed on each axis may, therefore, be higher than the actually specified speed. For this reason, upper limits must be sets on the rapid traverse rates and machining feedrates on the α and β axes so that the speeds in head fixing operation do not exceed the upper speed limits of the motors.
The maximum speeds on the X, Y, and Z axes that can be generated due to the rotation about the α and β axes can be determined with the following formula:

Fmax＝L×Fr

Fmax : Maximum speed on the X, Y, or Z axis
L : Length of the first or second arm
Fr : Speed on the α or β axis

Example)

For rapid traverse
Parameter No. 1420, α axis (Fα): 8000 deg/min
β axis (Fβ): 10000 deg/min
Parameter No. 15615, first arm (L1): 120mm
Parameter No. 15616, second arm (L2): 100mm

Fxy = L1×α
= 120×2π/360×8000=16755mm/min
Fyz = L2×Fβ
= 100×2π/360×10000=17453mm/min

Due to the rotation about the α axis, move commands with up to 16.8 mm/min can be issued for the X and Y axes, and due to the rotation about the β axis, move commands with up to 17.5 mm/min can be issued for the Y and Z axes.
It is, therefore, necessary to determine the rapid traverse rates on the α and β axes so that the rapid traverse rates on the individual axes plus the maximum speeds do not exceed the speed limits for the motors. With attitude control B, consider this thoroughly when selecting motors.

To operate the machine tool in the nozzle head fixing mode, specify the same gain and time constant for the X, Y, Z, α, and β axes. If different gain and time constants are specified, the axes may not work well together.

Due to attitude control, the compensation pulses output for the X, Y, and Z axes change from block to block. Only acceleration/deceleration after interpolation is effective to these interpolation pulses. It is necessary to specify a post-interpolation time constant that can accommodate sufficiently any abrupt compensation pulse changes between blocks.

Signal

- Attitude control B speed clamp select signal OTPMX2<G224#7>

[Classification] Input signal

[Function] Allows selection between maximum feedrate parameters for the automatic feedrate override function in attitude control B.

[Operation] When the signal (OTPMX2) is set to 0, parameter No. 15621 takes effect.
When the signal (OTPMX2) is set to 1, parameter No. 15622 takes effect.

- Attitude control mode select signal ALNAXS<G226#2>

[Classification] Input signal

[Function] Selects whether the nozzle is operated in nozzle head fixing mode or independent axis mode, during manual operation.

[Operation] When the attitude control mode select signal (ALNAXS) is set to 0, the nozzle is operated in nozzle head fixing mode.
When the attitude control mode select signal (ALNAXS) is set to 1, the nozzle is operated in independent axis mode.
Manual reference position return is always performed in independent axis mode, regardless of the state of the mode select signal. Attitude control is enabled once reference position return has been completed.

Signal address

	#7	#6	#5	#4	#3	#2	#1	#0
G224	OTPMX2							
G226						ALNAXS		

Parameter

1020	Axis names used in the program

[Data type] Byte axis

Select the names of the 4th and 5th axes from A, B, C, U, and V, and set the relevant values. When W-axis tracing is selected, select W as the name of the 6th axis.

Axis name	Setting value	Axis name	Setting value
A	65	U	85
B	66	V	86
C	67	W	87

	#7	#6	#5	#4	#3	#2	#1	#0
15600		NFX		RNC	MIA			

[Data type] Bit

MIA When attitude control B is applied in G53 mode, the nozzle is operated in:
- 0: Nozzle head fixing mode
- 1: Independent axis mode (Proximity point search and program restart are disabled for a program which includes G53.)

RNC Whether movement along an angular axis updates the workpiece coordinates and relative coordinates along the X-, Y-, and Z-axes, during manual reference position return
- 0: Updates
- 1: Does not update

NFX Memory operation for machine adjustment is performed in:
- 0: Nozzle head fixing mode (default)
- 1: Independent axis mode

> ⚠ **CAUTION**
> When NFX = 1, the actual coordinates of the end point will differ from those specified in the program. Set NFX to 0 after machine adjustment.

	#7	#6	#5	#4	#3	#2	#1	#0
15601							PA5	PA4

[Data type] Bit

PA4 The α axis rotates:
- 0: In the same direction as that defined for the reference position.
- 1: In the opposite direction to that defined for the reference position.

PA5 The β axis rotates:
- 0: In the same direction as that defined for the reference position.
- 1: In the opposite direction to that defined for the reference position.

	#7	#6	#5	#4	#3	#2	#1	#0
15602		FMX					OSL	TGC

[Data type] Bit

TGC For interaction control, the rotation of the β axis is specified in a command:
- 0: Using a sign different from that used for the α axis rotation command.
- 1: Using the same sign as that used for the α axis rotation command.

OSL In the stroke check before move, the offset of attitude control B is:
- 0: Not considered.
- 1: Considered.

FMX If an offset-type nozzle is used, the cutting speed is:
0: Not clamped.
1: Clamped in consideration of the maximum speed after attitude control.

15610 **Mechanical zero-degree position offset of the α axis**

15611 **Mechanical zero-degree position offset of the β axis**

[Data type] 2-word
[Unit of data] 0.001deg
[Valid data range] 0 to 360000
[Standard setting value] 0, 90000, 180000, 270000
Set the mechanical zero-degree position offset for the α and β axes.

15612 **Maximum speed for machining feed about the α axis**

15613 **Maximum speed for machining feed about the β axis**

[Data type] 2-word
[Unit of data] deg/min
[Valid data range] 6 to 15000
Set the maximum speed for machining feed about the α and β axes. When attitude control is performed in synchronization with the move command along the X-, Y-, and Z-axes, the nozzle is moved along the X-, Y-, and Z- axes at a lower speed corresponding to that when the rotation speed about the α or β axis is clamped to the maximum speed. When interaction control is specified, the same value must be set for the α and β axes.

15615 **1st arm length**

15616 **2nd arm length**

[Data type] 2-word
[Unit of data] 0.001mm (mm output)
0.0001inch (inch output)
[Valid data range] 0 to 500000
Set the length of the first and second arms.

15617 **Number of interaction gear teeth of the α axis (TGMLM)**

[Data type] Byte
[Unit of data]
[Valid data range] 0 to 127
When the number of the gear teeth exceeds the above range, specify a value divisible by the greatest common divisor of the number of the gear teeth of the α axis and the number of the gear teeth of the β axis.
Example)
When the number of the α axis gear teeth is 300, and the number of the β axis gear teeth is 200
Since 300:200= 3:2, specify 3 for the α axis and 2 for the β axis.

15618 **Number of interaction gear teeth of the β axis (TGMLS)**

[Data type] Byte

[Unit of data]

[Valid data range] 0 to 127

β axis interaction compensation is calculated using the number of α axis interaction gear teeth, TGMLM of parameter No. 15617, and this parameter value. The result is automatically specified for the β axis.

$$\beta \text{ axis interaction compensation} = \alpha \text{ axis movement distance} \times \frac{\text{TGMLS}}{\text{TGMLM}}$$

15619 **Nozzle length**

[Data type] 2-word

[Unit of data]

Increment system	IS-A	IS-B	IS-C	Unit
Millimeter machine	0.01	0.001	0.0001	mm
Inch machine	0.001	0.0001	0.00001	inch

[Valid data range] Sum of the values of parameters No. 15616 and No. 15619 ≤ 500000

Set the nozzle length.

When G71 is specified, the value specified with address R is set to this parameter.

15621 **Maximum speed 1 after attitude control**

[Data type] 2-word axis

[Unit of data] mm/min

[Valid data range] 0 to 240000

[Standard setting value] Specify the maximum speed after attitude control. The speed on each axis may be overridden so as not to exceed this setting.

The maximum speed check is not performed on an axis for which 0 is set.

15622 **Maximum speed 2 after attitude control**

[Data type] 2-word axis

[Unit of data] mm/min

[Valid data range] 0 to 240000

[Standard setting value] Specify the maximum speed after attitude control. The speed on each axis may be overridden so as not to exceed this setting. This parameter is effective when the attitude control B speed clamp select signal (G224#7, OTPMX2) is 1. When OTPMX2 is 0, parameter No. 15621 is effective. Parameter No. 15621 is effective to an axis for which 0 is set in this parameter.

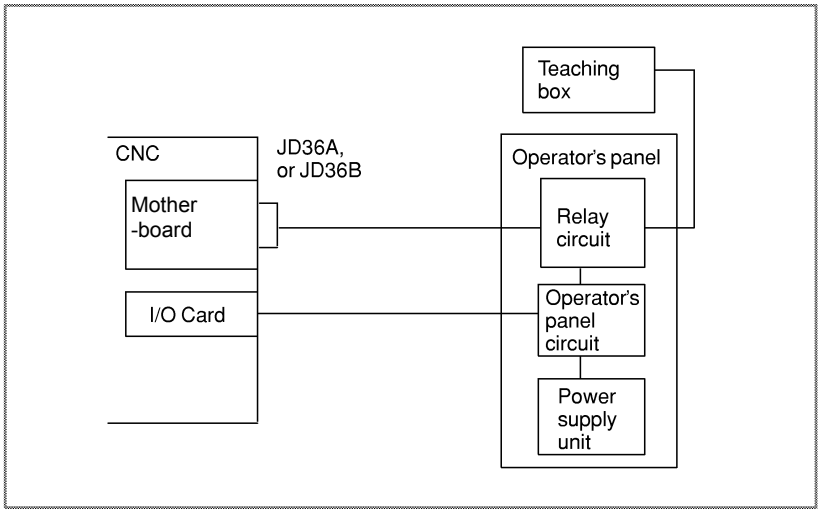
7.2 TEACHING BOX INTERFACE

Overview

If a teaching box interface option is specified, the JD36A or JD36B connector of the motherboard can be used as a teaching box interface. The parameter No.15640 specifies which connector to be used.
The teaching box reads the coordinates of the taught position from the CNC, converts them to NC commands, then registers the commands in CNC program memory. The teaching box is not supplied by FANUC; it must be manufactured or supplied by the machine tool builder. This section describes the specifications of the interface used to connect the teaching box.

Interconnection

Connect as follows:

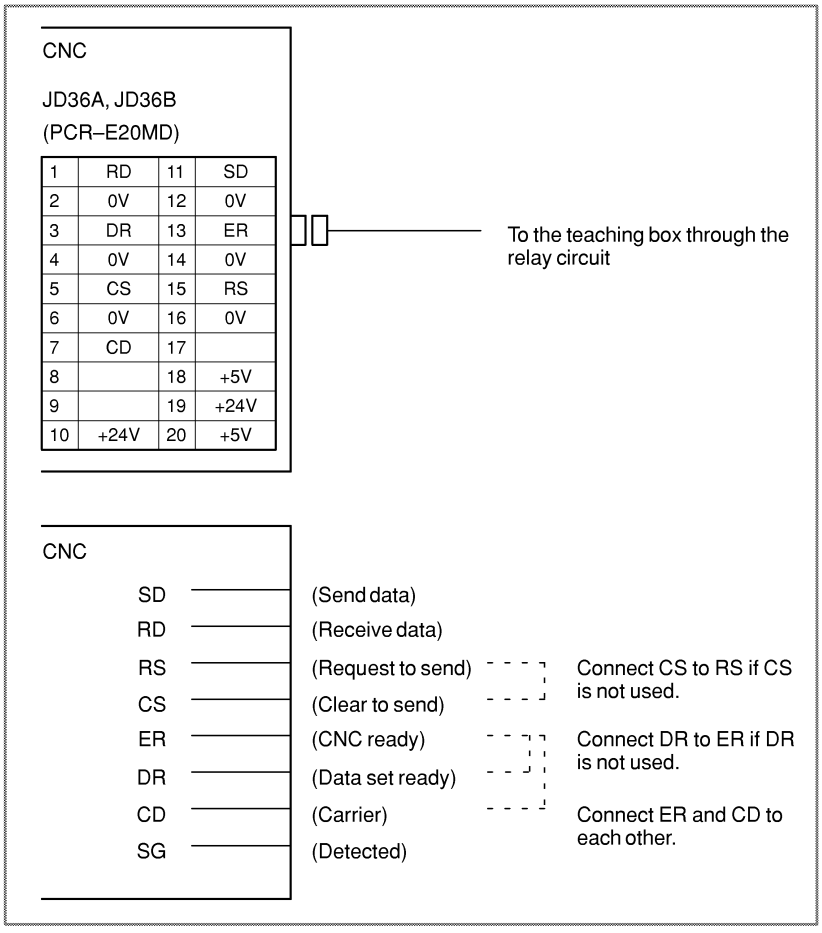


<1> Prepare a relay circuit on the operator's panel, and receive signals from the teaching box at this relay circuit.
<2> Separate the signals received at the relay circuit into two groups. Direct one group (RS-232C interface signals) to the JD36A or JD36B connector of the motherboard of the CNC, and the other group (I/O signals) to I/O cards through the operator's panel circuit.
<3> Prepare a power supply for the teaching box on the operator's panel and supply power to the teaching box through the relay circuit.
<4> It is recommended that an emergency stop button be installed on the teaching box. This emergency stop button should be handled together with the emergency stop button on the operator's panel.
<5> Teaching box exclusive right signal (input) TBES <G226#6>
The CNC can always communicate with a teaching box if it is available. If the CNC is started with no teaching box connected, or if the PMC, or macro executor tries to use the I/O interface, it is necessary to switch the exclusive right.

Setting bit 0 (TBE) of parameter No. 15641 to "1" can switch the communication exclusive right according to the teaching box exclusive right signal (TBES). Resetting the TBES signal to "0" relinquishes the exclusive right to communicate with the teaching box. Setting the TBES signal to "1" keeps communication with the teaching box.
Basically the CNC tries to respond to a conversation request from the teaching box whenever the request is made. It is recommended that the teaching box have a teaching box enable/disable switch that can be used to stop communication as required. When you want to use the TBES signal, switch it using the teaching box enable/disable switch. If you do not want use it, stop communication using the enable/disable switch.

RS-232C interface

The interface for the teaching box complies with the RS-232C standard.



Software interface

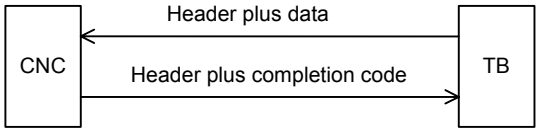
- Communication

The CNC can always communicate with the teaching box. The communication conditions are: Baud rate 4800, two stop bits, and no parity.

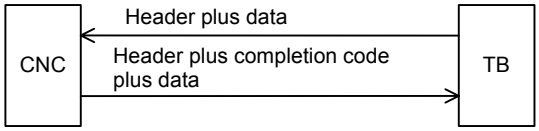
- Conversation mode

One conversation session consists of two communication phases. The conversation begins when the teaching box requests it, and the CNC responds to the request.

(a) When the teaching box sends data to the CNC

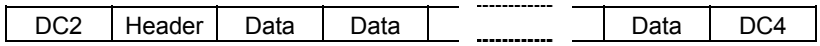


(b) When the teaching box requests data from the CNC



- Transmission format

One transmission message is configured as shown below.



(a) The transmission message must begin with DC2 and end with DC4.

- Headers

(b) Headers

ASCII
- A: Conversation check
- B: DI transmission
- C: DO transmission
- D: Machine position data (workpiece coordinates)
- E: Laser setting data request
- F: Laser setting data registration
- G: Current program number (program number, sequence number, the number of blocks relative to the start block)
- H: Program number registration
- I: Program number deletion
- J: Specified-block read
- K: Specified-block write (insertion)
- L: Specified-block deletion
- M: Sequence number search
- N: MDI operation request
- O: Nozzle-tip machine position data
- P: Three-dimensional conversion data request
- Q: Three-dimensional conversion data registration
- R: Expansion nonvolatile memory read
- S: Expansion nonvolatile memory write
- T: Step forward
- U: Step reverse

Notes

1 A command with header H, I, J, K, L, or M is acceptable only during the jog or handle mode.
2 A commands with headers N, T, and U are acceptable only during the MDI mode.

Data

(c) Data
The data must be represented in ASCII code. (Hexadecimal or NC data is external code.)
The data is sent and received as described below.

- DI/DO data
  Send the DI/DO data in ascending order of address.
- Communication data
  Convert the data to hexadecimal and send it starting at the lowest byte.

First byte	Second byte	Third byte	Fourth byte

- Data restoration
  When you restore the received data to its original form, arrange it starting at the lowest byte.

Fourth byte	Third byte	Second byte	First byte

8-digit O number

When the 8-digit O number options is added and bit 3 (TB0) of parameter No. 15641 is set to 1, the program numbers, block numbers, and sequence numbers used with the following headers are expanded from 2-byte to 4-byte format:

G, H, I, J, K, L, M

Completion code

- Completion code
  The CNC always attaches a completion code to its transmission message to indicate to the teaching box whether the communication was normal. The completion code consists of two bytes. The upper byte is sent before the lower.

  (Example) Completion code 32 DC2N32DC4

Completion codes

Upper byte	Lower byte	Meaning
0	0	Normal end
0	1	A command was rejected because command acceptance was disabled. (The CNC mode (JOG or MDI) was incorrect.)
0	2	The data length is incorrect.
0	3	A specified axis name is incorrect.
0	4	The specified command (header) is in an invalid format.
0	5	The memory area of program is insufficient. Remove any unnecessary programs.
0	6	A specified program number was not found.
0	7	A specified sequence number was not found.

Upper byte	Lower byte	Meaning
0	8	An end of record code (%) was sent during writing to a specified block. Make sure so that "%" is not sent.
0	9	The number of registered records exceeds 125 (basic), or 200, 400, or 1000 (option).
1	0	An attempt was made to register a program with a number with which another was already registered.
1	1	A specified program number does not fall within the range of 1 to 9999.
1	2	An attempt was made to edit programs No. 8000 to 8999, or programs No. 9000 to 9999. This alarm occurs if the specification of a parameter inhibits the editing of such programs. See the description of NC parameter No. 3202 for details.
1	3	The number of specified blocks exceeds 9999.
1	4	An attempt was made to write more than 99 characters to a specified block.
1	5	The delete command is incorrect.
1	6	The macro program is incorrect.
1	7	An attempt was made to read more than 120 characters from a specified block.
1	8	A program cannot be edited by teaching, because background editing occurs in the NC.
1	9	A specified program number, sequence number, or block length has a negative value.
2	0	An end of record code (%) was detected during reading from a specified block. This means that the last block was read.
3	0	In a sequence number search, a non-numeric item was specified for a program or block number.
3	1	During teaching box MDI operation, a numeric value was specified with no address specified.
3	2	During teaching box MDI operation, command O or N was issued.
3	3	During teaching box MDI operation, a specified numeric value consists of more than eight digits (excluding a minus sign).
3	4	During teaching box MDI operation, an invalid address was specified.
3	5	During teaching box MDI operation, an MDI operation was requested during the execution of another program.
3	6	In area R of the PMC, an error occurred during the setting of the DI/DO extended area.
5	0	For the step forward or step reverse function, a macro statement was specified.
5	1	For the step forward or step reverse function, an invalid G code was specified.
5	3	The next command was rejected because it was issued during execution of the step forward or step reverse function.
5	5	No option was specified for the step forward or step reverse function.

Block number

A block number is determined by counting the number of semicolons (EOBs), starting from the beginning of the program. For a program having only an O-number, block number 1 is assumed.

O0100; Block number 1
N0001 ; block number 2
N0002 ; block number 3
N0003 ; block number 4

Conversation format

(a) Conversation check
The teaching box (TB) can check whether it can communicate with the CNC.

TB⇒CNC

DC2	A	DC4

CNC⇒TB

DC2	A	Completion code	DC4

[Example]
Assume the CNC sends the following message to the TB:

DC2	A	DC4
12	41	14

The TB will respond to it with the completion code:

DC2	A	0	0	DC4
12	41	30	30	14

(b) DI (TB ⇒ PMC signal) transmission
The TB can send data to the internal relay area. (For area setting, see the Parameter section later.)

TB⇒CNC

DC2	B							DC4
		1st byte					nth byte	

CNC⇒TB

DC2	B	Completion code	DC4

[Example]
Assume that the DI signal data area is mapped at four bytes from R980 to R983 in the internal relay area and that the following data is sent to the DI signal data area.

R980 89H (10001001)
R981 ABH (10101011)
R982 CDH (11001101)
R983 EFH (11101111)

The following message is sent out:

DC2	B	8	9	A	B	C	D	E	F	DC4
12	42	38	39	41	42	43	44	45	46	14

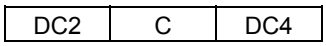
When the CNC receives this message, it responds with the completion code:

DC2	B	0	0	DC4
12	42	30	30	14

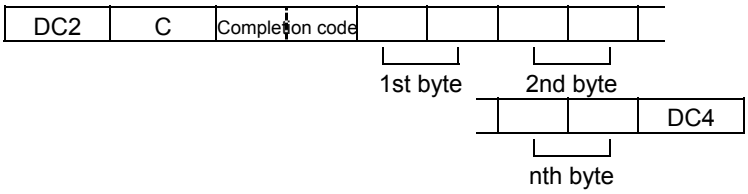
(c) DO (PMC ⇒ TB signal) transmission

The TB can read data from the internal relay area. (For area setting, see the Parameter section later.)

TB⇒CNC



CNC⇒TB



[Example]

Assume that the DO signal data area is mapped at four bytes from R988 to R991 in the internal relay area and this area contains data shown below:

R988 9AH
R989 BCH
R990 DEH
R991 F0H

Assume that the TB sends the following message to the CNC:

DC2	C	DC4
12	43	14

DC2	C	0	0	9	A	B	C	D	E	F	0	DC4
12	42	30	30	39	41	42	43	44	45	46	30	14

The CNC will respond with:

The C command may fail to read the expected signal state with a single communication. The reason for this is that the CNC, PMC, and teaching box differ in signal read timing. It is, therefore, recommended that a retry process be performed in the teaching box or that a timer that enables adjustment of the start of the C command be added.

(d) Machine position data request (Workpiece coordinate position)
The workpiece coordinate position along the axis specified by the CNC can be read by specifying the name of that axis.

TB⇒CNC

DC2	D		DC4

Axis name
0: X-axis 5: 6th axis
1: Y-axis 6: 7th axis
2: Z-axis 7: 8th axis
3: 4th axis A: All axes
4: 5th axis

CNC⇒TB

DC2	D	Completion code

								DC4

1st byte 2nd byte 3rd byte 4th byte

[Example]

When the X-coordinate of the workpiece coordinate position in the machine coordinate system is 12345.678, if the TB requests the workpiece coordinate position data, the following processing is performed. (Note that 12345678 is 0BC614EH in hexadecimal.)

Assume that the TB sends the following request to the CNC:

DC2	D	0	DC4
12	44	30	14

DC2	D	0	0	4	E	6	1	B	C	0	0	DC4
12	44	30	30	34	45	36	31	42	43	30	30	14

The CNC will respond with:

For -12345678, the following data is returned because it is EF439EB2H in hexadecimal:

DC2 D 0 0 B 2 9 E 4 3 E F DC4

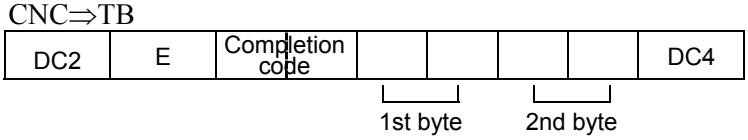
(e) Laser setting data request
Laser setting data can be read from the CNC.

TB⇒CNC

DC2	E		DC4

Data
0: Contouring output power
1: Contouring pulse frequency
2: Contouring pulse duty cycle
3: Piercing output power
4: Piercing pulse frequency
5: Piercing pulse duty cycle
6: Assist gas selection
7: Flow pattern selection

CNC⇒TB



[Example]

Assume that the contouring output power is 1000 W. This example illustrates how the CNC requests and receives data from the TB. Note that 1000 is 03E8H in hexadecimal.

Assume the TB sends the following request to the CNC:

DC2	E	0	DC4
12	45	30	14

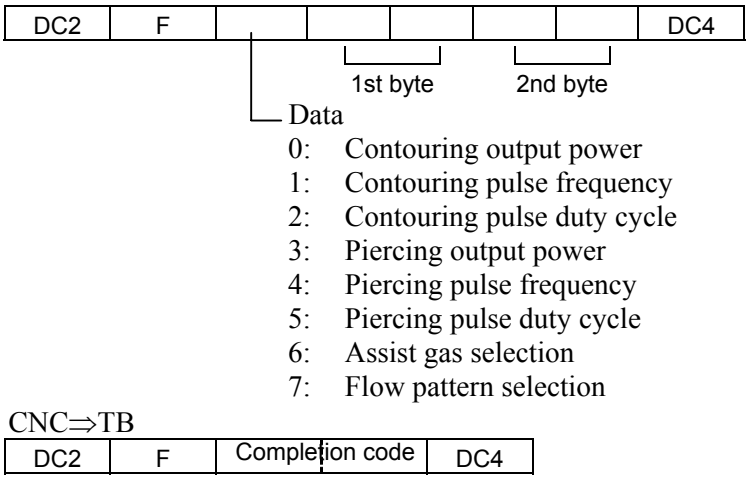
The CNC will respond with:

DC2	E	0	0	E	8	0	3	DC4
12	45	30	30	45	38	30	33	14

(f) Laser setting data registration

Laser setting data can be set with values.

TB⇒CNC

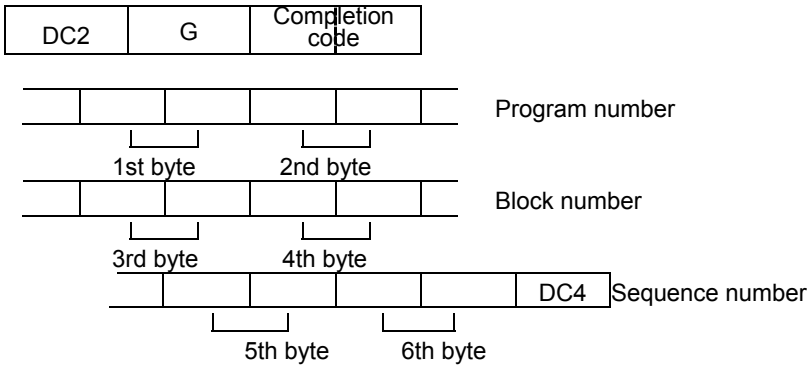


CNC⇒TB

(g) Current program number request

The program number, block number, and sequence number of the executed program can be obtained.

CNC⇒TB



⚠ CAUTION

1 The program number and block number that can be read with header G are those related to an executed program. Header G cannot be used to read the block number of a program currently under teaching editing. To read it, use a sequence number search by means of header M.
2 The program and block numbers that can be read with header G are updated when the memory or tape mode is executed. No program or block number is used during the MDI operation. So, program and block numbers are assumed to be 0.
3 When a block number is requested during the memory mode, it is returned as 0 if the OP (automatic operation in progress) signal is on.

(h) Program number registration

The program area is secured for a specified number.

TB⇒CNC

DC2	H					DC4

1st byte 2nd byte

CNC⇒TB

DC2	H	Completion code	DC4

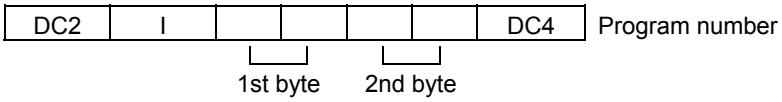
⚠ CAUTION

1 The H command is equivalent to pressing O****+INSERT from the MDI panel and, therefore, no ;(EOB) is inserted. To insert an EOB, write one by specifying block 0 with the K command.
More specifically, issue the commands in combination as follows:
Example) To register O0001

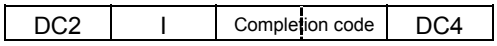
		Program number			
DC2	H	0	1	0	0	DC4

		Program number				Block number				Block length		Data	
DC2	K	0	1	0	0	0	0	0	0	0	1	;	DC4

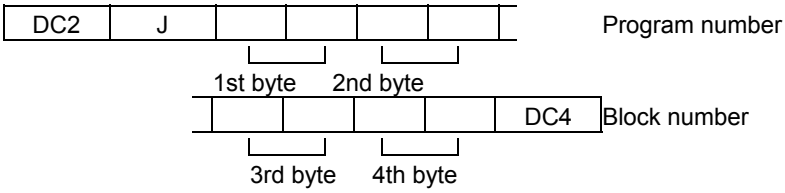
(i) Program number deletion
The program with a specified program number is deleted.
TB⇒CNC



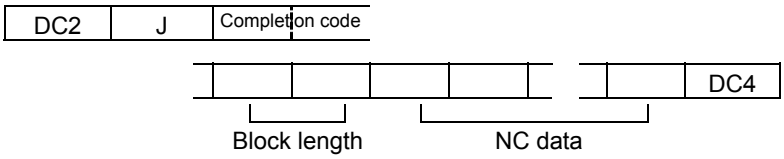
CNC⇒TB



(j) Specified-block read
By specifying a program number and block number (counted from the first block), the corresponding NC data and its block length (number of characters) can be read.
TB⇒CNC



CNC⇒TB



The following example illustrates how to read the NC data with a block length 18 (12H in hexadecimal) of block number 3 (0003H in hexadecimal) of program number 1000 (03E8H in hexadecimal).

Assume the TB sends the following message to the CNC:

DC2	J	E	8	0	3	0	3	0	0	DC4
12	4A	45	38	30	33	30	33	30	30	14

The block length and data will be read as follows:

DC2	J	0	0	1	2	G	0	0	X	0	Y	-	9	9	9
12	4A	30	30	31	32	47	30	30	58	30	59	2D	39	39	39

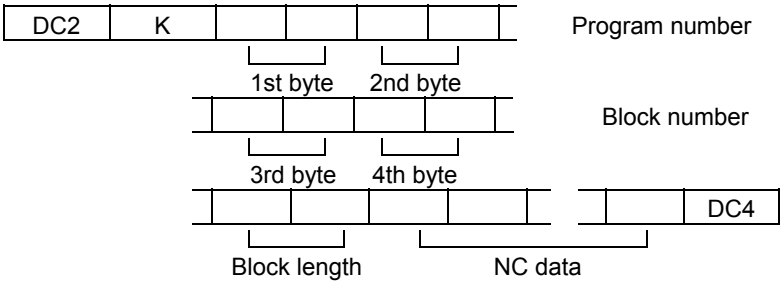
9	9	9	A	0	B	0	;	DC4
39	39	39	41	30	42	30	3B	14

⚠ CAUTION
If the J command is sent with OP (automatic operation in progress) set to 0, the program execution pointer (cursor) moves to the block from which data has been read. The pointer does not move if OP is set to 1.

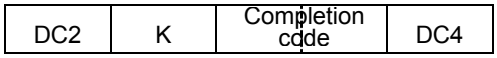
(K) Specified-block write

By specifying a program number, block number, block length, and NC data, the NC data can be written into the block that follows the specified block.

TB⇒CNC



CNC⇒TB



⚠ CAUTION

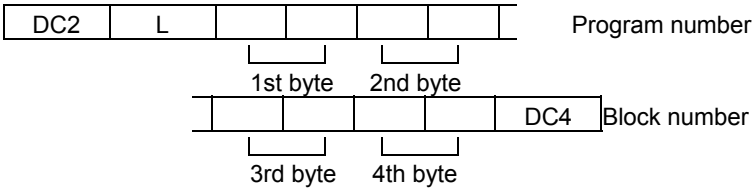
1 If you want insert NC data as the nth block, specify block number n-1. It will be inserted after the EOB of the (n-1)th block.

2 More than one block can be inserted with one instruction. One instruction can specify up to 99 characters.

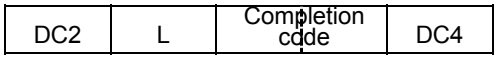
(l) Specified-block deletion

Specifying a program number and block number can delete the corresponding block.

TB⇒CNC



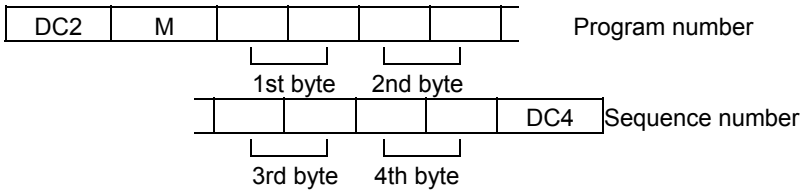
CNC⇒TB



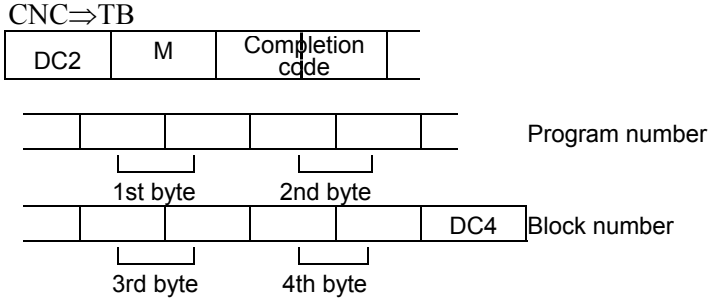
(m) Sequence number search

By specifying a program number and sequence number, a search can be performed for the sequence number while counting the number of blocks from the beginning of the program. Once the search has been completed, the program number and block number can be read.

TB⇒CNC



CNC⇒TB

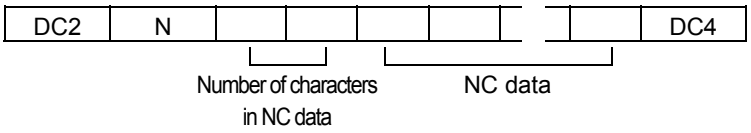


⚠ CAUTION
Create a sequence number as a 4-digit N code during program creation. The CNC searches for a sequence number using a 4-digit N code as a key.

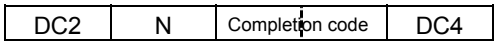
(n) MDI operation

MDI operation is enabled by specifying NC data, using the number of characters in the NC data.

TB⇒CNC



CNC⇒TB



[Example]

If the specified NC data is G00X0Y-999999A0C0;, the number of characters in it is 18 (12H in hexadecimal).

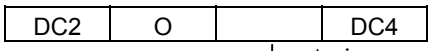
DC2	N	1	2	G	0	0	X	0	Y	-	9	9	9
12	4E	31	32	47	30	30	58	30	59	2D	39	39	39

9	9	9	A	0	C	0	;	DC4
39	39	39	41	30	43	30	3B	14

⚠ CAUTION
1 The above NC data can be transmitted during MDI operation only if both STL and SPL are off (neither automatic operation is being activated nor automatic operation is at a halt).
2 Automatic operation begins after the transmission of the NC data.
3 Set 1 in bit 7 (MCL) of parameter No. 3203 before attempting to use the N command.

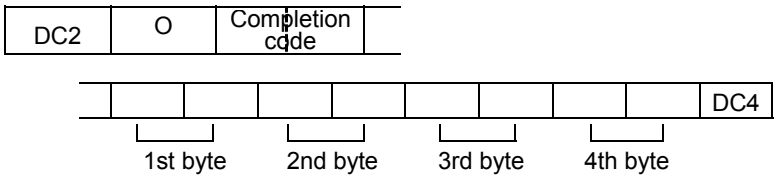
(o) Nozzle-tip machine position data request
The machine position data of a nozzle tip can be read by specifying the axis name.

TB⇒CNC



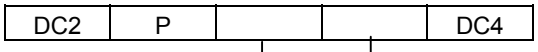
Axis name 0: X-axis 5: 6th axis
1: Y-axis 6: 7th axis
2: Z-axis 7: 8th axis
3: 4th axis A: All axes
4: 5th axis

CNC⇒TB



(p) Three-dimensional conversion data request
It is possible to read the coordinates of conversion points (P0, P1, P2, P3, Q0, Q1, Q2, Q3) of the three-dimensional conversion function registered as setting data.

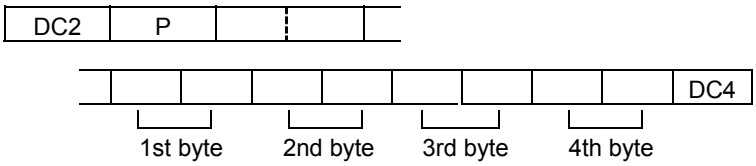
TB⇒CNC



Conversion point 0: Point P0
1: Point P1
2: Point P2
3: Point P3
4: Point Q0
5: Point Q1
6: Point Q2
7: Point Q3

Axis name 0: X-axis
1: Y-axis
2: Z-axis

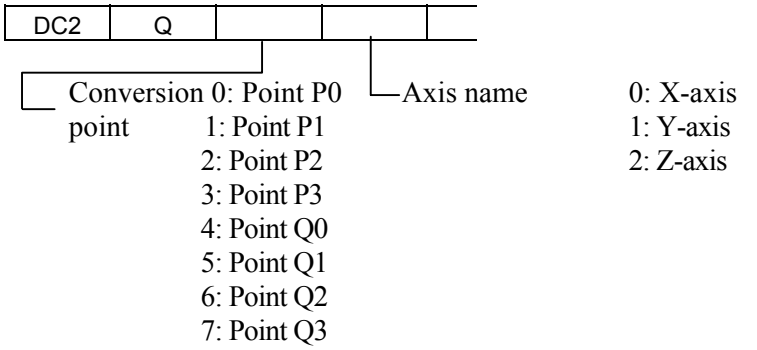
CNC⇒TB



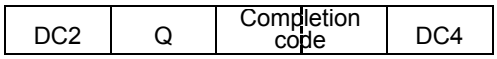
(q) Three-dimensional conversion data registration

It is possible to set the coordinates of conversion points (reference position and target points) of the three-dimensional conversion function.

TB⇒CNC



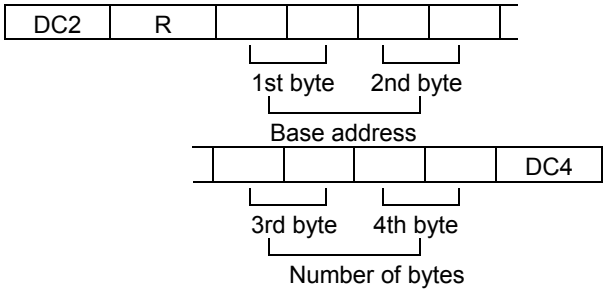
CNC⇒TB



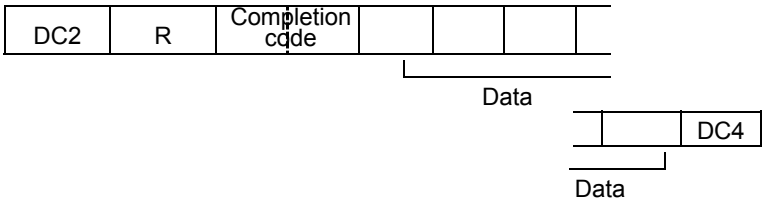
(r) Battery-powered memory read

Data can be read from battery-powered memory by specifying the target read area with its start address as the base address, and the number of bytes.

TB⇒CNC



CNC⇒TB



[Example]

Assume that the target read data is 8 bytes in an area with base address 1FA0 as shown below:

	High	Low
1FA0H	31H	30H
1FA2H	33H	32H
1FA4H	42H	41H
1FA6H	44H	43H

Issue a request as follows:

DC2	R	A	0	1	F	0	8	0	0	DC4
12	52	41	30	31	46	30	38	30	30	14

DC2	R	0	0	3	0	3	1	3	2	3	3	4	1
12	52	30	30	33	30	33	31	33	32	33	33	34	31

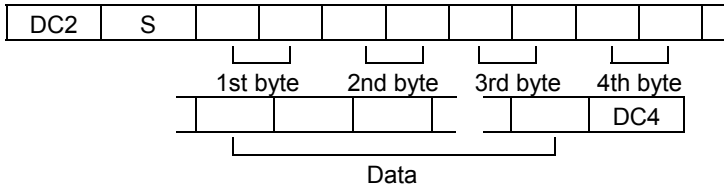
The following data will be read:

4	2	4	3	4	4	DC4
34	32	34	33	34	34	14

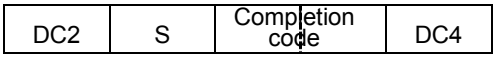
(s) Battery-powered memory write

Data can be written to battery-powered memory by specifying the target write area with its start address as the base address, the write data, and the number of bytes in the write data.

TB⇒CNC



CNC⇒TB



[Example]

Assume that the following write data is written to an area with base address 21A0 as shown below:

	High	Low
21A0H	01H	23H
21A2H	45H	67H
21A4H	89H	ABH
21A6H	CDH	EFH

Issue a request as follows:

DC2	S	A	0	2	1	0	8	0	0	2	3	0	1
12	53	41	30	32	31	30	38	30	30	32	33	30	31

6	7	4	5	A	B	8	9	E	F	C	D	DC4
36	37	34	35	41	42	38	39	45	46	43	44	14

The specified data will be written to the specified area.

Interface between the PMC and teaching box

The DI/DO signals transferred between the PMC and teaching box are mapped at addresses R980 to R995 in the internal relay area. Note that these addresses cannot be used for internal relaying. Of these addresses, R980 to R995 are assigned to the DI and DO signals as shown below.

Addresses R980 to R983: DI signal
Addresses R988 to R991: DO signal

Four bytes for DI and DO can be defined freely.

Bit 1 (TBX) of parameter No. 15641 can be used to specify whether to increase or decrease the number of DI/DO signals and whether to change the area.

If bit 1 (TBX) of parameter No. 15641 is set to "1" to expand the DI/DO signals, some other parameters must be specified, as described below.

(1) Specifying the start address of the area
Set the start address of the area to which DI signals are assigned, in parameter No. 15638. Set the start address of the area to which DO signals are assigned, in parameter No. 15639.

(2) Specifying the capacity
Sets the DI signal capacity, in bytes, in parameter No. 15643. Sets the DO signal capacity, in bytes, in parameter No. 15644.

(t) Step forward

The program is forwarded on a block-by-block basis, starting from a specified block.

TB⇒CNC

C2	T	DC4

CNC⇒TB

DC2	T	Completion code	

					DC4	Block number

1st byte 2nd byte

Procedure

Specify one of the following as the start block:

(1) Block executed in step forward or step reverse mode
(2) Block executed in memory mode
(3) Block found by a search performed upon a program restart
(4) Block found by a proximity point search
(5) Block specified by a J or K command in the teaching box.

↓

Select MDI operation mode.

↓

Send a T command from the teaching box.

↓

The tool moves and stops.

↓

Upon acceptance of a T command, the program is forwarded on a block-by-block basis.

Manual intervention

Set manual operation mode.

> ⚠ **CAUTION**
> See "Notes" in the description of the step reverse function.

(u) Step reverse

The program is reversed on a block-by-block basis, starting from a specified block.

TB⇒CNC

DC2	U	DC4

CNC⇒TB

DC2	U	Completion code	

					DC4

1st byte 2nd byte

Procedure

Specify one of the following as the start block:

(1) Block executed in step forward or step reverse mode
(2) Block executed in memory mode
(3) Block found by a search performed upon a program restart
(4) Block found by a near point search
(5) Block specified by a J or K command in the teaching box.

↓

Select MDI operation mode.

↓

Send a U command from the teaching box.

↓

The tool moves and stops.

↓

Upon acceptance of a U command, the program is reversed on a block-by-block basis.

Manual intervention

Set manual operation mode.

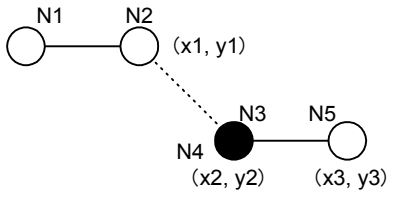
Operation

When step reverse is specified, the following occurs:

1) The block immediately preceding the current block is read.
2) If the block contains a move command, the G code of the move command is preserved.
3) Blocks are searched back for another move command.
4) The end point is obtained based on the block containing the move command found by the search.
5) A reverse move command is created based on the preserved G code and end point. Then, the tool starts moving.
6) After the tool stops, skipped blocks are executed.

(Example)

N1 G01Xx1Yy1 ;
N2 G14 ;
N3 G00Xx2Yy2 ;
N4 G13 ;
N5 G01Xx3Yy3 ;



1) When step reverse is specified after blocks N1 to N3 have been executed, block N3 is read.
2) Block N3 contains a move command, G00; thus, G00 is preserved.
3) Block N2 is read. It contains G14, which is not a move command. Then, the previous block N1 is read.
4) Block N1 contains a move command. The coordinates in this block are included to specify the end point.
5) Assuming that the coordinates indicate the end point, command G00Xx1Yy1 is created, then executed.
6) After the tool moves to the end point, G13, an inverse command of G14; contained in the skipped N2 block, is executed. Then, the program stops.

Relation with other functions

1) M code output
   M code output during step forward or step reverse is restricted by bit 1 (MEN) of parameter No. 15775.
2) F code and E code
   Processed as a block to be executed in both step forward and step reverse. However, the parameter speed (Parameter No. 15770) for step reverse is used as the actual feedrate.
   If omitted, an alarm occurs during automatic operation after step forward or step reverse because the feedrate during automatic operation and the laser power command are not set.
3) Macro call
   Macro calls by G65, the G code (Parameters Nos. 6050 to 6059) for which parameter setting was made, and the M code (Parameter Nos. 6080 to 6089) are restricted by bit 2 (MCL) of parameter No. 15775.
   When bit 0 (NST) of parameter No. 15775 is 0, no macro call is made during step reverse.
4) Subprogram call
   Subprogram calls by the M code (Parameters Nos. 6071 to 6079) for which parameter setting was made, ASCII code (Parameter Nos. 6090 and 6091), and M98 are restricted by bit 2 (MCL) of parameter No. 15775.
5) Spatial corner R insertion
   G33 operation is restricted by bit 3 (TIE) of parameter No. 15775.
   If G33 operation was disabled, G01 is used to operate it. During step reverse, G01 is used to operate it.

⚠ CAUTION

1 For move commands, the coordinates for all axes must be specified by absolute programming.
2 One of G codes G00, G01, G02, G03, or G12 must be specified in each block.
3 For circular interpolation, one of I, J, and K must be used. Normal processing cannot be performed by arc radius R programming.
4 During step forward or step reverse, no beam is output.
5 If step forward or step reverse which has already been specified is specified again before the operation is started (STL, SLP = 1), the second specification is ignored.
6 Those blocks to be executed in step forward or step reverse mode are affected by the J (specified block read), K (specified block insert), and L (specified block delete) commands. Once the J, K, or L command is specified, the program points to the block specified with the command. Then, if the T or U command is specified, the program points to a block other than that found by a near point search or that executed in memory mode. When the J, K, or L command must be specified before the T or U command, appropriate precautions should be applied. For example, first store the current block into the teaching box. Then, after specifying the J command, set the relevant block number before specifying the T or U command.
7 When bit 0 (NST) of parameter No. 15775 is 0, one block is surely executed for each command in step forward or step reverse. A block without movement is also executed.
8 If the previous block includes no movement command in the first step reverse, a movement command is searched for. That is, the beginning of the step reverse is always the movement command.
9 For a program including the execution macro calling G code, take actions as shown below. Since DO signal STPRCV (F0226#7) is output when a command for step forward or step reverse is received, read this signal by using the address function at the beginning of the execution macro. If the read value is 1, make a jump to M99. Basically, the execution macro during step forward or step reverse cannot operate. The execution macro calling G code cannot be determined on the NC side at the preprocessing level, perform processing at the beginning of the called execution macro. Care needs to be exercised since execution is made from the beginning of the called execution macro even in step reverse.

G code handling

With the step forward or step reverse function, G codes are handled as shown below.

G code	Function name	Step forward	Step reverse	Remarks
G00	Positioning	Valid	Valid	
G01	Linear interpolation	Valid	Valid	
G02	Circular interpolation	Valid	Valid	G03 for step reverse
G03	Circular interpolation	Valid	Valid	G02 for step reverse
G04	Dwell	Ignored	Ignored	
G05	High-speed remote buffer	Ignored	Ignored	
G06	Unused	Ignored	Ignored	
G07	Unused	Ignored	Ignored	
G08	Advanced preview control	Ignored	Ignored	
G09	Exact stop	Ignored	Ignored	

G code	Function name	Step forward	Step reverse	Remarks
G10	Data setting on	Ignored	Ignored	
G11	Data setting off	Ignored	Ignored	
G12	Spatial circular interpolation	Valid	Valid	
G12.1	Polar coordinate interpolation	Error	Error	
G13	Tracing mode on	Valid	Valid	G14 for step forward
G13.1	Polar coordinate interpolation	Error	Error	
G14	Tracing mode off	Valid	Valid	G13 for step forward
G15	Polar coordinate command	Error	Error	
G16	Polar coordinate command	Error	Error	
G17	Plane selection	Ignored	Ignored	
G18		Ignored	Ignored	
G19		Ignored	Ignored	
G20	Inch/metric	Ignored	Ignored	
G21		Ignored	Ignored	
G22	Stored stroke check	Error	Error	
G23		Error	Error	
G24	Piercing	Ignored	Ignored	
G25	Unused	Ignored	Ignored	
G26		Ignored	Ignored	
G27	Reference position return	Valid	Ignored	
G28		Valid	Ignored	
G29		Valid	Ignored	
G30		Valid	Ignored	
G30.1		Valid	Error	
G31	Skip function	Error	Error	
G32	Assist gas	Ignored	Ignored	
G33	Spatial corner R	Valid	Valid	G01 for step reverse
G34		Valid	Ignored	
G35	Unused	Ignored	Ignored	G00 for both step forward and step reverse
G36		Ignored	Ignored	
G37		Ignored	Ignored	
G38		Ignored	Ignored	
G39		Ignored	Ignored	
G40	Cutter compensation	Ignored	Ignored	
G41		Valid	Ignored	
G42		Valid	Ignored	
G43	Tool length compensation	Valid	Ignored	
G44		Valid	Ignored	
G45	Tool offset	Ignored	Ignored	
G46		Ignored	Ignored	
G47		Ignored	Ignored	
G48		Ignored	Ignored	
G49	Tool length compensation off	Ignored	Ignored	
G50	Scaling	Error	Error	
G51		Error	Error	
G52	Local coordinate system	Error	Error	
G53	Machine coordinate system	Valid	Valid	

G code	Function name	Step forward	Step reverse	Remarks
G54	Workpiece coordinate system	Error	Error	
G55		Error	Error	
G56		Error	Error	
G57		Error	Error	
G58		Error	Error	
G59		Error	Error	
G60	Single direction positioning	Valid	Valid	
G61	Exact stop mode	Ignored	Ignored	
G62	Automatic corner override	Ignored	Ignored	
G63	Power control	Ignored	Ignored	
G64	Cutting mode	Ignored	Ignored	
G65	Macro call	Ignored	Ignored	
G66		Ignored	Ignored	
G67		Ignored	Ignored	
G68	Three-dimensional coordinate conversion	Valid	Ignored	
G69		Valid	Ignored	
G70	Unused	Ignored	Ignored	
G71	A axis length compensation	Ignored	Ignored	
G72	Unused	Ignored	Ignored	
G73		Ignored	Ignored	
G74		Ignored	Ignored	
G75		Ignored	Ignored	
G76		Ignored	Ignored	
G77		Ignored	Ignored	
G78		Ignored	Ignored	
G79		Ignored	Ignored	
G80		Ignored	Ignored	
G81		Ignored	Ignored	
G82		Ignored	Ignored	
G83		Ignored	Ignored	
G84	Coordinate system rotation	Error	Error	
G85		Error	Error	
G86	Unused	Ignored	Ignored	
G87		Ignored	Ignored	
G88		Ignored	Ignored	
G89		Ignored	Ignored	
G90	Absolute programming	Valid	Valid	
G91	Incremental programming	Ignored	Ignored	
G92	Coordinate system setting	Error	Error	
G93	Unused	Ignored	Ignored	
G94		Ignored	Ignored	
G95		Ignored	Ignored	
G96		Ignored	Ignored	
G97		Ignored	Ignored	
G98	Three-dimensional conversion	Valid	Ignored	
G99		Valid	Ignored	
G107	Cylindrical interpolation	Error	Error	
G150	Normal direction control	Error	Error	
G151		Error	Error	
G152		Error	Error	

Signal

- Teaching box exclusire right signal TBES<G226#6>

[Classification] Input signal

[Function] Externally turns communication with the teaching box on/off.

[Operation] The CNC can always communicate with the teaching box provided it is connected. If the CNC is started while the teaching box is not connected, or if the PMC and so on try to use the I/O interface, it becomes necessary to switch the exclusive right.

Setting bit 0 (TBE) of parameter No. 15641 can switch the communication exclusive right according to the teaching box exclusive right signal (TBES). Resetting the TBES signal to 0 relinquishes the exclusive right to communicate with the teaching box. Setting the TBES signal to 1 maintains communication with the teaching box.

> ⚠ **CAUTION**
> If bit 0 (TBE) of parameter No. 15641 is set to 1, the CNC issues "DC1" each time the teaching box exclusive right signal (TBES) is switched from "0" to "1."
> If TBE is set to 0, the CNC issues "DC1" each time a reset is performed.

Signal

- Step forward or step reverse acceptance signal STPRCV<F226#7>

[Classification] Output signal

[Function] Reports the reception status of the step forward or step reverse command.

[Operation] When the CNC receives the T or U command from the teaching box, STPRCV is set to 1.

When block operation is completed, STPRCV is set to 0.

Signal address

	#7	#6	#5	#4	#3	#2	#1	#0
G226		TBES						

	#7	#6	#5	#4	#3	#2	#1	#0
F226	STPRCV							

Parameter

15638	DI area start address

15639	DO area start address

[Data type] Word
[Unit of data]
[Valid data range] 1 to 999

Set the start addresses of the internal relay areas (R areas) used to access DI/DO signals from the teaching box. The internal relay areas having the capacity specified with parameters Nos. 15643 and 15644 are allocated starting from the addresses set here.

15640	Channel to be connected to a teaching box

[Data type] Byte
[Unit of data]
[Valid data range] 1, 2

Specifies the channel to be connected to a teaching box.
Channel 1 (connector JD36A): Setting value = 1
Channel 2 (connector JD36B): Setting value = 2

	#7	#6	#5	#4	#3	#2	#1	#0
15641					TBO	TBA	TBX	TBE

[Data type] Bit

TBE As the channel of the teaching box, the right to occupy the RS-232C port is:
- 0: Always held by the CNC. (Current setting)
- 1: Switchable by the teaching box exclusive right signal (G226#6, TBES).

TBX The areas used to access DI/DO signals from the teaching box:
- 0: Are fixed.
- 1: Can be expanded.

TBA The state of data transfer to expansion nonvolatile memory is:
- 0: Not output. (Parameter No. 15642 is disabled.)
- 1: Output. (Parameter No. 15642 is enabled.)

TBO In the teaching box, an eight-digit program number is:
- 0: Not used.
- 1: Used. (The eight-digit program number option is necessary.)

15642	Address to which the state of data transfer to battery-powered memory is output

[Data type] Word
[Unit of data]
[Valid data range] 0 to 65528

Once the R or S command has been received from the teaching box, the following state data is written to battery-powered memory, starting from the address specified with this parameter:

Address specified with parameter No. 15642	+0	First address containing transfer data	
	+2	Number of bytes	
	+4	Completion code	
	+6		Control bit

Control bit

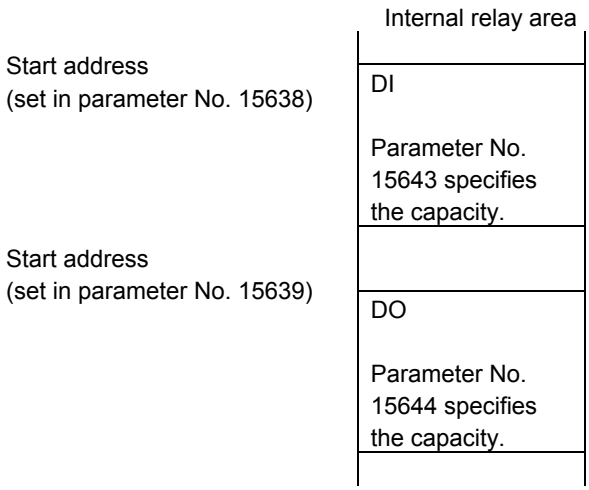
	#7	#6	#5	#4	#3	#2	#1	#0
+6								MSTBA

MSTBA＝1: Masks the R or S command.
If the R or S command is received, a completion code indicating an alarm is output.

15643	Number of DI sets

15644	Number of DO sets

[Data type] Byte
[Unit of data] Sets
[Valid data range] 1 to 15 (If 0 is specified, the expansion function is disabled.)
Set the DI/DO signal capacity, in bytes.
Sets the DI signal capacity, in bytes, in parameter No. 15643. Sets the DO signal capacity, in bytes, in parameter No. 15644.



Step forward/reverse function

15770	Feedrate when step forward or step reverse is specified

[Data type] 2-word
[Unit of data] mm/min
[Valid data range] 1 to 240000
Set the feedrate when step forward or step reverse is specified with the teaching box.

	#7	#6	#5	#4	#3	#2	#1	#0
15775					TIE	MCL	MEN	NST

[Data type] Bit

NST During step forward or step reverse
0: Bits 1 (MEN), 2 (MCL), and 3 (TIE) of parameter No. 15775 are valid.
1: These bits are invalid.

MEN In step forward or step reverse, the M code is:
0: Not output.
1: Output.

MCL In step forward, a macro or submacro call is:
0: Disabled.
1: Enabled (always disabled during step reverse).

TIE In step forward, spatial corner R is:
0: Enabled (operation is enabled with G01 during step reverse).
1: Disabled.

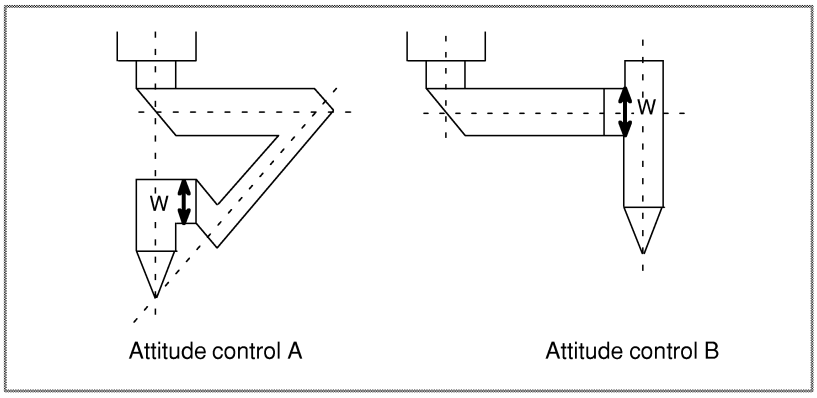
7.3 W-AXIS TRACING

Overview

The W-axis can be defined on the sixth axis as a tracing axis. See chapter 6 for details of the tracing control function.

W-axis

The W-axis, (sixth axis) is defined as the axis along which the nozzle moves linearly, at the end of the five-axis machining head.



The W-axis is attached in the same way as a normal linear axis. However, it is a dedicated tracing axis attached to the tip of a nozzle, it is characterized as follows:

(1) W-axis rapid traverse
Because the W-axis must operate in short strokes because of its axis configuration, it is used with its rapid traverse rate lowered.
A low rapid traverse rate for the W-axis can be set in the sixth axis part of parameters Nos. 1420 and 1424.

(2) Reference position return
For the W-axis, manual reference position return is performed at the manual rapid traverse rate. To enable reading of the reference position return deceleration signal (*DEC) at a stable speed, the CNC monitors the position error of the axis during feed. If the *DEC signal is not detected at a sufficiently high speed, an alarm is issued. This alarm may be often output, because the speed of W-axis traverse is too low. To suppress this alarm, set the minimum position error at which no alarm occurs, in the sixth axis part of parameter No. 1836.

(3) Manual continuous feed
The jog feedrate is determined according to the manual continuous feedrate setting signal. The jog feedrate determined this way may be too high for the W-axis command. So, a ladder program should be created which uses the manual feedrate override signals *JV0 to *JV15 to clamp the W-axis feedrate to a safe rate upon reception of the manual feed axis direction selection signal for the W-axis.

Switching between W-axis tracing and Z-axis tracing

When the W-axis tracing option is attached, the tracing axis is the W-axis. If both the W-axis tracing and Z-axis tracing options are attached, it is possible to switch the tracing axis between W- and Z-axes.

Commands

(1) If a G code is used
W-axis tracing
G13 (L0);
Z-axis tracing
G13L2;

(2) If an external signal is used
W-axis tracing
G225#0:ZTRM=0
Z-axis tracing
G225#0:ZTRM=1

NOTE
Before switching the tracing axis, cancel tracing control.

Parameter

1420 **Rapid traverse rate for the axis**

1424 **Manual rapid traverse rate for the axis**

[Data type] 2-word axis

[Unit of data]
[Valid data range]

Increment system	Unit of data	Valid data range	
		IS-A, IS-B	IS-C
Metric machine	1mm/min	30 to 240000	30 to 100000
Inch machine	0.1 inch/min	30 to 96000	30 to 48000

The rapid traverse rate for the W-axis (sixth axis) is specified on the sixth axis.

1836 **Minimum position error at a W-axis reference position return**

[Data type] Byte axis
[Unit of data] Detection unit
[Valid data range] 0 to 127
If 0 is specified, 128 is assumed.
[Guideline of setting] Highest value with which no alarm occurs at a reference position return

15541	Coefficient for conversion from W-axis tracing speed to control voltage

[Data type] Word

[Unit of data]

[Valid data range] 0 to 32767

[Setting method] Set the conversion coefficient obtained using the following formula:

$$\text{Conversion coefficient} = G \times \frac{P \times 4}{1000 \times Le} \times 2 \times 10^{-3} \times 4096$$

where ,

G: Tracing gain (sec^{-1}) Standard value = 30 sec^{-1}

Le: Machine travel per W-axis motor revolution (mm/rev)

P : Number of detected pulse coder pulses per W-axis motor revolution (p/rev)
Set 2048 when using a serial A or a motor.

7.4 TRACING AXIS SWITCHING

Overview

If the three-dimensional machining function is added with a W-axis tracing function, setting the tracing axis switching signal (ZTRM) to "1" switches the tracing axis to the X-axis. This function enables the Z-axis to trace the manual operation along the X- and Y-axes and therefore can be used in teaching operation for the workpiece surface.

Signal

- Tracing axis switching signal ZTRM<G225#0>

[Classification] Input signal
[Function] Externally switches the tracing axis between the Z-axis and W-axis.
[Operation] When the three-dimensional machining function is added together with a W-axis tracing function, setting the tracing axis switching signal (ZTRM) to 1 switches the tracing axis to the Z-axis. To enter tracing mode, the TCST signal must be set to 1.

Signal address

	#7	#6	#5	#4	#3	#2	#1	#0
G225								ZTRM

7.5 APPROACH FEED

Overview

If the three-dimensional machining function is added with a W-axis tracing function, setting the approach feed signal (ZAPR) to "1" selects the approach feed mode. During the approach feed mode, when the tracing sensor signal becomes 0 or grater (too close to the workpiece), jog feed in the X-, Y-, and Z-directions stops. This function enables the nozzle to stop when it gets too close to the workpiece during jog feed, and therefore, it can be used in teaching.
To release the stop state, set the approach feed signal (ZAPR) to 0, turn off the jog feed select signal, then specify jog feed such that the nozzle is retracted from the workpiece.

Signal

- Approach feed signal ZAPR<G225#1>

[Classification] Input signal
[Function] Enables the stopping of jog feed according to the tracing sensor signal.
[Operation] When the three-dimensional machining function is added together with a W-axis tracing function, setting the approach feed signal (ZAPR) to 1 selects approach feed mode. During approach feed mode, when the tracing sensor signal becomes 0 or greater (too close to the workpiece), jog feed in the X-, Y-, and Z-directions stops.

Signal address

	#7	#6	#5	#4	#3	#2	#1	#0
G225							ZAPR	

Parameter

15552	Minimum position shift for stopping approach

[Data type] Word
[Unit of data] 0.001mm
[Valid data range] 0 to 32767
[Standard setting value] 50
When the nozzle is moved toward the workpiece by approach feed, jog feed is stopped once the detected position shift in the negative direction exceeds the value set in this parameter.

7.6 PROXIMITY POINT SEARCH FUNCTION

Overview

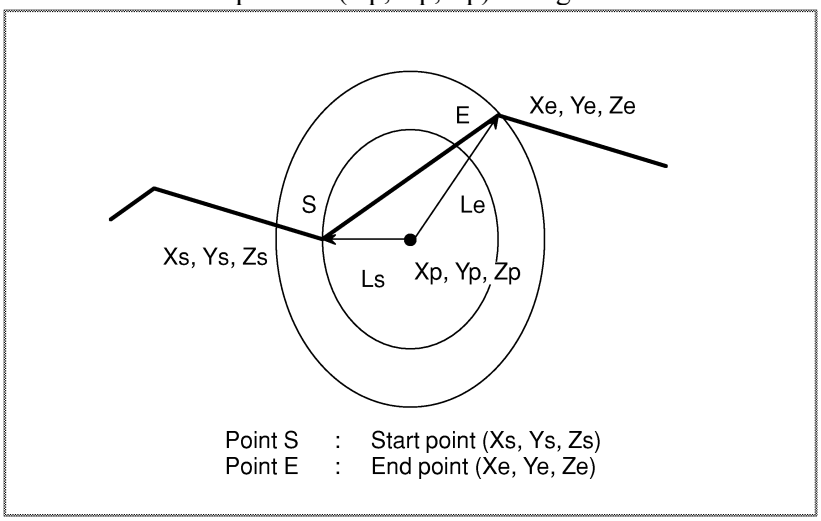
This function can search for the start point of a block located within the constant distance specified in the appropriate parameter from the current nozzle position, and position the tool at that position so that machining can restart at that position.

Operation

After the program is set and the memory operation mode is selected, triggering a cycle start with the proximity point search signal (NRSRH) set to "1" causes a search through the program for a block with the following condition. The search begins at the first block. When this search starts, the proximity point search in progress signal (LNSR) and automatic operation started signal (STL) are set to "1".
When a block with the following conditions is found, the nozzle is positioned at the beginning of this block. After nozzle positioning is completed, the machine stops, and the automatic operation started signal (STL) is reset to "0". Under this condition, resetting the proximity point search signal (NRSRH) to "0" and triggering a cycle start will reset the LNSR signal and cause machining to begin at the block found.

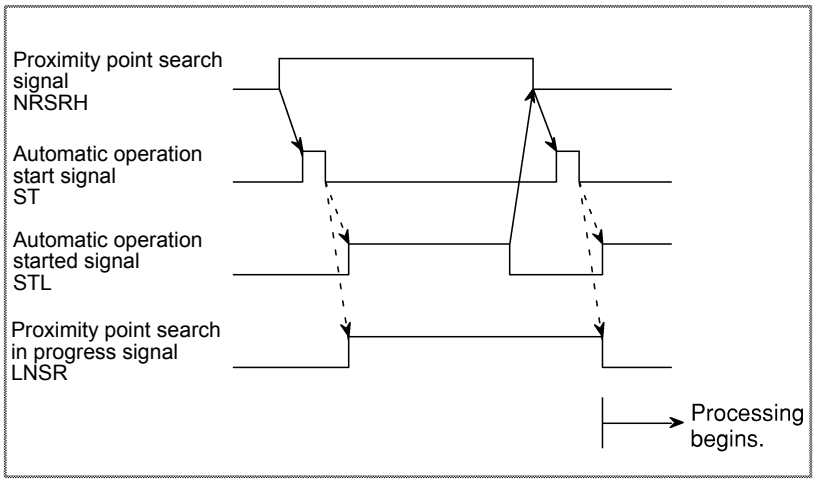
Conditions for a block to be searched for

(1) Distance Ls from the start point (Xs, Ys, Zs) of a block to the current nozzle position (Xp, Yp, Zp) is smaller than distance L specified in parameter No. 15635.
(2) Distance Le from the end point (Xe, Ye, Ze) of a block to the current nozzle position (Xp, Yp, Zp) is larger than distance Ls.



Timing chart

The timing chart for a proximity point search is shown below.
When the automatic operation started signal (STL) becomes "0", the proximity point search signal (NRSRH) should be turned from "1" to "0".



Cautions

1 The program on which to execute the proximity point search function must be the one that was executed in memory operation immediately before a proximity point search is executed. Otherwise, the proximity point search cannot determine the correct position. The reason for this is that the machine position at the start of normal operation is stored as the reference position when a proximity point search is executed. The buffer used to store this machine position is not provided for each program; only the position for the program that last performed automatic operation (MEM, MDI, or DNC) is stored. Thus, a proximity point search cannot be performed after MDI or DNC operation.

2 A proximity point search cannot be performed on the program that was active immediately before the power is turned on, after the power is turned on.

3 While a proximity point search is being executed, a re-search cannot be performed. Once a proximity point search is executed and a block is found (G226#0 (NRSCH) = 1, F225#1 (LNSR) = 1, F000#5 (STL) = 0), alarm PS4000 is raised if an attempt is made to start a cycle again. To perform a re-search, perform a reset first.

4 If a proximity point search does not find a block in which distance Ls between the current nozzle position and the start point of the block is smaller than the value specified in parameter No. 15635, alarm PS4000 is raised.

5 If, during the execution of a proximity point search, the current nozzle position is near the stored reference position for the proximity point search, the nozzle moves to the stored reference position for the proximity point search.

6 A dwell command is not executed during a proximity point search.

7 During a proximity point search, all M and T codes are output; they must be processed by the PMC.
8 Laser power is not output during a proximity point search.
9 If a search target program contains a command related to reference position return, this command must be followed by an absolute command. During a search, the G27, G28, G29, and G30 commands are ignored, and the coordinates are set up again with the subsequent absolute command.
10 Positioning to the searched-for block is performed on all axes simultaneously. Upon the completion of positioning, the nozzle assumes the position at the start point of the block.
11 In a system with attitude control B attached, if the operation of G53 is not placed in the head fixing mode (bit 3 (MIA) of parameter No. 15600 = 0), alarm PS4002 is raised.
12 If the nozzle is to be positioned in a block in G33 mode, the nozzle is positioned at the coordinates specified by the program. It is not positioned at the end point of the arc automatically inserted.
13 Tracing in a proximity point search must be W-axis tracing. If Z-axis tracing is specified, alarm PS4001 is raised.
14 In the program on which a proximity point search is performed, manual operation must be performed with manual absolute on, regardless of whether it is before or after machining.
15 After a proximity point search, manual intervention is not possible before the program is restarted.
16 During a proximity point search, move commands with the machine coordinate system (G27, G28, G29, G30, and G53) are ignored.
17 If the end point of a block is near the reference position and the next block is G27, G28, G29, G30, or G53, this block is assumed to be near the reference position.

Signal

- Proximity point search signal NRSRH<G226#0>

[Classification] Input signal
[Function] Selects the proximity point search function.
[Operation] 1 Place the system in memory mode.
2 Search for the beginning of the program.
3 Set the proximity point search signal (NRSRH) to "1."
4 Press the start button.
5 The above steps execute a proximity point search.
During the search, the proximity point search in progress signal (LNSR) and the automatic operation started signal (STL) are output.
6 Upon the completion of the search, the automatic operation started signal is set to "0."
Then, set the proximity point search signal to "0" and press the start button.
The proximity point search in progress signal is set to "0" and machining can restart at the searched-for block.

- Proximity point search in progress signal LNSR<F225#1>

[Classification] Output signal
[Function] Notifies the PMC that a proximity point search is in progress.
[Output condition] This signal is set to 1 in the following case:

- When a cycle start is triggered while the proximity point search signal (NRSRH) is set to 1

This signal is set to 0 in the following case:

- When positioning by means of a proximity point search has been completed, after which a cycle start is triggered while the proximity point search signal (NRSRH) is set to 0

Signal address

	#7	#6	#5	#4	#3	#2	#1	#0
G226								NRSRH
F225							LNSR	

Parameter

	#7	#6	#5	#4	#3	#2	#1	#0
15630	NMT	NMC	NSC		NRE	NSR		

[Data type] Bit

NSR During search for a block the automatic operation signal OP (F000#7) is:
0: Posted.
1: Not posted.

NRE When the proximity point search function attempts positioning to the end point,
0: Alarm 4000 (No proximity point is found) is raised.
1: The positioning is allowed.

NSC If, with the program restart function (conforming to the laser specifications) and the proximity point search function, a program is to restart at the end point of the block into which a spatial corner R is to be inserted:
0: The program restarts at the program-specified point at which a corner R is not inserted.
1: The program restarts at the end of the inserted corner R.

NMC With program restart function using attitude control B (laser specifications) and the proximity point search, positioning is:
0: Executed for all axes at the same time. (Note: Executed in non-interpolation mode.)
1: Executed for the fourth and fifth axes first, then for the remaining axes. (Note: Executed in non-interpolation mode.)

NMT If, in a proximity point search, the end point of the block is near the reference position, and the next block is a block without movement:
0: The system searches for the next proximity point.
1: The system assumes the block without movement to be a proximity point.

15635	Proximity point distance for a proximity point search

[Data type] 2-word
[Unit of data] 0.001mm
[Valid data range] 0 to 99999999

Sets the reference distance for proximity point search.
A block is determined to be a proximity point block when distance Ls from the start point of the block to the current nozzle position is smaller than the distance specified in parameter No. 15635, and distance from the end point of the block to the current nozzle position is larger than distance Ls.

Alarm and message

No.	Message	Description
4000	P/S ALARM	In a proximity point search, no proximity point has been found until "END OF RECORD."
4001	P/S ALARM	In a proximity point search, the tracing axis is the Z-axis.
4002	G CODE UNAVAILABLE DURING SEARCH	In a proximity point search, G53 is specified in independent axis mode (bit 3 (MIA) of parameter No. 15600 = 1).

7.7 MANUAL OPERATION IN HAND COORDINATE SYSTEM

Overview

In attitude control A and attitude control B, the coordinate system defined from the current nozzle position, with the nozzle head assumed its zero point, is called the hand coordinate system. In the hand coordinate system defined in an arbitrary space, operation can be performed on one or more axes at the same time using the feed signal for a single X, Y, or Z axis, achieving axial movement in the hand coordinate system.
The use of this function facilitates the positioning of the nozzle when creating programs through teaching.

Definition of the hand coordinate system

(1) For attitude control A (zero-offset type head)
- The direction of the normal of the nozzle is defined as +Zh.
- Assuming a point that lies on a line parallel to +Y from point A of the reference position to be point B, the direction from the nozzle head and parallel to AB is defined as +Yh.
- Assuming the direction of the index finger of the left hand to be +Yh and the direction of the thumb to be +Zh, the direction of the middle finger of the left hand that is at right angles to them is defined as +Xh.

(2) For attitude control B (offset-type head)
- The direction of the normal of the nozzle is defined as +Zh.
- The direction of the arm on the α axis is defined as +Xh.
- Assuming the direction of the middle finger of the left hand to be +Xh and the direction of the thumb to be +Zh, the direction of the index finger of the left hand that is at right angles to them is defined as +Yh.

Jog feed

Jog feed axis direction signals ±X, ±Y and ±Z enable travel in the direction of ±"Xh, ±Yh, and ±Zh, respectively.
Simultaneous operation of one axis is performed for jog feed using the hand coordinate system if axes include the α and β axes.
When jog feed axis direction signal $\pm\alpha$ and $\pm\beta$ are specified, the rotation axis operates in the nozzle head fixing mode. When execution of the command for the rotation axis is stopped, the hand coordinate system is updated to an new coordinate system. Then, the linear axis command is executed for the hand coordinate system.

Handle feed

When the signal for selecting an axis for manual handle feed, HX, is turned on, a feed can be performed in the direction of the ±Xh axis using the manual pulse generator.
In the same way, the ±HY and ±HZ signals enable travel in the direction of the ±Yh and ±Zh axes.
When hand coordinate system mode select signal HNDCD is 1, handle feeds using H4 (4th axis: α axis) and H5 (5th axis: β axis) are not possible.
To perform handle feeds of the α and β axes, the HNDCD signal must be set to 0. When the signal for selecting an axis for manual handle feed, H4 or H5, is selected, the machine tool can easily be operated by coding a ladder program that sets the HNDCD signal to 0.

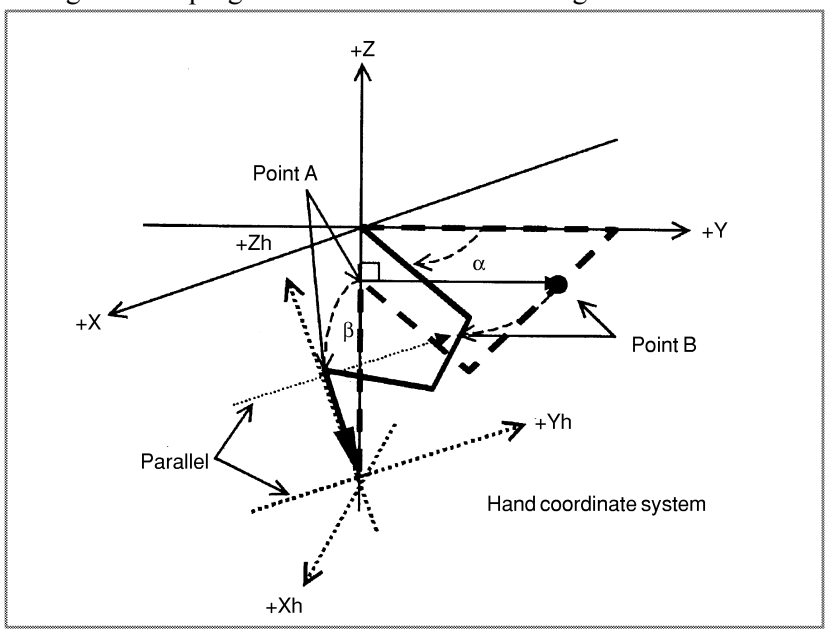


Fig. 7.7 (a) For attitude control A

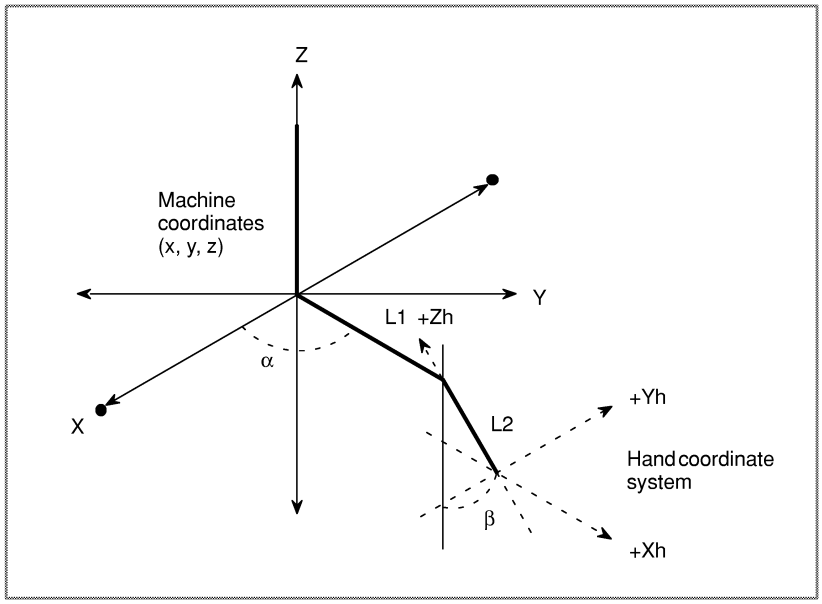


Fig. 7.7 (b) For attitude control B

Caution

The manual feed speeds on the X, Y, and Z axes must be the same.

Signal

- Hand coordinate system mode select signal HNDCD<G226#3>

[Classification] Input signal

[Function] Enables jog and handle feed in a coordinate system defined from the current nozzle position, with the nozzle head assumed its zero point.

[Operation] When the hand coordinate system mode select signal (HNDCD) is set to "1" in manual operation mode, jog and handle feed can be performed in the hand coordinate system.

Signal address

	#7	#6	#5	#4	#3	#2	#1	#0
G226					HNDCD			

8 CONTROL FUNCTION

8.1 OPTICAL PATH LENGTH COMPENSATION

Overview

The distance between the oscillator and the condensing lens varies as the reflecting mirror moves along its axis (if there is one). The light propagation distance at which a stable processing characteristic is realized is generally limited to within a certain range. In a large machine, in which the reflecting mirror has to move a long distance exceeding such a limit because of its mechanical structure, it has been conventionally impossible to maintain a stable characteristic over the entire stroke. The optical path length compensation function is developed to avert this problem. This function consists of an axis to adjust the length of the optical path. If a move command is issued to the reflecting mirror, the optical path adjustment axis is automatically moved to keep the optical path length.

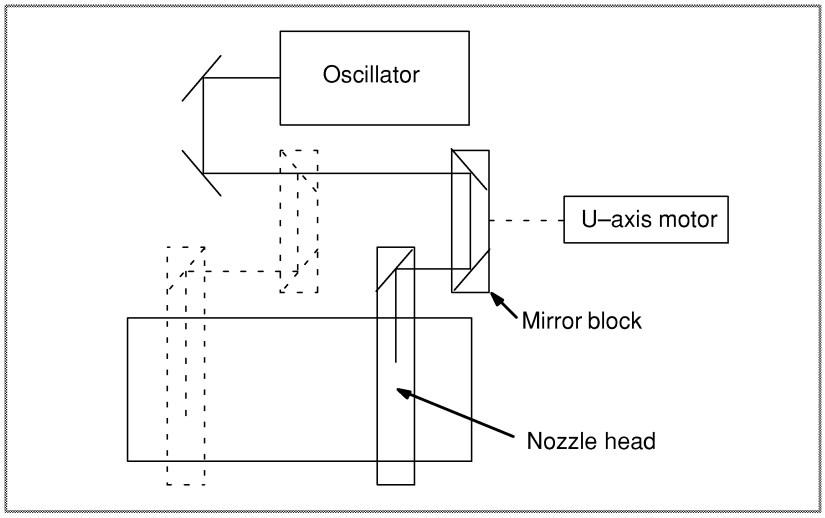
Function selection

When the option for optical path length compensation is specified, resetting bit 1 (FMS) of parameter No. 15702 to "0" enables optical path length compensation.

Mechanism to implement control

The mechanism described below is necessary to use optical path length compensation.

1 Prepare an axis (called the U-axis) that enables the beam-reflecting mirror block to move linearly in order to change the light propagation distance.
2 Configure the U-axis so that moving the mirror block changes the light propagation distance α (1 to 511) times as large as the distance through which the mirror block moves.
3 Configure the U-axis so that its maximum speed is not lower than $1/\alpha$ of the total rapid traverse rate of the axis along which the optical path is changed.
4 Prepare a reference position for all axes including the U-axis. The length of the optical path is calculated based on the reference position.
5 Provide a measure to prevent interference between the U-axis and any other axes.



Controlled axes

The following conditions apply to the controlled axes.

1 Either an incremental pulse coder or absolute pulse coder (APC) can be used for a controlled axis. The two types can be used in one system; it is allowed to use an incremental for one controlled axis and an absolute for another.

2 The U-axis can be assigned to any axis from the fourth to the eighth. Which axis to use is specified using parameter No. 15703.

3 Because the U-axis move command is determined from the move distance of an axis on which the optical path length varies, a controlled axis (except the U-axis) on which the optical path length changes is specified in parameter No. 15700.

4 If the move direction of an axis on which the optical path length changes does not match the polarity of the change in the optical path length, the polarity can be inverted using parameter No. 15701 for calculation purposes.

5 Parameter No. 15702 can specify whether to reflect the move amount of a controlled axis under tracing control in the move command for the U-axis.

6 Optical path length compensation is available.
The optical path length with all axes (including the U-axis) at the reference position is regarded as the reference optical path length. This optical path length can be compensated for error. As a result, the reference optical path length can be set up regardless of where the reference position is set up.
If parameter No. 15704 specifies a mirror position compensation value, setting the optical path length compensation start signal (LRCS) to "1" with all axes at the reference return position causes the U-axis to shift automatically from the reference position by the specified distance, then triggers optical path length compensation.
For the APC axis, even if it has not returned to the reference position, the LRCS signal is accepted provided that the reference position has been established.

Move command calculation and setting

The amount of U-axis movement is calculated as follows:

$$\Delta U = \frac{64}{\text{Parameter No.15705}} (\pm \Delta X \pm \Delta Y \pm \Delta Z...)$$

$\Delta U, \Delta X, \Delta Y, \Delta Z...$: Move command value for each axis

The U-axis is defined only for the machine coordinate system, which is updated according to the above calculation.
For axes not specified in parameter No. 15700, the move command value is assumed to be 0 for calculation purposes. For axes on which polarity inversion is specified in parameter No. 15701, the algebraic sign is inverted for calculation purposes. Parameter No. 15705 specifies the ratio of the move distance of an axis on which the optical path length varies to the distance traveled by the U-axis to resume the original optical path length.

Activation of optical path length compensation

Optical path length compensation should be activated according to the following procedure.

1 After the U-axis and all axes selected in parameter No. 15700 (described later) have returned to the reference position, select the job mode, and set the optical path length compensation start signal (LRCS) to "1", and optical path length compensation will begin.
If an APC is used, it is unnecessary to execute a reference position return for axes for which the reference position has been established.
2 The optical path length compensation signal (LRCS) is acceptable only in the jog mode. A ladder program should set the LRCS signal to "1" after the jog mode is securely selected.
3 The CNC monitors the optical path length compensation start signal (LRCS) for both its rising and steady states. So, this signal should stay at "1" as long as optical path length compensation is being carried out.
4 When optical path length compensation begins, the optical path length compensation signal (LCIN) becomes "1".
5 Whatever the current operation mode is, optical path length compensation is stopped when the optical path length compensation start signal (LRCS) becomes "0".

Optical path length compensation stop

If an emergency stop, servo-off, or U-axis overtravel occurs, the CNC judges that optical path length compensation cannot continue. The CNC also sets the coptical path length compensation stop request signal (CSTP) to "1" and posts it to the PMC.

Restart in the stop state

The PMC should be provided with a ladder program that performs the following restart procedure when the optical path length compensation stop request signal (CSTP) becomes "1".

1 The optical path length compensation start signal (LRCS) is reset from "1" to "0" when the optical path length compensation stop request signal (CSTP) becomes "1".
2 The current operation mode is stored.
3 When the error mentioned above is reset, the jog mode is selected after the servo preparation completion signal (SA) is kept at "1" for at least 50 ms.
4 A reference position return is carried out for all axes (except in a system with an APC).
5 After it is confirmed that a reference position return has been completed for all axes, the optical path length compensation start signal (LRCS) is turned from "0" to "1".
6 After it is confirmed that the optical path length compensation signal (LCIN) is "1", the original operation mode is resumed.

Note

1 The U-axis is provided with overtravel and stored stroke limits.
2 If the mirror block on the U-axis interferes with any axis, a provision to detect the interference and stop operation should be made on the machine side.
3 The optical path length compensation start signal (LRCS) must be kept at "0" in the manual reference position return mode. For this purpose, a ladder program should select the jog mode after a reference position return is completed, and then set the optical path length compensation start signal (LRCS) to "1".
4 The machine coordinates of the U-axis may encounter an error in 0.001 mm units (if the least input increment is IS-B) depending on a value specified in parameter No. 15704. But it does not affect the machining characteristic.
5 Before setting the optical path length compensation start signal (LRCS) to "1" in a machine in which all axes operate on APCs, allow at least 50 ms after the servo completion signal (SA) becomes "1"
6 Do not issue a move command (regardless of whether it is automatic or manual) to the U-axis during optical path length compensation.
7 An individual machine lock for the U-axis does not work during optical path length compensation.

Signal

- Optical path length compensation start signal LRCS<G224#0>

[Classification] Input signal
[Function] Starts optical path length compensation.
[Operation] Optical path length compensation begins when the optical path length compensation start signal (LRCS) is set to "1" with all axes at the reference position. If an axis on which the optical path length changes moves, the U-axis (optical path length adjustment axis) moves in order to cancel the change in optical path length and resume the original optical path length.

- Optical path length compensation signal LCIN<F223#0>

[Classification] Output signal
[Function] Informs the PMC that optical path length compensation is under way.
[Output condition] This signal becomes “1” when:
- Optical path length compensation begins.

This signal becomes “0” when:
- The optical path length compensation start signal (LRCS) becomes "0".
- The optical path length compensation stop request signal (CSTP) becomes "1".

- Optical path length compensation stop request signal CSTP<F223#1>

[Classification] Output signal
[Function] Informs the PMC that optical path length compensation cannot continue.
[Output condition] This signal becomes “1” when:
- An emergency stop, servo-off, or U-axis overtravel occurs.

This signal becomes “0” when:
- The cause of the stop request is removed, and the optical path length compensation start signal (LRCS) is acceptable.

Signal address

	#7	#6	#5	#4	#3	#2	#1	#0
G224								LRCS
F223							CSTP	LCIN

Parameter

	#7	#6	#5	#4	#3	#2	#1	#0
15700	8	7	6	5	4	Z	Y	X

[Data type] Bit

X to 8
0: Axis on which the length of the optical path changes (used as a basis for calculation of the U-axis move command)
1: Axis on which the length of the optical path does not change (not used as a basis for calculation of the U-axis move command)

> ⚠ **CAUTION**
> Specify 0 for non-existing axes.

	#7	#6	#5	#4	#3	#2	#1	#0
15701	8	7	6	5	4	Z	Y	X

[Data type] Bit

X to 8
0: Does not invert the polarity of the calculated move amount for the axis.
1: Inverts the polarity of the calculated move amount for the axis.

> ⚠ **CAUTION**
> Specify 0 for non-existing axes.

	#7	#6	#5	#4	#3	#2	#1	#0
15702	MRO					MCO	FMS	TXC

[Data type] Bit

TXC
0: Specifies to include the move amount of a controlled axis under tracing control in the move command calculation for the U-axis.
1: Specifies not to include the move amount of a controlled axis under tracing control in the move command calculation for the U-axis.

FMS
0: Specifies to enable optical path length compensation.
1: Specifies to disable optical path length compensation.

MCO The sign of the compensation amount for the reference position of the axis of mirror movement is:
0: Plus.
1: Minus.

MRO The optical path length compensation stop request signal is set to 1 when:
0: An overtravel occurs on the mirror block axis.
1: An overtravel occurs on the mirror block axis and the axis specified in parameter No. 15700.

15703	MIRAXS

[Data type] Byte

[Unit of data]

[Valid data range] 4 to 8

Selects which axis to be used as the U-axis along which the mirror block moves.

15704	U-axis reference position compensation value

[Data type] Word
[Unit of data] mm
[Valid data range] -32767 to 32767
[Standard setting value] 0

This value is specified as a distance from the reference position so that the position of the mirror block axis (U-axis) is compensated to obtain the optimum propagation distance

15705	Optical path length compensation coefficient

[Data type] Word
[Unit of data] 1/64
[Valid data range] 64 to 32767
[Standard setting value] 128

The result of adjusting the total movement of the axes specified in parameter No. 15700 with this coefficient is used as a move command for the U-axis.

Alarm and message

No.	Message	Contents
4056	OPT. PATH NOT SET	The mirror block position cannot be corrected. The position of the U-axis (mirror block move axis) cannot be calculated from the current position of any axis. Perform reference position return.

8.2 MACHINING CONDITION SETTING FUNCTION

Overview

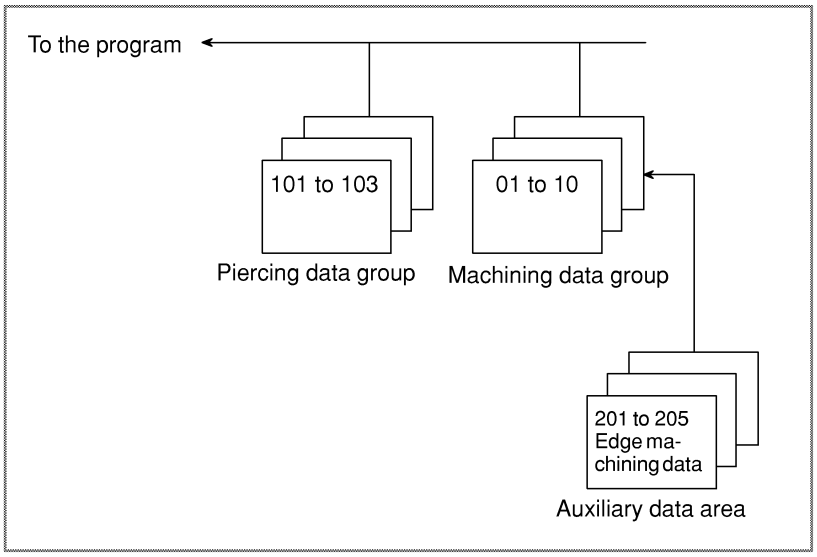
Items necessary for laser machining are grouped, and the related data items are numbered and registered in a data area. Specifying a data number by a program causes the associated data to be read for laser machining.
The data area has a storage capacity to hold the groups of data necessary for machining one type of workpiece (such as material quality and plate thickness). Simply specifying the data number can set the necessary conditions for machining. Because the data area assures high-speed access, the data in it can be readily changed by manual operation during program execution. Moreover, the changed data can be registered in the data area, enabling easy update of machining conditions.

Data area configuration

(1) Data items are assembled in sets, the data item sets are grouped, and the data item groups constitute a data area.
(2) The data area consists of a piercing data group, machining data group, and auxiliary data group.
(3) The program can specify piercing and machining data groups using address E followed by a set number.

Exxx ;
Machining data set number: 001 to 010
Piercing data set number: 101 to 103

(4) The auxiliary data group is specified among data items in the machining data group. It cannot be specified directly using address E.



Data group items

- Piercing data group

Piercing data items are provided for the high-speed piercing function as described below.
To specify an ordinary piercing function, specify 0 for the step count. In this case, piercing is performed based on the peak value, initial frequency, initial duty cycle, and piercing time. See the chapter for the high-speed piercing function for how high-speed piercing is performed.

(1) The piercing data group consists of the items listed below.

Item	Setting range	Setting unit
Peak value	0 to 9999	W
Initial frequency	5 to 2000	Hz
Initial duty cycle	0 to 100	%
Frequency increment	0 to 2000	Hz
Duty cycle increment	0 to 99	%
Step time	0 to 9.999	s
Step count	0 to 99	Cycle
Piercing time	0001 to 999.999	s
Assist gas pressure	0 to 2.55	MPa
Assist gas type	1 to 7	Type
Assist gas setting time	0 to 9.9	s
Standard shift	-9.999 to 9.999	mm

(2) Capacity
Three sets of the above items constitute a group.

(3) Calling method
If the program specifies a piercing data set number (101 to 103) after address E, the data set corresponding to the specified number is read as active data.

Exxx ;
└── Piercing data set number (101 to 103)

- Machining data group

(1) The machining data group consists of the items listed below.

Item	Setting range	Setting unit
Feedrate	0 to 99999	mm/min
Contouring peak value	0 to 9999	W
Contouring frequency	5 to 2000	Hz
Contouring duty cycle	0 to 100	%
Assist gas pressure	0 to 2.55	MPa
Assist gas type	1 to 7	Type
Assist gas setting time	0 to 9.9	s
Standard shift	-9.999 to 9.999	mm
Beam diameter correction amount	-9.999 to 9.999	mm
Edge machining selection	0/201 to 205	Auxiliary data number
Start-up selection	0/201 to 205	Auxiliary data number

(2) Capacity
Ten sets of the above items constitute a group.

(3) Calling method
If the program specifies a machining data set number (001 to 010) after address E, the data set corresponding to the specified number is read as active data for control when a cutting feed command is executed.

Exxx ;
└──── Machining data set number (001 to 010)

- Auxiliary data group

An edge machining data group is provided as auxiliary data group. The edge machining data is used for making sharp corners and in a start-up function for a shift from piercing to figure cutting. The edge machining data is called from the "edge machining selection" or "start-up selection" item of the machining data group.
See the chapters for the edge machining function and start-up function for detailed descriptions of edge machining and start-up operation, respectively.

(1) The edge machining data group consists of the items listed below.

Item	Setting range	Setting unit
Edge machining angle	0 to 180	Degrees
Piercing peak value	0 to 9999	W
Piercing peak frequency	5 to 2000	Hz
Piercing peak duty cycle	0 to 100	%
Piercing peak time	0 to 999.999	s
Piercing peak assist gas pressure	0 to 2.55	MPa
Piercing peak assist gas type	0 to 99	Type
Return distance	0 to 99.999	mm
Return speed	0 to 9999	mm/min
Return frequency	5 to 2000	Hz
Return duty cycle	0 to 100	%

(2) Capacity
Five sets (201 to 205) of the above items constitute a group.

(3) Calling method
The edge machining data is called indirectly. If the "edge machining selection" or "start-up selection" item of the machining data group is set with a number from 201 to 205, the edge machining data is called simultaneously with the machining data.

Data area display

(1) Soft key
Pressing the <OFFSET/SETTING> key on the MDI causes the following soft keys to appear.

MACHINING	PIERCING	EDGE		(OPRT)

(2) Data name display
The name of the currently displayed data appears at the top of the screen.
Example
[MACHINING DATA], [PIERCING DATA]

(3) Active data number display
The currently active machining and piercing data set numbers appear after the data name display.
Example
[MACHINING DATA] ACTIVE NO. = 5, PIERCING NO. = 103
To clear the E number with a reset, set bit 6 of parameter No. 15004 to 1.

(4) Data display
- Machining data screen
- Piercing data screen
- Edge machining data screen

Changing data

(1) Data change function based on screen operation
When the corresponding screen is selected for display and the [OPRT] soft key is pressed, it becomes possible to change data. Place the cursor on the desired item and perform the appropriate operations.
(a) When data at the number corresponding to the current machining operation is corrected, the active data except for correction is immediately corrected.
(b) For the correction data, the changed data becomes effective when a block that involves buffer rewriting is executed.

(2) Data correction function based on an external signal
The data of a specified item in the machining data set corresponding to the current machining operation can be incremented and decremented by sending the correction data from the PMC to the CNC.
(a) Specifying the R area
Three bytes of correction data are assigned to the R area of the PMC. Specifying the R area start address in parameter No. 15360 causes three bytes to be secured starting at the start address.

(b) Correction data

The three bytes secured in the R area by a parameter are assigned to "change item specification," "amount of change," and "change scale factor," as described below. The CNC reads the three bytes of data at 16 ms intervals for data correction. The actual change data is the data of an item specified by the "change item specification" (corresponding to the machining data set number selected with the E code) and incremented/decremented by the "amount of change" multiplied by the "change scale factor."

Start address	Change item specification

[Data type] Byte
[Valid data range] 1 to 255

Change item	Data
Feedrate	1
Output	2
Frequency	3
Duty cycle	4
Tracing standard shift	5
Assist gas pressure	6

Start address + 1	Amount of change

[Data type] Byte
[Valid data range] ±127
[Unit of data] See the following table.

Change item	Units
Feedrate	1mm/min
Output	1W
Frequency	1Hz
Duty cycle	1%
Tracing standard shift	0.001mm
Assist gas pressure	0.01MPa

Start address + 2	Change scale factor

[Data type] Byte
[Valid data range] 1 to 255

(c) Data transfer

The CNC reads the "amount of change" at 16 ms intervals. If the read data is not 0, it also reads the "change item specification" and "change scale factor." After reading all data, the CNC writes 0 in the "amount of change" to signify the end of data reception. The PMC should check whether the "amount of change" is 0. If it is 0, the PMC should set new data in the "change item specification" and "change scale factor" (need not be set if the previous data can be used), then rewrite the "amount of change."

Command data

(1) Items of command data
- Feedrate
- Peak value
- Frequency
- Duty cycle
- Assist gas pressure
- Assist gas type
- Standard shift
- Correction value

Override is applied to the feedrate, peak value, frequency, duty cycle, and assist gas pressure.

(2) Command data display
A screen is provided to display command data.

Execution of data

(1) Piercing command
(a) When G24 is executed, a specified E code is written to the piercing data E code buffer. The E code is read from the buffer, and the data set corresponding to the number specified in the E code is read from the data area and used for piercing.

```
G24Exxx ;
      └── Piercing data set number (101 to 103)
```

(b) The piercing data area number can be specified separately. The specified E code is written to the piercing data E code buffer. In this specification method, only the condition is specified at the beginning of the program, and G24; is issued later without specifying the E code.

```
Exxx ;
:  └── Piercing data set number (101 to 103)
:
:
G24 ;
```

(2) Reading machining data
(a) When a cutting command is executed, the specified E code is written to the machining E code buffer. The E code is read from the buffer, and the data set corresponding to the number specified in the E code is read from the data area and used for machining.

```
Cutting feed command { G01 }+   Exxx ;
                     { G02 }      └── Machining data set number
                     { G03 }          (1 to 10)
                     { G12 }
```

(b) The machining data set number can be specified separately. The specified E code is written to the machining E code buffer. In this specification method, only the condition is specified at the beginning of the program, and a cutting feed command is issued later without specifying the E code.

```
Exxx ;
:
:
:
:
G01X_Y_;
```

Machining data set number (1 to 10)

(3) Switching the assist gas type

G32 is used to turn on and off the assist gas and switch the gas type between piercing assist gas and machining assist gas. The shutter is opened and closed simultaneously when the assist gas is turned on and off. However, shutter open/close control can be disabled by setting a parameter.

```
G32Lx ;
```

0 = stop the assist gas.
1 = select the machining assist gas.
2 = select the piercing assist gas.

(4) Sample program

```
G92 X- Y- Z-;      : Select the coordinate system.
E001;              : Specify the machining data set number in
                     the data area.
E101;              : Specify the piercing data set number in the
                     data area.
M200;[macro call]
    G32L2;         : Activate the assist gas according to the E101
                     data and open the shutter.
    G24;           : Perform piercing according to the E101 data.
    G32 L1;        : Switch the assist gas type according to the
                     E001 data.
G01 X-Y-;          : Perform start-up machining if an auxiliary
                     data set number is specified in the "start-up
                     selection" item.
X-Y-;              : Execute cutting according to the E001 data.
:
:
:
M201;[macro call]
  G32L0;           : Stop the assist gas and close the shutter.
M30;               : End the program.
```

Data expansion

The data area for the machining condition setting function can be accessed at high speed, but its capacity is not big. To handle many types of workpiece materials, it is necessary to prepare a separate data file and transfer the necessary data from the data file to the data area. By enhancing the battery-powered memory that can be controlled by the PMC and the CNC-PMC window function, application software for using the battery-powered memory as a data file was developed using the PMC C language.

- Reading comments

An M code is available for transferring comments. The M code can be specified in parameter No. 15350. The M code can pass a comment consisting of up to 24 alphanumeric characters to the PMC using the window function. The comment can be used to specify the material of a workpiece.

```
Mxxx (**************) ;
          |
          |____ Up to 24 alphanumeric characters, including a
                decimal point and sign
```

In this M code, xxx is a value specified in parameter No. 15350.

- Transferring data

(1) Data transfer using the PMC-CNC window function
The PMC-CNC window function enables data transfer between the CNC data area and the battery-powered memory. In this method, all machining conditions are previously registered in the battery-powered memory, and the necessary data is specified using the M code for comment reading and transferred to the data area, in order to assure high-speed access during machining.

(2) Data transfer between the data area and macro executer
System variables have been assigned to data items so that data can be read from and written to the data area using conversational macros and execution macros.

(a) Piercing data

Item	101	102	103
Peak value	#6500	#6515	#6530
Initial frequency	#6501	#6516	#6531
Initial duty cycle	#6502	#6517	#6532
Frequency increment	#6503	#6518	#6533
Duty cycle increment	#6504	#6519	#6534
Step time	#6505	#6520	#6535
Step count	#6506	#6521	#6536
Piercing time	#6507	#6522	#6537
Assist gas pressure	#6508	#6523	#6538
Assist gas type	#6509	#6524	#6539
Assist gas setting time	#6510	#6525	#6540
Standard shift	#6511	#6526	#6541

(b) Machining data

Item	001	002	003	004	005
Feedrate	#6300	#6315	#6330	#6345	#6360
Contouring peak value	#6301	#6316	#6331	#6346	#6361
Contouring frequency	#6302	#6317	#6332	#6347	#6362
Contouring duty cycle	#6303	#6318	#6333	#6348	#6363
Assist gas pressure	#6304	#6319	#6334	#6349	#6364
Assist gas type	#6305	#6320	#6335	#6350	#6365
Assist gas setting time	#6306	#6321	#6336	#6351	#6366
Standard shift	#6307	#6322	#6337	#6352	#6367
Cutter compensation amount	#6308	#6323	#6338	#6353	#6368
Edge machining selection	#6309	#6324	#6339	#6354	#6369
Start-up selection	#6310	#6325	#6340	#6355	#6370

Item	006	007	008	009	010
Feedrate	#6375	#6390	#6405	#6420	#6435
Contouring peak value	#6376	#6391	#6406	#6421	#6436
Contouring frequency	#6377	#6392	#6407	#6422	#6437
Contouring duty cycle	#6378	#6393	#6408	#6423	#6438
Assist gas pressure	#6379	#6394	#6409	#6424	#6439
Assist gas type	#6380	#6395	#6410	#6425	#6440
Assist gas setting time	#6381	#6396	#6411	#6426	#6441
Standard shift	#6382	#6397	#6412	#6427	#6442
Cutter compensation amount	#6383	#6398	#6413	#6428	#6443
Edge machining selection	#6384	#6399	#6414	#6429	#6444
Start-up selection	#6385	#6400	#6415	#6430	#6445

(c) Edge data

Item	201	202	203	204	205
Edge operation angle	#6700	#6715	#6730	#6745	#6760
Piercing peak value	#6701	#6716	#6731	#6746	#6761
Piercing frequency	#6702	#6717	#6732	#6747	#6762
Piercing duty cycle	#6703	#6718	#6733	#6748	#6763
Piercing time	#6704	#6719	#6734	#6749	#6764
Piercing assist gas pressure	#6705	#6720	#6735	#6750	#6765
Piercing assist gas type	#6706	#6721	#6736	#6751	#6766
Return distance	#6707	#6722	#6737	#6752	#6767
Return speed	#6708	#6723	#6738	#6753	#6768
Return frequency	#6709	#6724	#6739	#6754	#6769
Return duty cycle	#6710	#6725	#6740	#6755	#6770

(d) Active E code

Item	-
Piercing data set number	#6030
Machining data set number	#6031

- Reading command data

Command data can be read during execution.

(1) Reading command data from the PMC
Command data can be read from the PMC through the CNC-PMC window.

(2) System variable for the command data
System variables have been assigned so that the macro executer can access command data.

Item	Variable
Feedrate	#6040
Peak value	#6041
Frequency	#6042
Duty cycle	#6043
Assist gas pressure	#6044
Assist gas type	#6045
Standard shift	#6046
Correction amount	#6047

Parameter

	#7	#6	#5	#4	#3	#2	#1	#0
15004		ECH						

[Data type] Bit

ECH With a reset, the active E number is:
0: Not erased.
1: Erased.

15350 **Comment read M code**

[Data type] Word
[Unit of data]
[Valid data range] 1 to 999
Specify the code number of the auxiliary function for reading comments.

15360 **Correction data R area start address**

[Data type] Word
[Unit of data]
[Valid data range] 1 to 997
Specifying the R area address in the PMC enables correction data to be assigned, starting at this address. If the correction function is not used, this parameter should be reset to 0.

> ⚠ **CAUTION**
> Function codes 183 and 184 are supported by the FS16-LA and FS16-LB, but not by the FS16*i*-LB. (When nonvolatile memory expansion is used, C for the PMC is required. Use C to access battery-powered memory.)

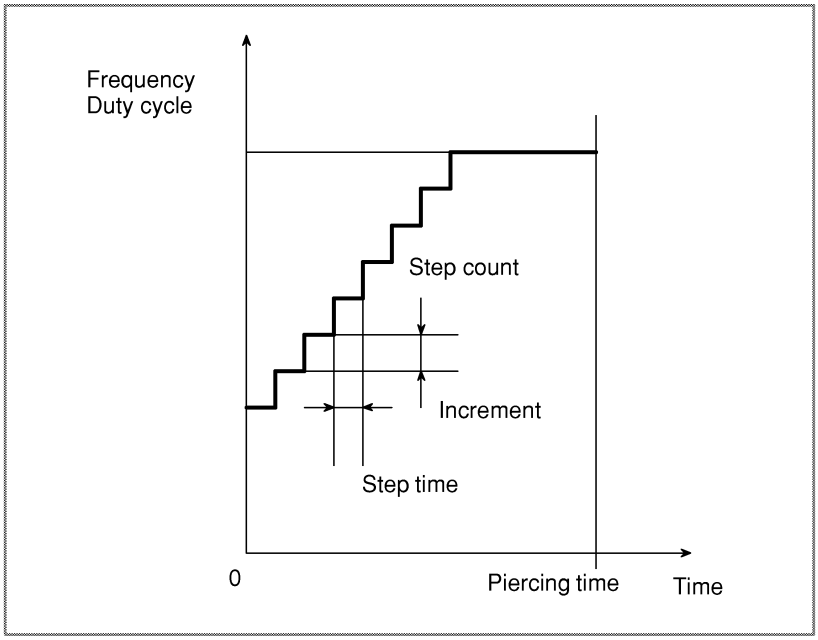
8.3 PIERCING FUNCTION

Overview

The output power for piercing is changed in steps so that the optimum output power can be selected according to the requirement of a particular application. Applying the optimum power enables stable piercing with the shortest possible time.

Control method

(1) Output control
The average output is controlled by fixing the output peak value and increasing the pulse frequency and duty cycle in every unit time.



Setting

Piercing is performed by setting the following items.
When the machining condition setting function is used, the following items can be registered in advance for three sets.

1 Peak value
2 Initial frequency
3 Initial duty cycle
4 Frequency increment
5 Duty cycle increment
6 Step time
7 Step count
8 Piercing time
9 Assist gas pressure
10 Assist gas type
11 Assist gas setting time
12 Standard shift

Operation

Piercing is performed as follows:

(1) The assist gas selection signals (AG1 to AG3) are asserted to output an analog signal indicating the assist gas pressure.
(2) When the assist gas setting time elapses, an output command is executed according to the specified peak value, initial frequency, and initial duty cycle.
(3) When the specified step time elapses, the frequency and duty cycle are increased by the specified increment.
(4) After the frequency and duty cycle are repeatedly varied as many times as the step count at intervals of the specified step time, the output is kept unchanged.
(5) When the piercing time elapses, the piercing operation is terminated.

Command

(1) When the machining condition setting function is used
  (a) Selecting the piercing data
  Issuing a command with the E address followed by a piercing data set number causes the data corresponding to the specified number to be selected.
    E101 ;
  (b) Command
  After selecting the piercing data, issuing G24; starts piercing.
    E101 ;
    G24 ;
  (c) Selecting the assist gas
  To perform piercing with the assist gas specified as the piercing data, use the following commands.

E101 ;	Specify a piercing data set.
E5 ;	Specify a machining data set.
G32L2 ;	Select the assist gas data (L1 = machining data group; L2 = piercing data group)
G24 ;	Piercing command

(2) Command using the G code
  G24S - P - Q - I - J - K - H - R - ;
  where
    S : Output peak value
    P : Initial pulse frequency
    Q : Initial pulse duty cycle
    I : Frequency increment
    J : Duty cycle increment
    K : Step time
    H : Step count
    R : Piercing end time

Function for changing piercing time from the outside

When this function is used for piercing, the following operation takes place.

(1) If "prolongation" is operated on during piercing, the final continuation time is extended.
(2) If "curtailment" is operated on during piercing, piercing ends at the rising edge of the signal.
(3) If either "prolongation" or "curtailment" is operated on, bit 1 of parameter No. 15003 can be used to specify whether to update the piercing time set in a parameter. When the piercing condition, which is set in the data area for the machining condition setting function, is selected, however, the piercing time set in the parameter cannot be updated.

Override

No override is applied to the piercing data (such as output peak value, frequency, or duty cycle).

8.4 EDGE MACHINE FUNCTION

Overview

The edge machine function consists of edge detection, deceleration and stop control, piercing, and feedrate and power control for a shift from piercing to cutting. This function is intended to produce a sharp edge.

Conditions for use

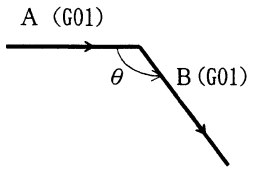
The following conditions apply to use of this function.

(1) The machining condition setting function (option) is required.
(2) The automatic corner override function cannot be used with this function.
(3) Automatic corner deceleration cannot be used with this function.

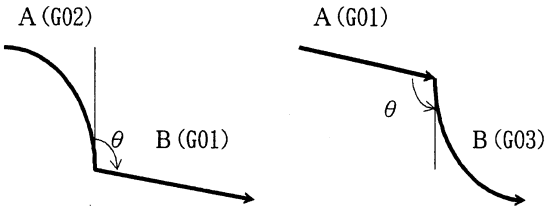
Edge decision

(1) Angle
Corner θ made by two cutting feed blocks (A and B) is calculated in G64 mode (cutting feed).

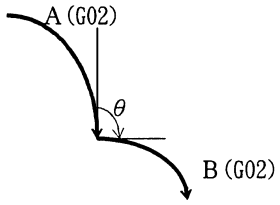
(a) Straight line to straight line



(b) Straight line to arc



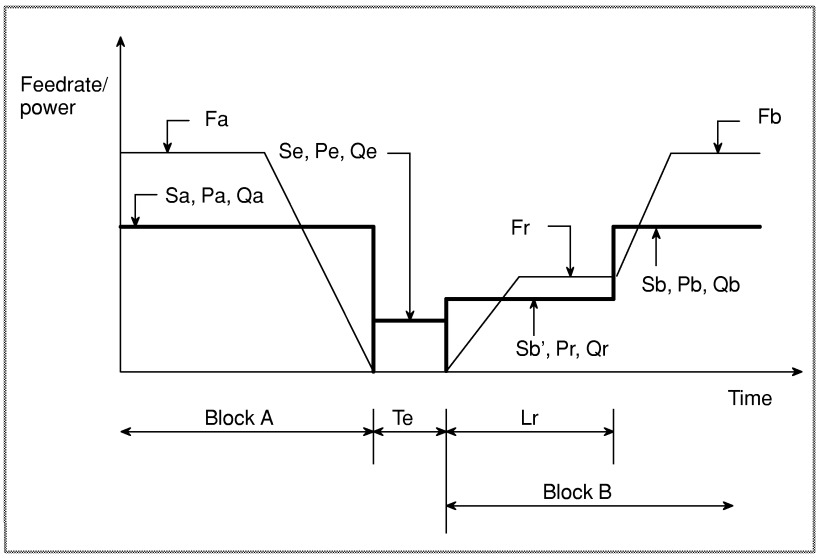
(c) Arc to arc



(2) Edge
If a calculated angle is smaller than or equal to the specified value, it is assumed to be a corner, and the nozzle decelerates and stops at the end point of block A for feedrate and power control.

Operation

The operation shown below occurs during a shift from block A to block B.



Data for block A

Fa : Feedrate in block A
Sa : Output peak value in block A
Pa : Pulse frequency in block A
Qa : Pulse duty cycle in block A

Edge machining data

Se : Piercing output peak value
Pe : Piercing pulse frequency
Qe : Piercing pulse duty cycle
Te : Piercing time
Lr : Return distance
Fr : Return speed
Pr : Return frequency
Qr : Return duty cycle

Data for block B

Fb : Feedrate in block B
Sb : Output peak value in block B
Pb : Pulse frequency in block B
Qb : Pulse duty cycle in block B

(1) The nozzle decelerates and stops at the end point of block A.
(2) The output power is maintained until the nozzle decelerates and stops.
(3) When piercing ends, movement specified in block B begins.
(4) Before shifting to block B, the feedrate is set to the return speed, the output is set to the peak value for cutting specified in block B, the return frequency, and duty cycle. The operation of block B starts under these conditions and continues until the return distance is moved through.
(5) After the nozzle moves through the return distance, the machining conditions of block B are selected, and machining continues under these conditions.

Setting the data

The data area for the machining condition setting function can hold five sets of the data listed below.

Item	Setting range	Setting unit
Edge operation angle	0 to 180	Degrees
Piercing peak value	0 to 7000	W
Piercing pulse frequency	5 to 2000	Hz
Piercing pulse duty cycle	0 to 100	%
Piercing time	0 to 999.999	s
Piercing assist gas pressure	0 to 2.55	MPa
Piercing assist gas type	0 to 7	-
Return distance	1 to 99.999	mm
Return speed	1 to 9999	mm/min
Return frequency	5 to 2000	Hz
Return duty cycle	0 to 100	%

The return distance must not exceed the length of one block.

Return peak value Sb' can be specified in parameter No. 15059.

This is intended to use the output peak value Sb' that is different from the peak value Sb of block B during movement through the distance Lr. If this parameter is 0, machining is performed with Sb' = Sb.

Selecting the edge function

The edge machine function is enabled by setting an edge data number from 201 to 205 in the "edge selection" item in the machining data group. To disable this function, reset the "edge selection" item to 0.

Edge machining command

If a program specifies a machining data set number using the E address, when the program is executed, the "edge selection" item in the specified machining data is referenced, and the edge data set number is read for edge machining.

Cutter compensation

If a very small block is created for cutter compensation, angle decision is made on the angle made by the current block and the very small block, resulting in the angle differing from the one specified by the program. If cutter compensation is applied during edge machining, a very small block is created at the edge, causing the following operations.

1 Piercing is performed before the very small block created for cutter compensation.

2 Execution of the very small block begins with the return data, and operation continues to the next block. After the return distance is moved through, the programmed machining conditions are applied.

To execute edge machining with the path on the machining program in cutter compensation mode, set bit 3 of parameter No. 15007 to 1.

Assist gas

If assist gas switching is to occur during piercing for edge creation, bit 4 of parameter No. 15004 can be used to specify whether to output the laser beam during assist gas setting time.

If assist gas switching is not to occur, specify 0 at assist gas selection or select the same assist gas data as for machining.

If, in the process of assist gas switching at the start of piercing for edge machining, at the start of the subsequent return distance cutting, and at the start of start-up machining, the specified assist gas setting time is to be ignored when the gas type and gas pressure defined with the specified edge selection number and start-up selection number are the same as those for cutting, set bit 3 of parameter No. 15011 to 1.

If machining is to be performed with the assist gas output conditions defined with the specified edge selection number and start-up selection number instead of the assist gas output conditions during return distance cutting in edge machining and start-up machining, set bit 0 of parameter No. 15011 to 1.

If bit 0 of parameter No.15011 and bit 3 of parameter No. 15011 are set at the same time, the setting of parameter No. 15011 takes effect. The setting of bit 3 is ignored.

Override

Override is applied to the following items.

1 Return speed
2 Return peak value
3 Return frequency
4 Return duty cycle

Tracing control

During edge machining tracing control, a value specified for machining is made effective as the standard shift.

Single-block stop and dry run

The edge machine function does not work for single-block stop and dry run.

Other settings for machining

If material remains to be cut near a corner in edge machining, set bit 2 of parameter No. 15007 to 1. The situation may improve. If you want to perform edge machining even in the exact stop mode, set bit 4 of parameter No. 15007 to 1.
To make the edge machine function and the arc-radius-based feedrate clamp function usable at the same time, set bit 7 of parameter No. 15010 to 1.

Parameter

	#7	#6	#5	#4	#3	#2	#1	#0
15004				EDG				

[Data type] Bit

EDG 0: Specifies to turn off the laser beam at assist gas switching for edge machining.
1: Specifies not to turn off the laser beam at assist gas switching for edge machining.

	#7	#6	#5	#4	#3	#2	#1	#0
15007				XSC	ECK	ESE		

[Data type] Bit

ESE If piercing is to be executed in edge machining, it is:
0: Executed upon the completion of distribution.
1: Executed after a smoothing error check is performed upon the completion of distribution.

ECK In edge machining, the angle is judged with:
0: The actual machining path.
1: The path in the machining program.

XSC In exact stop mode, the edge machine function is:
0: Not executed.
1: Executed.

	#7	#6	#5	#4	#3	#2	#1	#0
15010	OVE							

[Data type] Bit

OVE Edge machining and feedrate clamp by arc radius:
0: Cannot be used at the same time.
1: Can be used at the same time.

	#7	#6	#5	#4	#3	#2	#1	#0
15011			CSC		LVE			EDS

[Data type] Bit

EDS The cutting conditions to be assumed during the execution of the return distance in edge machining and start-up machining are:
0: The same as usual.
1: Not the same as usual. For the laser power, assist gas type, and assist gas pressure, the piercing operation conditions for edge machining are used.

NOTE
When this setting is enabled, this setting has higher priority than bit 3 of No. 15011.

LVE At the start of edge machining and at the start of return distance cutting that follows, assist gas switching is performed:
0: According to the conventional specification.
1: By ignoring settling time if the gas type and gas pressure remain unchanged.

NOTE
This setting is disabled when bit 0 of No. 15011 is set to 1.

CSC If all of SPQF are specified in the first G01, G02, and G03 blocks after G24 in the start-up machining mode:
0: Start-up machining is performed as conventionally done, regardless of the specification of SPQF.
1: Start-up machining is canceled, and cutting is performed according to the values of SPQF specified.

	#7	#6	#5	#4	#3	#2	#1	#0
15012	EXS			CVA				

[Data type] Bit

CVA When the edge machine function is used, angle determination is:
0: Based on bit 3 of parameter No. 15007.
1: Made according to the program path, regardless of the setting of bit 3 of parameter No. 15007.

EXS When the edge machine function is executed, switching to the piercing operation execution condition occurs:
0: Upon completion of distribution (when bit 2 of parameter No. 15007 = 0) or upon completion of acceleration/deceleration (when bit 2 of parameter No. 15007 = 1)
1: After an in-position check is made for all axes.

15059	Return peak value

[Data type] Word
[Unit of data] W
[Valid data range] 0 to 7000

When the nozzle is leaving a corner during edge machining, it keeps running with the return speed, return frequency, and return duty cycle until it moves through the specified return distance, but it continues to use the programmed output peak value. If a value has been specified as a return peak value, it is used instead of the programmed value.

8.5 START-UP FUNCTION

Overview

When a shift occurs from the piercing command G24 to a cutting command block, stable machining is assured by performing the same operation as the start-up function (for a corner subjected to edge machining) through the specified return distance.

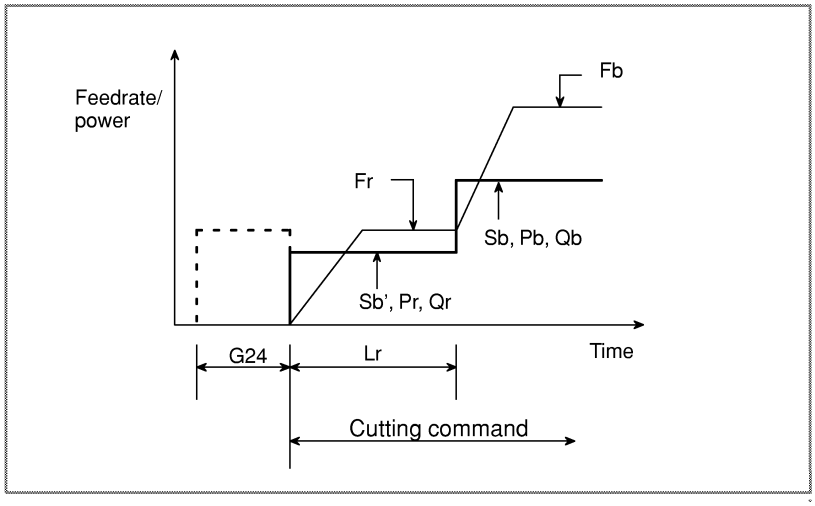
Conditions for use

The following conditions apply to use of this function.

(1) The machining condition setting function (option) and edge machining function are required.
(2) The automatic corner override function cannot be used with this function.
(3) Automatic corner deceleration cannot be used with this function.

Operation

When the piercing command G24 ends, the next block (cutting command) is executed. The return data for edge cutting becomes effective for the start-up of this block.



Lr : Return distance
Fr : Return speed
Pr : Return frequency
Qr : Return duty cycle
Fb : Cutting command feedrate
Sb : Cutting command output peak value
Pb : Cutting command pulse frequency
Qb : Cutting command pulse duty cycle

1 When the piercing command G24 ends, movement specified by the cutting command begins.

2 The cutting operation is performed with the cutting output peak value specified, the return speed being used as the feedrate, and the return frequency and duty cycle being as those of the output power. These conditions continue until the return distance is moved through.
3 After the return distance is moved through, the machining conditions of the cutting command are selected, and machining continues under these conditions.

Setting the data

The edge machining data for the machining condition setting function is used for start-up machining. The data area for the edge machining condition setting function can hold five sets of the data items listed below. The data items that have no value in this table are ignored in the start-up function.

Item	Setting range	Setting unit
Edge operation angle	-	-
Piercing peak value	-	-
Piercing pulse frequency	-	-
Piercing pulse duty cycle	-	-
Piercing time	-	-
Piercing assist gas pressure	-	-
Piercing assist gas type	-	-
Return distance	1 to 99.999	mm
Return speed	1 to 9999	mm/min
Return frequency	5 to 2000	Hz
Return duty cycle	0 to 100	%

The return distance cannot exceed the length of a single block.
Return peak value Sb' can be specified in parameter No. 15059. This is intended to use the output peak value Sb' that is different from the peak value Sb of block B during movement through the distance Lr. If this parameter is 0, machining is performed with Sb' = Sb.

Selecting the start-up function

The stat-up function is enabled by setting an edge data number from 201 to 205 in the "start-up selection" item in the machining data group. To disable this function, reset the "start-up selection" item to 0.

Start-up command

If a program specifies a machining data set number using the E address, when the program is executed, the "start-up selection" item in the specified machining data is referenced, and the edge data set number is read for execution of the start-up function.

Override

Override is applied to the following item.
1 Return speed
2 Return peak value
3 Return frequency
4 Return duty cycle

Tracing control

The standard shift used for piercing specified by the E code continues to be effective during execution of the start-up function. When a start-up is completed (the return distance has been moved through), the standard shift for cutting is selected.
If piercing is not based on the E code, the currently effective standard shift continues to be effective for the start-up function.

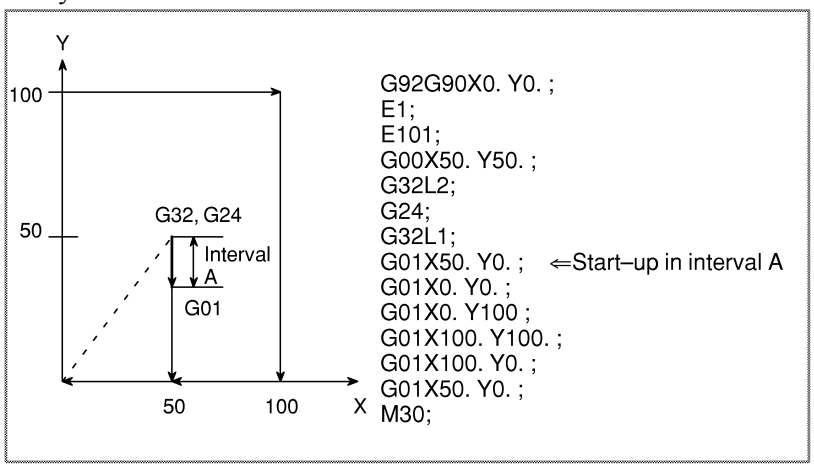
Single-block stop and dry run

The start-up function does not work for single-block stop and dry run.

Sample program

The following sample program uses the start-up function.

1 The nozzle is positioned at a point (X50, Y50). At this point, the G32 assist gas and G24 piercing commands are executed in the stated sequence.
2 When piercing is completed, the cutting assist gas is selected, and machining begins.
3 A start-up operation is performed in interval A (specified return distance), where machining is carried out using the feedrate, output peak value, frequency, and duty cycle specified for a return operation.
4 When the start-up operation ends, machining continues using the programmed feedrate, output peak value, frequency, and duty cycle.



Parameter

For information on the specifiable parameters, see the section on edge machining.

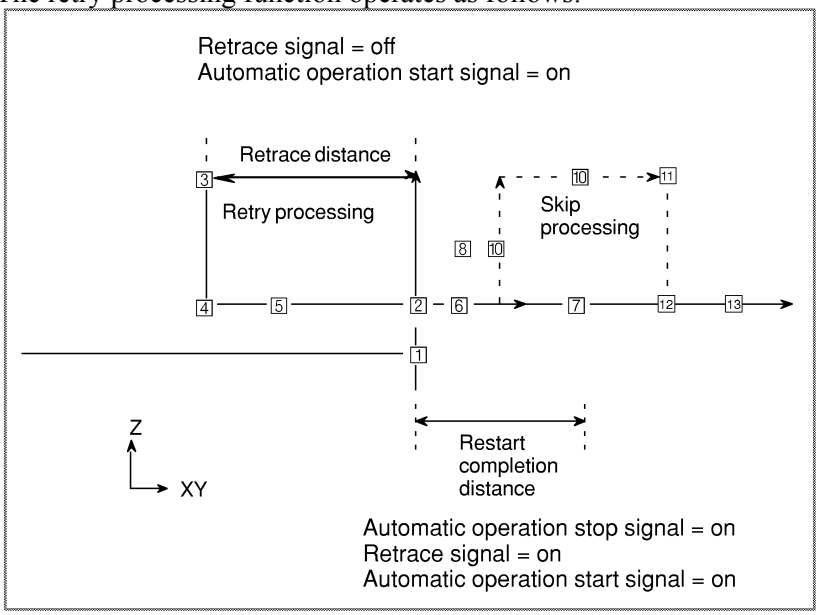
8.6 RETRY PROCESSING FUNCTION

Overview

A burning condition may occur during laser machining, disabling further machining. In such a case, a normal operation may be able to be resumed by returning the nozzle to a point where it was before the burning condition occurred and by retrying processing. This is done using the retry processing function. This function operates as follows: When a machining failure is detected, the nozzle moves back along the machining path to a specified point with the beam turned off. When it gets to the specified point, it enters a machining state and goes forward along the same machining path toward the point where it started going backward (retrace start point). When it gets to the retrace start point, the nozzle resumes machining as directed by the program.
This function cannot be used with the three-dimensional machining function. Because the retry processing function is based on the FS16-M retrace function, it is necessary to specify the retrace function and conform to the retrace function specification.

Operation

The retry processing function operates as follows:



[1] Sets the retry processing mode signal (RVSLSR) to "1", and resets the automatic operation stop signal (*SP) to "0" according to the machining failure detection signal during program execution. After that, specifies as follows:
- Movement = discontinued
- Beam = off
- Assist gas = off
- Tracing control = off (*1)

[2] Sets the retrace signal (RVS) to "1" to start automatic operation, stores the current position of the nozzle as the retrace start point, then retraces in the positive Z-axis direction through the distance specified in parameter No. 15650, under the following conditions.
- Beam = off
- Assist gas = off
- Tracing control = off

[3] When the retract operation is completed, retraces through the distance specified in parameter No. 15651 and stops (*2). When the retrace completed signal (RVSARV) becomes "1", resets the retrace signal (RVS) to "0" to trigger a cycle start:
- If the program directs tracing control = on at the end of retracing, the nozzle approaches the workpiece.
- If the program directs tracing control = off at the end of retracing, Z-axis retracting is canceled in fast forward mode (drops through the distance specified in parameter No. 15650), the nozzle gets close to the workpiece.

[4] Creates the assist gas command (G32) automatically and executes it.

[5] Creates a move command with the retrace start point as the goal, turns on the laser beam, and resumes forward trace. When the nozzle gets to the retrace start point, calls the block executed in step 1 and restarts program execution.

[6] After restarting, checks whether the retry completion distance (specified in parameter No. 15652) is exceeded.

[7] Continues machining if no machining failure occurs after moving through the retry completion distance.

[8] Repeats steps [2] to [4] if a machining failure occurs before moving through the retry completion distance.

[9] If a retry is repeated a specified number of times (specified in parameter No. 15653) unsuccessfully, assumes that retry processing is impossible, and stops retry and triggers skip processing.
- Z-axis retract
- Beam = off
- Assist gas = off
- Tracing control = off (*1)

[10] Start positioning at the end of the block mentioned in step [1]. A single-block stop occurs at the end of the block.

[11] If the skip completion signal (RVSSKE) or retrace completion signal (RVSARV) is "1", resets the retrace signal (RVS) to "0" to trigger a cycle start.
- If tracing control is on in the block mentioned in step [1], the nozzle approaches the workpiece.
- If tracing control is off in the block mentioned in step [1], Z-axis retracting is canceled in fast forward mode, the nozzle gets close to the workpiece.

[12] Executes the assist gas command (G32), then the piercing command (G24). (*3)
This piercing operation is performed under the most recently used conditions. (*5)
When piercing is completed, executes the assist gas command (G32) again to switch to the machining assist gas:
- Assist gas = on
- Beam = on

[13] Executes the next block.

Notes

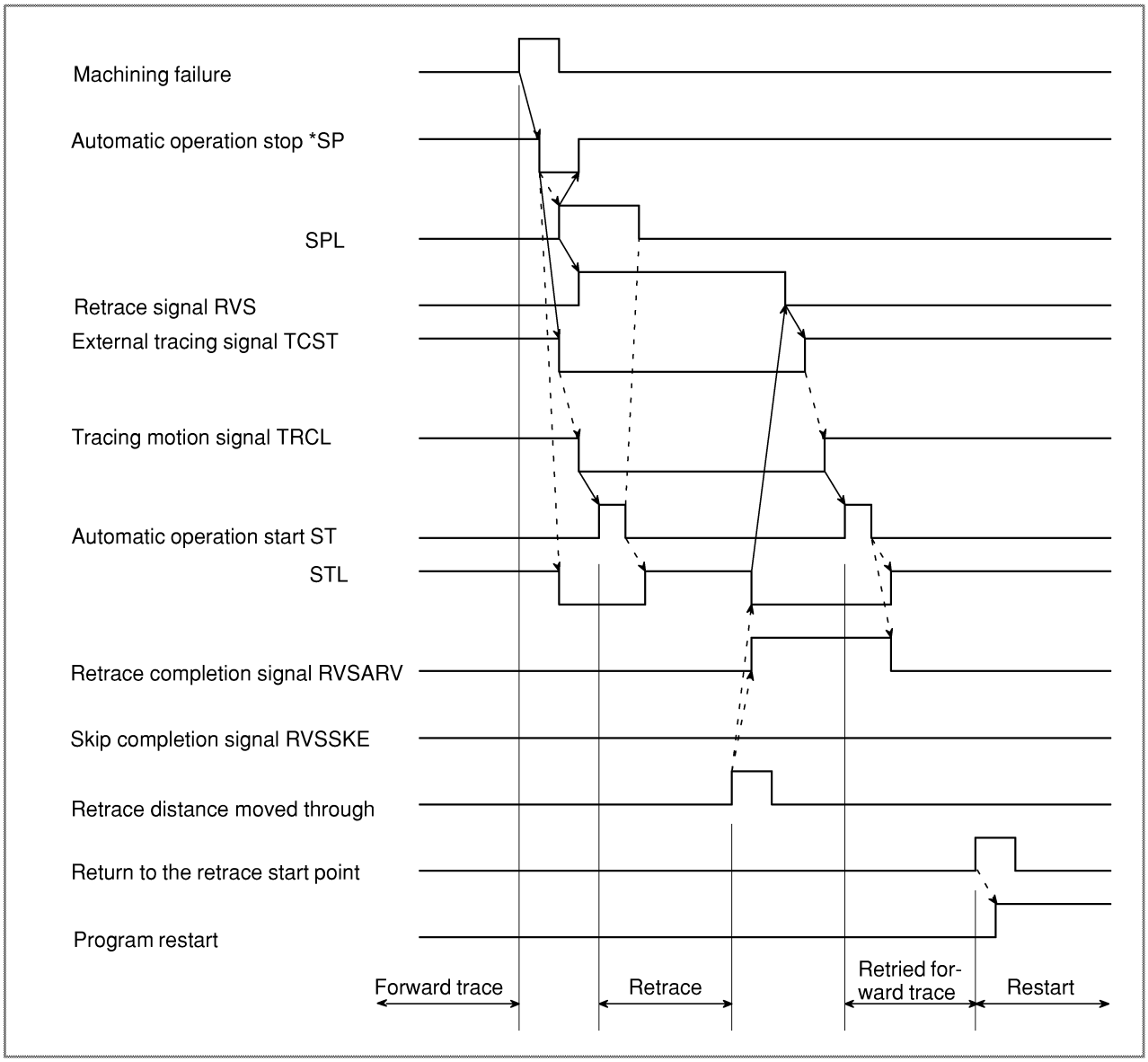
(1) When using the external tracing on/off function, reset the tracing start signal (TCST) to "0" using a ladder program, and check that the tracing motion signal (TRCL) is "0".
(2) In addition to the distance, the following conditions terminate retracing.
  (a) The newly read command is G00.
  (b) The newly read command is a Z-axis move command.
  (c) A skipped block is encountered.
  (d) The G92 command is encountered.
(3) A skip always causes the nozzle to get close to the workpiece and triggers piercing. Even if the skipped position is the end point of machining, piercing takes place.
(4) If the following conditions are encountered, it is assumed that machining cannot be continued, and the machining continuation impossible signal (RVSERR) is output to terminate machining.
  (a) During G24 execution, the number of detected machining failures exceeds the retry count. (During piercing, detection of machining failures must be disabled.)
  (b) During G32 execution, a machining failure is detected, resulting in a shift to a skip.
(5) The piercing command related to a skip operation can be executed with values specified in dedicated parameters (parameter Nos. 15669 to 15682).
(6) This function can be used only for X-Y facing. It cannot be used with the three-dimensional machining function and other functions.

PMC processing

To use the retrace function complying with the FS16-L specification, it is necessary to process signals in the PMC. The solid-line arrow (⟶) indicates the processing on the PMC side, and the broken-line arrow (⇢) indicates the processing internal to the CNC.

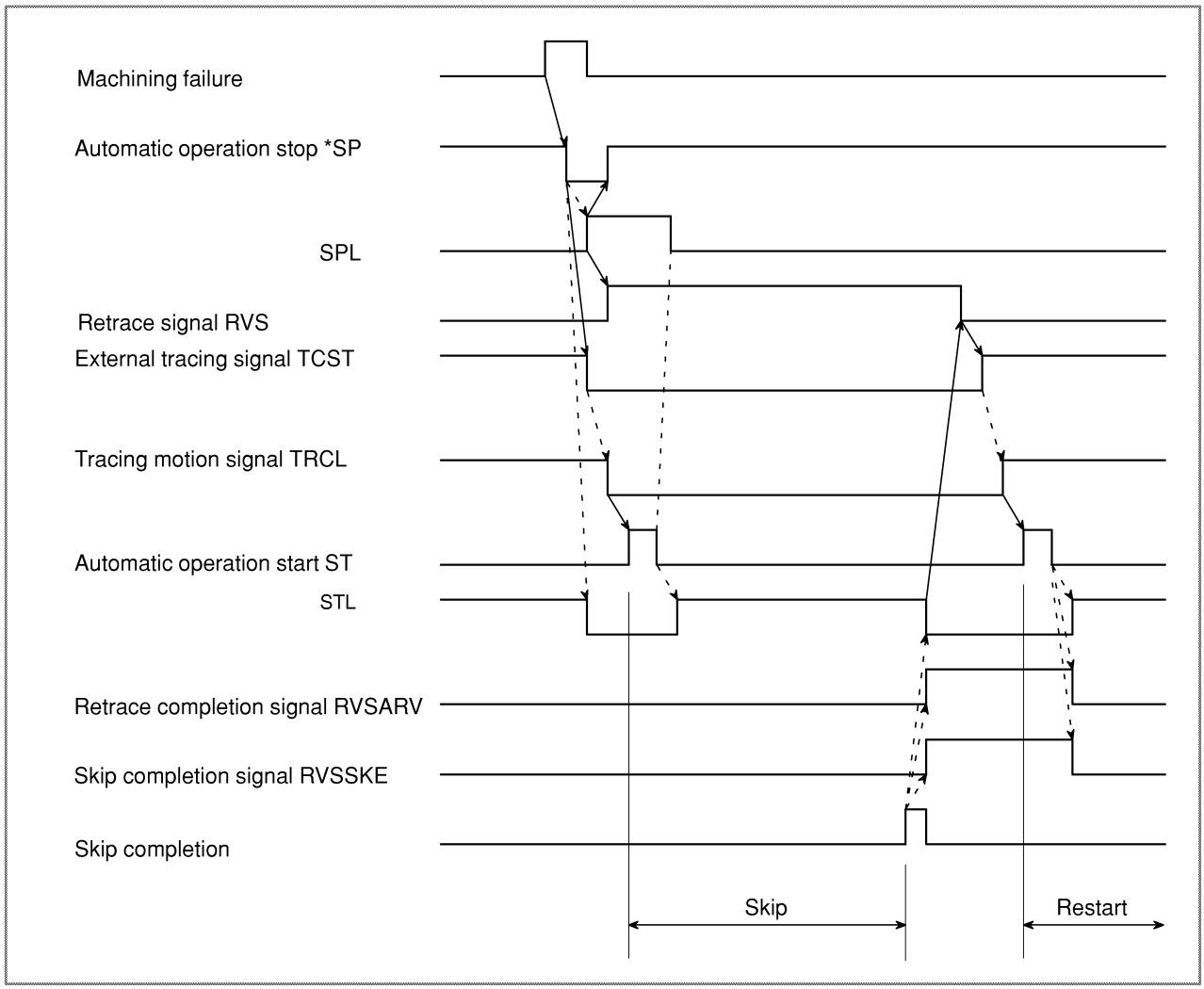
Ordinary retracing

The following timing chart applies to ordinary retracing.



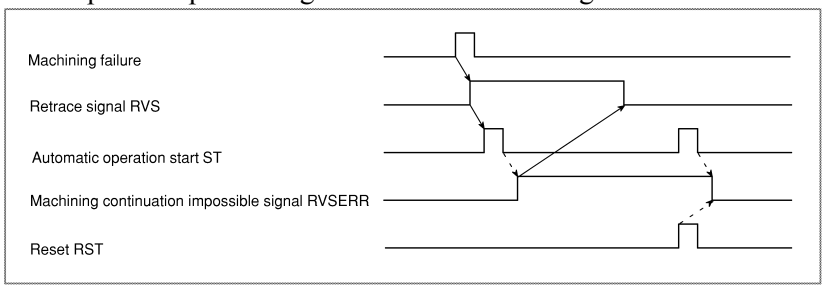
Skip processing

The following timing chart applies to skip processing.



Machining continuation impossible

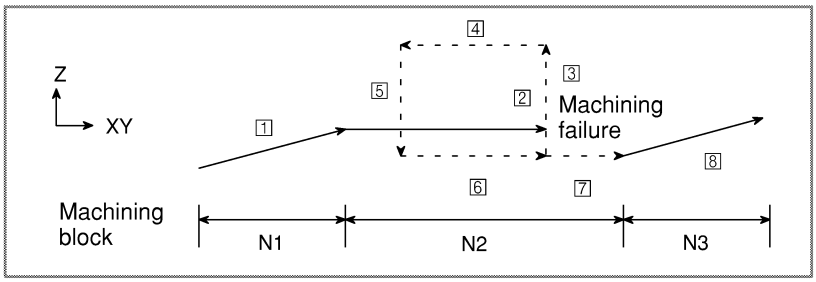
If a machining continuation impossible signal is output, the PMC should perform processing to terminate machining.

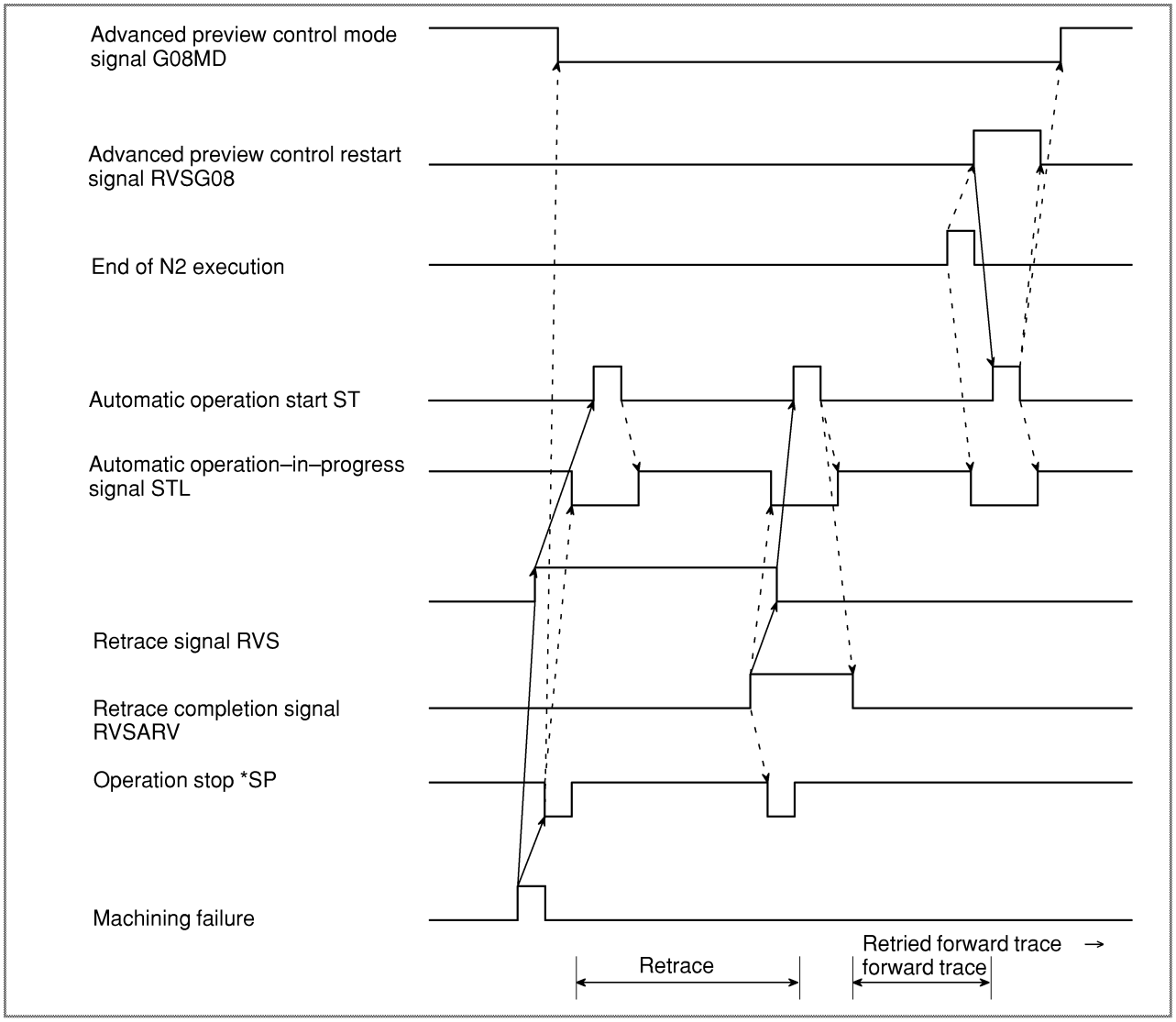


Advanced preview control restart

When the retry processing function is used, advanced preview control is performed as follows:

When [1] and [2] are being executed with advanced preview control mode turned on, if a machining failure is detected at [2] in the course of operation by the N2 block, a retrace occurs. At this point, advanced preview control mode is turned off automatically. [3] to [7] are executed with advanced preview control mode turned off. A single-block stop occurs at the end of the N2 block, and advanced preview control mode is turned on. After the advanced preview control restart signal (RVSG08) is set to "1", triggering a cycle start restarts machining at <8> with advanced preview control mode turned on.





Signal

- Retry processing mode selection signal RVSLSR<G226#7>

[Classification] Input signal

[Function] Enables the retry processing function.

[Operation] If the retry processing mode selection signal is "0", the retrace function is enabled. If the signal is "1", the retry processing function is enabled. If only the retry processing function is being used, this signal must always be "1". If it is necessary to switch this signal, switch it before setting the retrace signal (RVS) to "1". Once retrace has began, do not switch the signal until the retrace start point is reached.

- Retrace signal RVS<G007#0>

[Classification] Input signal
[Function] Starts retracing.
[Operation] If both retry processing mode selection signal (RVSLSR) and automatic operation stop signal (SPL) are "1", setting the retrace signal (RVS) to "1" retracts the Z-axis and triggers a retrace. When retracing ends and the automatic operation stop signal (SPL) becomes "0" resetting the retrace signal (RVS) to "0" to trigger a cycle start causes forward tracing.

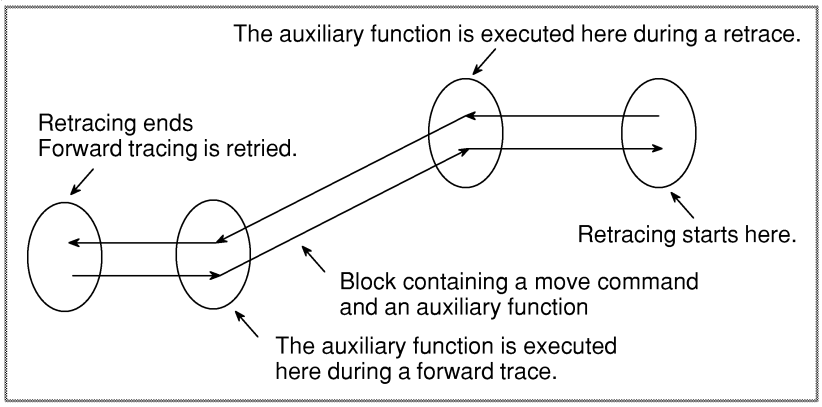
- Retrace-in-progress signal RVSL<F082#2>

[Classification] Output signal
[Function] Informs the PMC that the nozzle is moving backward along the machining path.
[Output condition] This signal becomes “1” when:
- The retrace signal (RVS) becomes "1" to begin retracing.

This signal becomes “0” when:
- The retrace signal (RVS) becomes "0" to begin forward tracing (including restarted forward tracing).
- The nozzle is at a stop because there is no block to retrace.

During retracing, the M, T, and second auxiliary functions are executed in the same way as during a forward trace. If this is undesirable, use the retrace-in-progress signal (RVSL) to direct the PMC to perform its own processing.

If the M, T, or second auxiliary function is in the same block as a move command, the output position of the code and strobe signals differs between forward tracing and retracing. So, use this signal and the distribution end signal (DEN), as required, to direct the PMC to perform its own processing.



- Retrace completion signal RVSARV<F225#0>

[Classification] Input signal
[Function] Informs the PMC that a retrace is completed.
[Output condition] This signal becomes “1” when:
- The specified distance has been retraced.
- The nozzle is positioned at the end of the block during a skip.

This signal becomes “0” when:
- The retrace signal (RVS) is reset to "0" to trigger a cycle start after the retrace completion signal (RVSARV) becomes "1".

- Skip completion signal RVSSKE<F225#2>

[Classification] Input signal
[Function] Informs the PMC that a skip is completed.
[Output condition] This signal becomes “1” when:
- A skip is completed.

This signal becomes “0” when:
- The retrace signal (RVS) is reset to "0" to trigger a cycle start after the skip completion signal (RVSSKE) becomes "1".

When a skip is completed, the skip completion signal (RVSSKE) and retrace completion signal (RVSARV) become "1" simultaneously. When the retrace signal (RVS) is reset to "0" to trigger a cycle start, they become "0" simultaneously.

- Machining continuation impossible signal RVSERR<F225#3>

[Classification] Output signal
[Function] Informs the PMC that machining cannot be continued.
[Output condition] This signal becomes “1” when:
- A machining failure is detected more times than the specified retry count during execution of the G24 command.
- A machining failure is detected during execution of the G32 command, and a skip is started.

This signal becomes “0” when:
- The retrace signal (RVS) is reset to "0" to trigger a cycle start.
- The reset button is pressed.

When the machining continuation impossible signal (RVSERR) signal is received, switch off the system power using a ladder program to perform the following procedure.

(Example)
- Cause a reference position return in reference position return mode.
- Set the oscillator RUN to off to stop the oscillator.
- Shut off the system power.

The machining continuation impossible signal (RVSERR) is cleared by a reset signal. But do not retry processing even after it is cleared.

- Advanced preview control restart signal RVSG08<F225#4>

[Classification] Output signal

[Function] Informs the PMC that advanced preview control is turned on automatically.

[Output condition] If a machining failure occurs during advanced preview control mode, this mode is turned off automatically, and the retry processing function is executed. To select advanced preview control mode again, the CNC makes an automatic single-block stop at the end of a block where the machining failure occurred, turns on advanced preview control automatically, and sets the advanced preview control restart signal (RVSG08) to "1". After making sure that the advanced preview control restart signal (RVSG08) signal becomes "1", the PMC should trigger a cycle start. Advanced preview control will be turned on to retry processing.

- Advanced preview control-in-progress signal G08MD<F066#0>

[Classification] Output signal

[Function] Informs the PMC that advanced preview control is in progress.

[Output condition] This signal becomes “1” when:

- Advanced preview control mode has been selected.

This signal becomes “0” when:

- Advanced preview control mode has not been selected.

Signal address

	#7	#6	#5	#4	#3	#2	#1	#0
G007								RVS
G226	RVSLSR							
F066								G08MD
F082						RVSL		
F225				RVSG08	RVSERR	RVSSKE		RVSARV

Parameter

15650	Z-axis retract amount

[Data type] 2-word

[Unit of data]

Increment system	IS-A	IS-B	IS-C	Unit
Metric input	0.01	0.001	0.0001	mm
Inch input	0.001	0.0001	0.00001	inch

[Valid data range] 0 to 99999999

Specify the distance through which the Z-axis retracts, before starting retracing or skipping. If this parameter is 0, the Z-axis will not retract.

15651	Retrace distance

[Data type] Word
[Unit of data] mm/inch
[Valid data range] 0 to 8000
Specify the distance at which a retrace is to end. This distance begins at the retrace start point and ends at the point where a retrace is to end. If the distance is 0, a retrace will not be done. Instead, a skip will occur.

15652	Retry completion distance

[Data type] Word
[Unit of data] mm/inch
[Valid data range] 0 to 8000
After the retry processing point is passed during a retried forward trace, the moved distance is monitored. If a machining failure does not occur until the distance specified in this parameter is moved through, it is assumed that machining has been retried normally. If a machining failure is detected before this distance is moved through, a retrace occurs again, and retries are counted.

15653	Retry count

[Data type] Word
[Unit of data]
[Valid data range] 0 to 100
When the retry processing point is passed during a retried forward trace, if a machining failure is detected before the retry completion distance (specified in parameter No. 15652) is passed through, the Z-axis is retracted, and retries are counted. If the number of retries performed exceeds the retry count specified in parameter No. 15653, a retrace will not be done; instead this block is skipped. If the retry count is 0, a skip occurs immediately without performing a retrace.

	#7	#6	#5	#4	#3	#2	#1	#0
15669								N2S

[Data type] Bit
N2S 0: Specifies that piercing during a retried forward retrace be performed as directed by the program.
1: Specifies that piercing during a retried forward retrace be performed as specified in parameter Nos. 15670 to 15682.

15670	Piercing power

[Data type] Word
[Unit of data] W
[Valid data range] 0 to 7000
Specify how much high-speed piercing power is to be used during a skip.

15671 **High-speed piercing initial frequency**

[Data type] Word
[Unit of data] Hz
[Valid data range] 5 to 2000
Specify the initial frequency for high-speed piercing to be used during a skip.

15672 **High-speed piercing frequency increment**

[Data type] Word
[Unit of data] Hz
[Valid data range] 0 to 2000
Specify the frequency increment for high-speed piercing to be used during a skip.

15673 **High-speed piercing initial duty cycle**

[Data type] Word
[Unit of data] %
[Valid data range] 0 to 100
Specify the initial duty cycle for high-speed piercing to be used during a skip.

15674 **High-speed piercing duty cycle increment**

[Data type] Word
[Unit of data] %
[Valid data range] 0 to 100
Specify the duty cycle increment for high-speed piercing to be used during a skip.

15675 **High-speed piercing step time**

[Data type] Word
[Unit of data] msec
[Valid data range] 0 to 32767
Specify the step time for high-speed piercing to be used during a skip.

15676 **High-speed piercing step count**

[Data type] Word
[Unit of data]
[Valid data range] 0 to 32767
Specify the step count for high-speed piercing to be used during a skip.

15677 **High-speed piercing end time**

[Data type] 2-word
[Unit of data] msec
[Valid data range] 0 to 99999999
Specify the end time for high-speed piercing to be used during a skip.

15678 **Standard shift**

[Data type] Word
[Unit of data] 0.001mm
[Valid data range] Parameters Nos. 15531 to 15532
Specify the standard shift for piercing to be used during a skip. This value determines the reference distance from the tip of the quill to the workpiece for Z-axis tracing control.

15679 **Assist gas selection**

[Data type] Word
[Unit of data]
[Valid data range] 0 to 7
Select the type of assist gas to be used during a skip.

15680 **Flow pattern selection**

[Data type] Word
[Unit of data]
[Valid data range] 1, 2, 3
Select the pattern of assist gas flow to be used during a skip.

15681 **Assist gas pressure setting time for piercing**

[Data type] Word
[Unit of data] 10msec
[Valid data range] 0 to 32767
Specify the assist gas pressure setting time for piercing to be used during a skip.

15682 **Assist gas pressure for piercing**

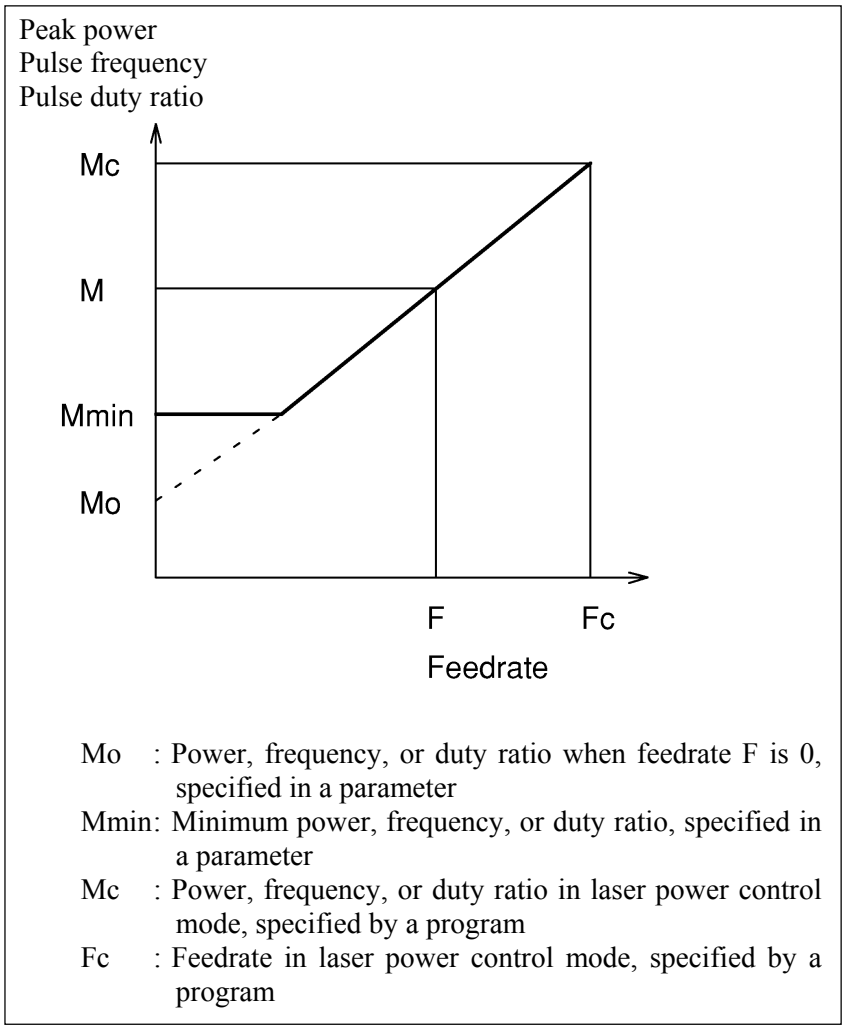
[Data type] Word
[Unit of data] 0.01MPa
[Valid data range] 0 to 255
Specify the assist gas pressure for piercing to be used during a skip.

8.7 LASER POWER CONTROL

Overview

When a difference is detected between the actual speed and the programmed speed in a corner portion, for example, the laser power control function adjusts the peak power, pulse frequency, and pulse duty ratio to achieve uniform machining.
When the laser power control mode, described later, is selected by a G code or external signal, the power, pulse frequency, and pulse duty ratio are controlled to maintain the following relation:

$$M = Mo + (Mc - Mo)\frac{F}{Fc}$$



Mo : Power, frequency, or duty ratio when feedrate F is 0, specified in a parameter
Mmin: Minimum power, frequency, or duty ratio, specified in a parameter
Mc : Power, frequency, or duty ratio in laser power control mode, specified by a program
Fc : Feedrate in laser power control mode, specified by a program

Fig. 8.7

Power control mode

Laser power control mode can be selected using a G code or an external signal. When the system enters power control mode, the power control mode in progress signal (F224#1) is output.

G codes

G63P1; Laser power control mode

G63P0; Laser power control mode cancel

External signal

G224#1 Power control mode signal

Enabling or disabling the function

The power control function can be enabled or disabled using the laser setting screen or a parameter.

Using the laser setting screen

To enable the power control function, set 1 in the power control field on the laser setting screen.

Using a parameter

To enable the power control function, set bit 0 of parameter No. 15000 to 1.

Selecting a control item

The peak power, pulse frequency, and pulse duty ratio can be selectively controlled as specified in parameter No. 15096. One or more items can be selected.

Axis of power control

The power control function calculates the elements controlling the laser output (peak power, pulse frequency, and pulse duty ratio) from the nozzle feedrate. The machine axes related to the operation of the nozzle should be specified in parameter No. 15089 so that the feedrate can be obtained accurately. If nothing is specified in this parameter, the first and second axes are assumed.

Avoid specifying the synchronization axis of simple synchronous control. The synchronization axis is related to the movement of the nozzle, but this axis and the master axis form a pair, which should be considered as a single axis.

Dead zone for variations in feedrate

The feedrate fluctuates slightly even in the steady state. The fluctuations result in variations in the values calculated from the feedrate. These variations can be avoided by setting an allowable feedrate variation (dead zone) in a parameter.

If the difference between the actual feedrate and programmed feedrate in a current block does not exceed the value specified in the parameter, the movement is considered as being made at the programmed feedrate, causing no change in the values.

Delay compensation of the mechanical system

The power control function changes the values of the laser output in proportion to the programmed speed. The mechanical system (servo system) lags behind the laser output, and the operation of the mechanical system does not match the changes in the laser output in practice. To compensate for the delay, a first-order delay filter is applied to the feedrate data of the mechanical system. The filter delays the changes in the laser output. The setting of the first-order delay filter is made in a parameter.

Use with the cutting condition setting function (E code command)

If an E code is specified to change cutting conditions in power control mode, the data corresponding to MC and FC in Fig. 8.7 is replaced with the cutting condition data specified with the E code to continue processing.

Use with the edge machine function, start-up machining function, and step control function

If step control (E301 to E305) is specified, the system cannot enter power control mode. If skip control is specified in power control mode, power control mode is automatically canceled. If edge machining/start-up machining (E205 to E205) is specified, the operation differs depending on bit 7 (EGM) of parameter No. 15096.

If EGM = 0

If the system enters edge machining/start-up machining mode (a code E201 to E205 is specified in the machining program), power control mode is canceled.

If EGM = 1

Even if the system enters edge machining/start-up machining mode, power control mode is not canceled. Power control is stopped from the time of piercing at the corner edge until the completion of travel for a return distance. While power control is being stopped, the beam output conditions are controlled by edge machining/start-up machining.

Signal

- Power control mode signal PWCTL<G224#1>

[Classification] Input signal

[Function] Specifies a transition to or from power control mode.

[Operation] Transition to or from power control mode is carried out as follows:

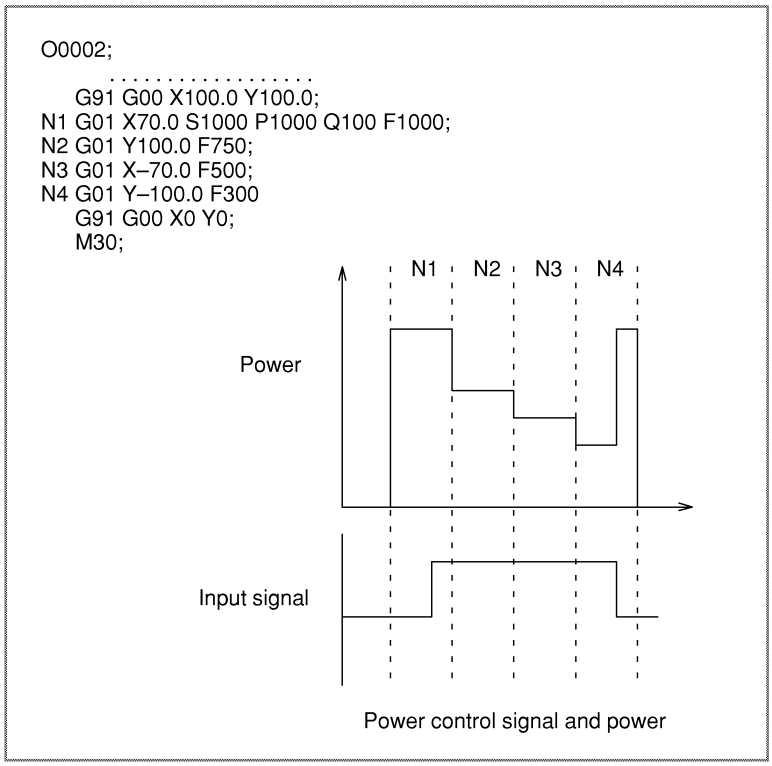
Transition to power control mode = (G63 P1) OR (Power control mode signal on)

The system is in power control mode while G63 P1, specified in a machining program, is valid or while the PMC holds the power control mode signal to 1.

Return from power control mode = (G63 P0) AND (Power control mode signal off)

When G63 P0 specified in a machining program is valid and when the power control mode signal is set to 0, power control mode is cancelled. The system usually enters the G63 P0 state immediately after the CNC is activated or upon a reset. If G63 P1 is not programmed, G63 P0 need not be specified. That is, if the transition is made by an external signal, the return is made by turning off that external signal. If the transition is made by G63 P1 specified in a machining program, the return is made by G63 P0.

The figure below shows the variations in power when the power control mode signal is used (when only the power is controlled).



- Power control mode in progress signal PCMD<F224#1>

[Classification] Output signal
[Function] Notifies the PMC that the system has entered power control mode.
[Operation] This signal is output upon the completion of transition to power control mode.

Signal address

	#7	#6	#5	#4	#3	#2	#1	#0
G0224							PWCTL	

	#7	#6	#5	#4	#3	#2	#1	#0
F0224							PCMD	

Parameter

	#7	#6	#5	#4	#3	#2	#1	#0
15000			FLT					LPC

LPC 0: The power control function is disabled.
1: The power control function is enabled.
While this parameter is set to 0, the system cannot enter power control mode. The G code and input signal specifying a transition to power control mode are ignored.

FLT 0: The filter is disabled in power control mode.
1: The filter is enabled in power control mode.
When this parameter is set to 1, parameter No. 15094 becomes valid, and the specified output can be delayed.

	#7	#6	#5	#4	#3	#2	#1	#0
15089	LP8	LP7	LP6	LP5	LP4	LPZ	LPY	LPX

LP* 0: The * axis is not used for feedrate calculation.
1: The * axis is used for feedrate calculation.
Based on the composite speed along the axes selected by this parameter, the elements of the laser output are calculated. If no axis is selected, the first axis (LPX) and second axis (LPY) are assumed.

15090	Minimum power

[Unit of data] W
[Valid data range] 0 to 7000
This parameter specifies the minimum power. If the power calculated from the current feedrate is below the setting made with this parameter, the power is limited to this setting.

15091	Minimum pulse frequency

[Unit of data] Hz
[Valid data range] 5 to 2000
This parameter specifies the minimum pulse frequency. If the frequency calculated from the current feedrate is below the setting made with this parameter, the frequency is limited to this setting.

15092	Minimum pulse duty ratio

[Unit of data] %
[Valid data range] 0 to 100
This parameter specifies the minimum pulse duty ratio. If the duty ratio calculated from the current feedrate is less than the value set for this parameter, the duty ratio is limited to this setting.

15094	Power control filter time constant

[Unit of data] msec
[Valid data range] 8 to 32767
This parameter specifies the time constant of the first-order delay filter for delaying and synchronizing the output to the machine feed.
The characteristic of the first-order delay filter is expressed as follows:

$$O_n = O_{n-1} + (I_n - O_{n-1})\frac{Ts}{Tc}$$

Ts : Always 8 milliseconds (sampling time)
Tc : Set by this parameter (time constant)

15095	Allowable variation in power control speed

[Unit of data] mm/min (command unit for B8F1-08 or earlier) or %

[Valid data range] 0 to 255

The feedrate used for calculation fluctuates slightly even in the steady state. This parameter specifies the width of the dead zone for the feedrate fluctuations in order to avoid unnecessary variations in values (power, pulse frequency, and pulse duty ratio) resulting from these changes in the feedrate.

This parameter is valid when parameter No. 15450 is 0.

To set a value of 256 or greater, use parameter No. 15450.

This parameter needs to be set as follows according to the setting of bit 6 (SDB) of parameter No. 15096.

When SDB is 0, set a speed. Therefore, the allowable speed variation is always the same value.

When SDB is 1, set the ratio (0 to 100%) to the specified speed when a transition to power control mode is performed.

	#7	#6	#5	#4	#3	#2	#1	#0
15096	EGM	SDB		SQ0		PCD	PCF	PCP

PCP The power is:
- 0: Not controlled according to the feedrate.
- 1: Controlled according to the feedrate.

PCF The pulse frequency is:
- 0: Not controlled according to the feedrate.
- 1: Controlled according to the feedrate.

PCD The pulse duty ratio is:
- 0: Not controlled according to the feedrate.
- 1: Controlled according to the feedrate.

SQ0 When the specified peak power (S) or specified pulse duty ratio (Q) is 0:
- 0: The power control function is executed.
- 1: The power control function is interrupted.

SDB The allowable variation of the power control speed (parameter No. 15095) is set:
- 0: By directly setting a speed (mm/min).
- 1: By setting the ratio (0 to 100%) to the specified speed when a transition to power control mode is performed.

EGM When the system is in edge machining mode or in start-up machining mode:
- 0: Power control mode is canceled.
- 1: Power control is stopped during the piercing of edge machining or start-up machining and during return distance movement.

The system is in edge machining mode or in start-up machining mode when an E number for specifying edge machining or start-up machining is selected.

15097 **Parameter for calculating the rate of change in output (Output when feedrate F is 0)**

[Unit of data] W
[Valid data range] 0 to 7000

This parameter specifies the power when feedrate F is 0. The rate of change in output is calculated from this setting and the programmed output in power control mode Mc.

15098 **Parameter for calculating the rate of change in frequency (Frequency when feedrate F is 0)**

[Unit of data] Hz
[Valid data range] 5 to 2000

This parameter specifies the frequency when feedrate F is 0. The rate of change in frequency is calculated from this setting and the programmed frequency in power control mode Mc.

15099 **Parameter for calculating the rate of change in the duty ratio (Duty ratio when feedrate F is 0)**

[Unit of data] %
[Valid data range] 0 to 100

This parameter specifies the duty ratio when the feedrate F of Mo is 0. The rate of change in the duty ratio is calculated from this setting and the programmed duty ratio in power control mode Mc.

15450 **Allowable variation in power control speed (2)**

[Unit of data] mm/min
[Valid data range] 0 to 32767

When this parameter is 0, parameter No. 15095 is valid. The setting range of this parameter is different from that of parameter No. 15095. For details on the settings, see descriptions of parameter No. 15095.

NOTE
1 To use the laser power control function in high-precision contour control (HPCC) mode, select laser power control mode before selecting high-precision contour control mode. To cancel laser power control mode, do so after canceling high-precision contour control mode.
2 The laser power control function cannot be used together with the pulse enhanced function. In power control mode, the pulse enhanced function is disabled.
3 The laser power control function can be used only for linear axes. The laser power control function cannot be used with the cylindrical interpolation function or other functions related to a rotation axis.
4 The laser power control function cannot be used together with a function related to three-dimensional machining.

8.8 LASER GAS MIXER FUNCTION

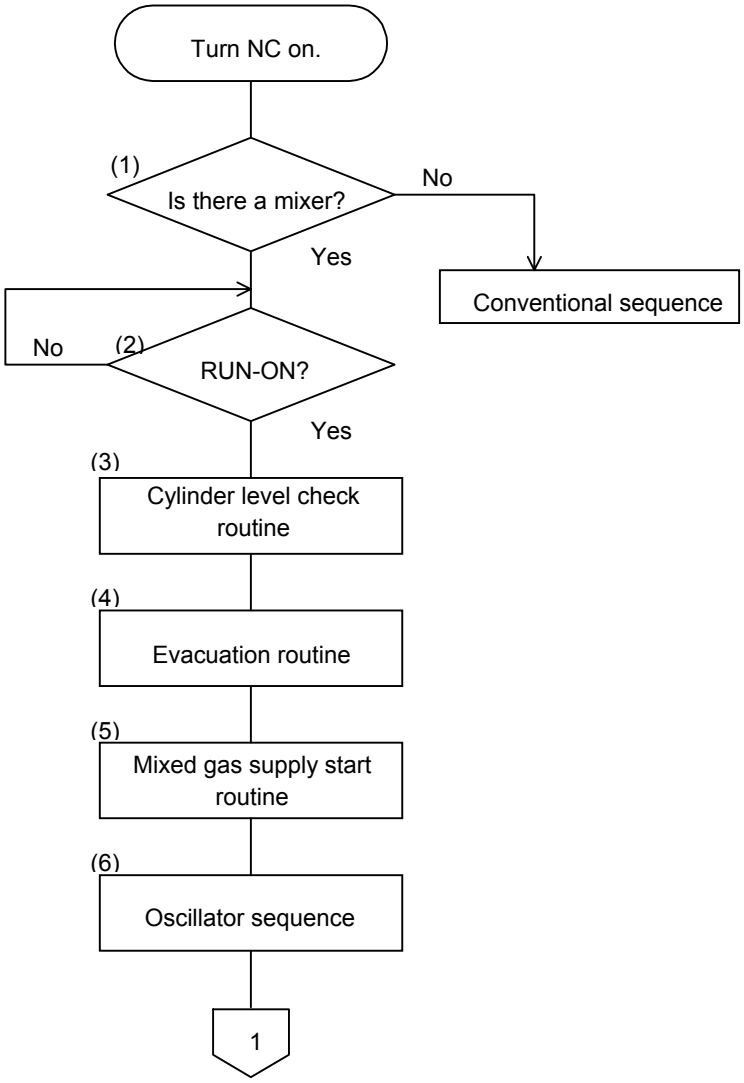
Overview

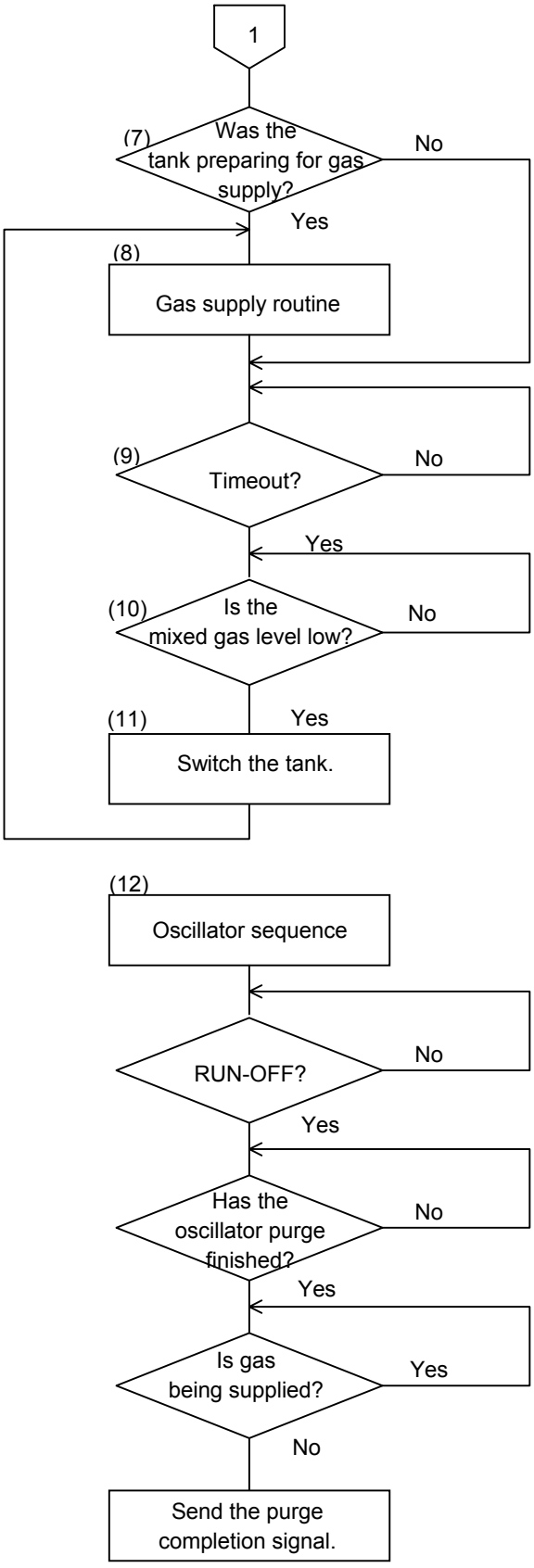
When a mixed laser gas is not available, the laser gas mixer function is used to create a laser gas by mixing nitrogen, helium, and CO_2 gases in a predetermined proportion. A special laser gas mixer is necessary. For details, read the manual provided with the laser gas mixer.

Mixture sequence

See the flowchart below.

(1) When the mixer is not connected, the conventional sequence is used.
(2) RUN-ON starts the mixer operation.
(3) Check the levels of the CO_2-gas, helium, and nitrogen cylinders. If any level is too low, 111 is displayed on the diagnostic screen (No. 987).
(4) The tank is evacuated if the previous operation stopped while the tank was being supplied with gases. Otherwise, this step is skipped.
(5) The previous operation stop status is checked. According to the status, the gas supply is started. When the low-order bits of parameter No. 15009 are 0000, tank A is supplied with gases, mixes those gases, then starts supplying the mixed gas.
(6) After the mixed gas supply starts, the laser oscillator sequence starts.
(7) If the previous operation was stopped while the tank was preparing to supply gas, the gas supply starts immediately.
(8) First, the cylinder levels are checked. If any cylinder level is too low, 111 is displayed on the diagnostic screen (No. 987). The sequence remains stopped until the cylinder is replaced. When the BCAN signal (G221#5) is set to 1 after the cylinder is replaced, the gas supply starts. The tank in which the gas level is low is supplied with the gases in a predetermined proportion.
(9) After the tank is filled with the gases, a wait time (of about 1 hour) is necessary to ensure a uniform mixture. Then, the tank is switched.
(10) The gas level of the mixed gas tank is checked.
(11) If the gas level of the mixed gas tank is low, the tank is switched to another tank.
(12) RUN-OFF stops the mixer. POWER-OFF should not be done until the gas supply is completed. POWER-OFF during gas supply may result in the gases being mixed in the wrong proportion.


Turn NC on.
(1)
Is there a mixer?
No
Yes
Conventional sequence
No
(2)
RUN-ON?
Yes
(3)
Cylinder level check routine
(4)
Evacuation routine
(5)
Mixed gas supply start routine
(6)
Oscillator sequence
1


1
(7)
Was the tank preparing for gas supply?
No
Yes
(8)
Gas supply routine
(9)
Timeout?
No
Yes
(10)
Is the mixed gas level low?
No
(11)
Yes
Switch the tank.
(12)
Oscillator sequence
RUN-OFF?
No
Yes
Has the oscillator purge finished?
No
Yes
Is gas being supplied?
Yes
No
Send the purge completion signal.

First activation after installation of mixer

Immediately after installation, the mixer state is not known. Therefore, the mixer must be initialized. To discharge the internal gas, evacuation, gas supply, mixing, and so on must be performed.
To perform this operation, set all the bits of parameter No. 15009 to 0.

Replacing a gas cylinder

After replacing a gas cylinder, hold the BCAN signal (G221#5) to 1 for about 500 milliseconds. This operation is necessary to inform the NC that the cylinder has been replaced. After this operation, the mixer automatically starts the following operation:

(1) Discharges air from the external gas piping between the cylinder and the mixer.
This step is performed to prevent the gas from being mixed with air.

(2) Resumes the operation from the wait state for requesting cylinder replacement (due to low cylinder level).
When a low cylinder pressure is detected while the mixer is being supplied with gases, 111 is displayed on the diagnostic screen No.987. Only the mixer stops its operation temporarily. A resume operation is necessary.

Leak check

To check the mixer for leaks, hold the LCAN signal (G221#4) to 1 for about 500 milliseconds in the state before RUN-ON. The operation up to evacuation sealing is performed automatically. The leak check terminates by RUN-ON. An operator must check whether there is a leak.

First activation after restoration of the NC

The entire mixer sequence is managed according to the flags specified in parameter No. 15009. If the stored data is lost due to replacement of the memory module or a memory clear operation, parameter No. 15009 must be reset, as is done after installation of the mixer, described above.

Signal

- Leak check start signal LCAN<G221#4>

[Classification] Input signal
[Function] Checks the mixer for leaks.

- Cylinder replacement signal BCAN<G221#5>

[Classification] Input signal
[Function] Informs the NC that a cylinder has been replaced.

Signal address

	#7	#6	#5	#4	#3	#2	#1	#0
G221			BCAN	LCAN				

Parameter

	#7	#6	#5	#4	#3	#2	#1	#0
15009	TME	BCG	BEM		BS2	BS1	AS2	AS1

[Data type] Bit

AS2, AS
00: Tank A is being supplied with gases.
01: Tank A is mixing the gases.
10: Tank A is supplying the mixed gas.
11: Tank A is preparing for gas supply.

BS2, BS1
00: Tank B is being supplied with gases.
01: Tank B is mixing the gases.
10: Tank B is supplying the mixed gas.
11: Tank B is preparing for gas supply.

BEM
0: The supply pressure of the gas cylinder has fallen.
1: The supply pressure of the gas cylinder is normal.

BCG
0: The gas cylinder has been replaced.
1: The gas cylinder has not been replaced.

TEM
0: The supply pressure of the tank has fallen.
1: The supply pressure of the tank is normal.

15710 **External piping (between cylinder and mixer) discharge time**

[Data type] Word
[Unit of data] sec
[Valid data range] 0 to 32767

15711 **Gas mixture wait time**

[Data type] Word
[Unit of data] min
[Valid data range] 0 to 32767

15712 **Mixer evacuation time**

[Data type] Word
[Unit of data] min
[Valid data range] 0 to 32767

15713 **Helium discharge time**

[Data type] Word
[Unit of data] msec
[Valid data range] 0 to 32767

15714 **Nitrogen/CO_2 gas discharge time**

[Data type] Word
[Unit of data] msec
[Valid data range] 0 to 32767

15715 **Degree of vacuum of gas pressure**

[Data type] Word
[Unit of data] (1 = 13Pa)
[Valid data range] 0 to 32767

15716	Evacuation wait time

[Data type] Word
[Unit of data] min
[Valid data range] 0 to 32767

Alarm and message

No.	Message	Contents
4136	High internal pressure	The internal pressure of the mixer is too high.
4137	Abnormal mixer power	The power to the relay PCB in the mixer is abnormal.
4138	Insufficient degree of vacuum	The mixer does not reach a predetermined degree of vacuum within a predetermined evacuation time.
4139	Abnormal mixer pressure switch	The supply pressure of the laser gas is low, but the supply pressure of the tank is not low.

⚠ **CAUTION**
For details of how to operate the laser gas mixer, read the operator's manual provided with the laser gas mixer.

8.9 REFLECTION BEAM MONITOR FUNCTION

Overview

When a highly reflective workpiece is laser-cut, the cutting face may reflect the laser beam back to the laser resonator. Should this occur, the cutting face and rear mirror form a false resonator, increasing the laser power. The resultant laser beam may damage an optical component.
To prevent such damage from occurring, the function monitors the laser power. If the laser power exceeds a predetermined level, the reflection beam is judged as returning to the resonator, and an alarm is output.

Reflection beam monitoring

(1) If the laser power exceeds a specified value by a value greater than or equal to the setting made with parameter No. 15265, an alarm is raised.
(2) If the laser power is greater than or equal to the setting made with parameter No. 15266, an alarm is raised.

Parameter

15265 **Allowable output increase**

[Data type] Word
[Unit of data] W
[Valid data range] 0 to 32767
If the difference between the specified value and the actual output is greater than or equal to this value, an alarm is raised.

15266 **Maximum output**

[Data type] Word
[Unit of data] W
[Valid data range] 0 to 32767
If the actual output is greater than or equal to this value, an alarm is raised.

Alarm and message

No.	Message	Contents
4168	Abnormal beam reflection	The magnitude of the reflection beam from the workpiece has reached a predetermined level.

8.10 PULSE ENHANCED FUNCTION

Overview

If an overridden value of output power Pc exceeds a predetermined value (parameter No. 15213), the pulse duty ratio is limited to 50% or less.
The overridden value of output power Pc is limited to a predetermined value (parameter No. 15210).
If the duty ratio is limited to 50%, the power value obtained after power compensation and power feedback addition is limited to the setting made with parameter No. 15207. If the duty ratio is not limited to 50%, the power value is limited to the setting made with parameter No. 15212.

Parameter

15212 **Maximum power when the pulse duty ratio is not limited**

[Data type] Word
[Unit of data] W
[Valid data range] 0 to 32767

When the pulse duty ratio is not limited to 50% according to the setting made with parameter No. 15213, the power value obtained after power compensation and power feedback addition cannot exceed this value.

15213 **Criterion for clamping the duty ratio**

[Data type] Word
[Unit of data] W
[Valid data range] 0 to 32767

If an overridden value of the power Pc exceeds this setting, the pulse duty ratio is limited to 50% or less, and the power value is limited to the setting made with parameter No. 15210.

NOTE
When this function is not used, set identical values in parameters No. 15210 and No. 15213 and in parameters No. 15207 and No. 15212.

8.11 AI CONTOUR CONTROL

Overview

This function is intended for high-speed and high-precision machining. The use of this function can hold down the delay due to acceleration/deceleration and the delay in the servo system, which increase as the feedrate increases, reducing the machining profile error. This also enables linear acceleration/deceleration before look-ahead interpolation with the look-ahead of up to 40 blocks, achieving smooth acceleration/deceleration over multiple blocks and permitting higher-speed machining.
This function is limited to two-dimensional commands.
The following functions are enabled in the AI contour control mode.

(1) Linear acceleration/deceleration before look-ahead interpolation (look-ahead of up to 40 blocks)
(2) Automatic corner deceleration
(3) Feedrate clamp by acceleration
(4) Feedrate clamp by arc radius
(5) Block overlap (usually five blocks, up to 40 blocks depending on the parameter setting)
(6) Advanced preview feed forward

For details of the above functions, see the descriptions of the respective functions.

Specifications

Axis control

Name	Function
Number of controlled axes	3 to 8
Number of simultaneous controlled axes	Up to 6
Axis name	The three basic axes are fixed at X, Y, and Z. Other axes may be assigned any of U, V, W, A, B, and C.
Least input increment	0.001 mm, 0.001 deg, 0.0001 inch

Interpolation functions ○: Specifiable ×: Not specifiable

Name	Function
Positioning (G00)	○ (Linear interpolation type positioning)
Single direction positioning (G60)	×
Exact stop (G09)	○
Exact stop mode (G61)	○
Automatic corner override (G62)	×
Linear interpolation (G01)	○
Circular interpolation (G02, G03)	○ (Possible in multiple quadrants)

Name	Function
Helical interpolation (G02, G03)	○ (Circular interpolation plus max. 2 axes linear interpolation) If the helical interpolation option is provided, linear interpolation can be performed on up to two axes. The specified feedrate must include the speed on the helical axis.
Conical/spiral interpolation (G02, G03)	×
Exponential interpolation (G02.3, G03.3)	×
Dwell (G04)	○ (Specified in seconds.)
Polar coordinate interpolation (G12.1, G13.1)	×
Cylindrical interpolation (G07.1)	×
Skip function (G31)	○ *
Reference position return (G28)	○ If the zero point is not established, P/S alarm No. 090 is raised. *
Reference position return check (G27)	○ *
Second, third, and fourth reference position returns (G30)	○ *
Floating reference position return (G30.1)	○ *
Normal direction control (G41.1, G42.1)	×
Absolute command (G90)/ incremental command (G91)	○

Feed functions ○: Specifiable ×: Not specifiable

Name	Function
Rapid traverse rate	240 m/min (0.01 mm) max.
	100 m/min (0.0001 mm) max.
Rapid traverse rate override	F0, 25, 50, 100%
1% rapid traverse rate override	0 to 100 %
Feed per minute	○
Rapid traverse bell-shaped acceleration/deceleration	×
Linear acceleration/deceleration before cutting feed interpolation	○ (Look-ahead of up to 40 blocks)
Feedrate override	0 to 254 %
Second feedrate override	×
One-digit F code feed	×
Inverse time feed (G93)	×
External deceleration	○

Tool compensation functions ○: Specifiable ×: Not specifiable

Name	Function
Cutter compensation C (G40, G41, G42)	○

Name	Function
Tool length compensation (G43, G44, G49)	○

Program input ○: Specifiable ×: Not specifiable

Name	Function
Plane selection (G17, G18, G19)	○
Local coordinate system (G52)	○ *
Workpiece coordinate system (G54-G59) (G54.1Pxx)	○ *
Workpiece coordinate system (G92)	○ *
Workpiece coordinate system preset (G92.1)	○ *
Interruption type custom macro	×

Laser functions ○: Specifiable ×: Not specifiable

Name	Function
Laser output command	○ G01S_P_Q_; is specifiable.
Piercing command (G24)	○ Including high-speed piercing.
Assist gas command (G32)	○
Z-axis tracing control (G13/G14)	○ If Z-axis tracing control is performed, the Z-axis cannot be placed under AI contour control.
Power control (G63)	○
Cutting condition setting function	○ E codes are specifiable. Neither cutter compensation amounts or feedrates can be specified.
Edge machine function, start-up machining	○
Step function	×
Beam delay control	○ The delay amount is specified in a separate parameter.
Retry processing function	×
Optical path length compensation	○ The mirror axis for optical path length compensation cannot be placed under AI contour control.
Buffer expansion	○
Interaction control	○
Attitude control A, B	○ Cannot be used together with helical interpolation B.
3-dimentional conversion (G98/G99)	×
3-dimentional coordinate system conversion (G68/G69)	×
Spatial corner R insertion (G33/G34)	×
Spatial circular interpolation (G12)	×
Proximity point search	×
Machining head A axis length compensation function (G71)	×

Name	Function
Program restart (laser specifications)	×

Others ○: Specifiable ×: Not specifiable

Name	Function
Cycle start / feed hold	○
Dry run	○
Single block	○
Interlock	○
Machine lock	○ If the machine lock signals for the individual axes (MLK1 to MLK8) are turned on/off, no acceleration/deceleration is applied to the axes for which the machine lock has been applied.
Control in/control out command ( )	○
Optional block skip command (/n:n is a number)	○
Auxiliary function (Mxxxx)	○ Only function code signals and function strobe signals are output.
Tool function (Txxxx)	○ Only function code signals and function strobe signals are output.
Second auxiliary function (Bxxxx)	○ Only function code signals and function strobe signals are output.
Simple synchronous control	○ It is not possible to switch between synchronization and no synchronization.
Program restart	×
Retrace function	×
Macro executor (execution macro)	×
MDI operation	× If G05.1Q1 is specified in MDI mode, P/S alarm No. 5113 is raised. In AI contour control mode, it is not possible to perform operation by switching to MDI mode.
Manual intervention	× If manual intervention is performed, it is necessary to return the coordinates to the position of intervention at a restart. Otherwise, P/S alarm No. 514 is raised.

* Look-ahead of multiple blocks is not performed.

Conditions for entering AI contour control mode

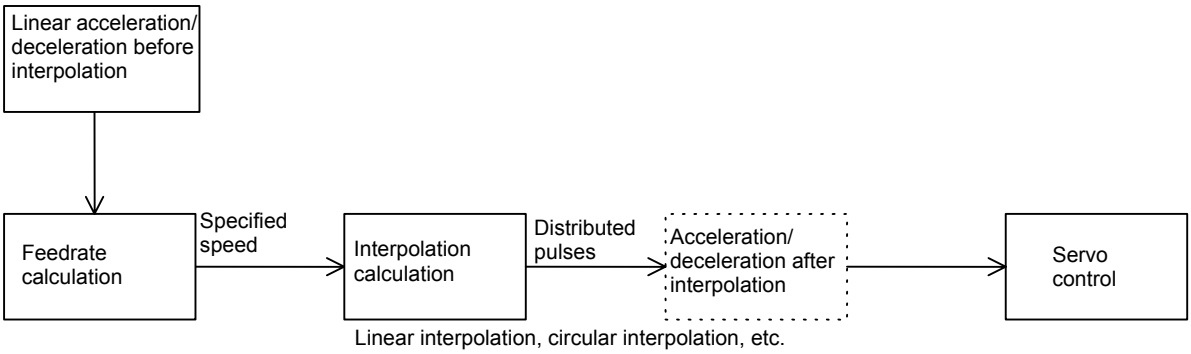
To specify G05.1Q1, the modal must be as given below. If these conditions are not satisfied, P/S alarm No. 5111 is raised.

G code	Meaning
G00	Positioning
G01	Linear interpolation
G02	Circular interpolation (CW)
G03	Circular interpolation (CCW)

G code	Meaning
G13.1	Polar coordinate interpolation cancel mode
G15	Polar coordinate command cancel
G40	Cutter compensation cancel
G40.1	Normal direction control cancel mode
G49	Tool length compensation cancel
G50	Scaling cancel
G50.1	Programmable mirror image cancel
G64	Cutting mode
G67	Macro modal call cancel
G69	Coordinate rotation cancel

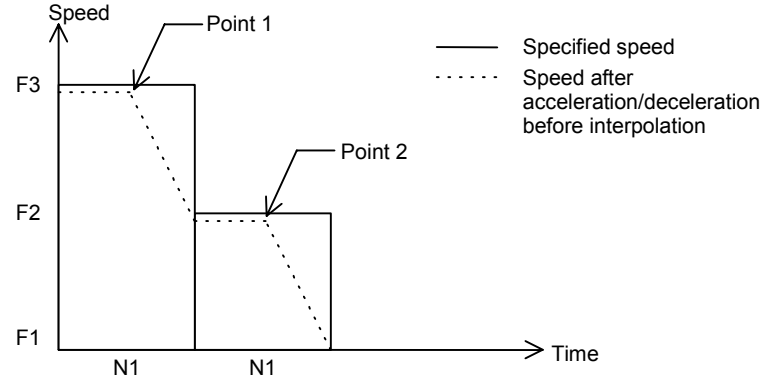
Linear acceleration/deceleration before look-ahead interpolation

This function can perform look-ahead of up to 40 blocks for a feed-per-minute cutting feed command so that linear acceleration/deceleration can be applied before interpolation, that is, to the specified speed. With acceleration/deceleration after interpolation, acceleration/deceleration is applied to interpolated data, so that the interpolated data is changed. With acceleration/deceleration before interpolation, on the other hand, acceleration/deceleration is applied to the feedrate data before interpolation, so that interpolated data is not changed by acceleration/deceleration. For this reason, interpolated data may be applied to a specified straight line or curve at any time to remove any machining profile error attributable to acceleration/deceleration delay.



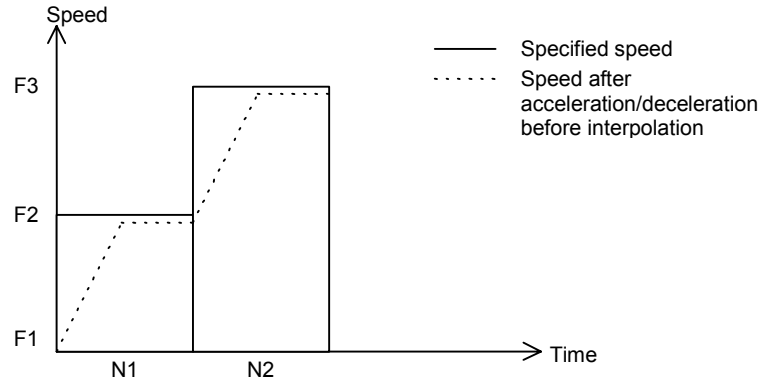
(Deceleration example)

During execution, to achieve the speed specified for one block, deceleration starts in the previous block.



To reduce the speed from speed F3 to speed F2, deceleration must start at point 1.
To reduce the speed from speed F2 to speed F1, deceleration must start at point 2.
Because look-ahead of up to 40 blocks can be performed, deceleration can extend over several blocks.

(Acceleration example)
During execution, acceleration is performed so that the speed specified for one block is achieved.



Automatic corner deceleration

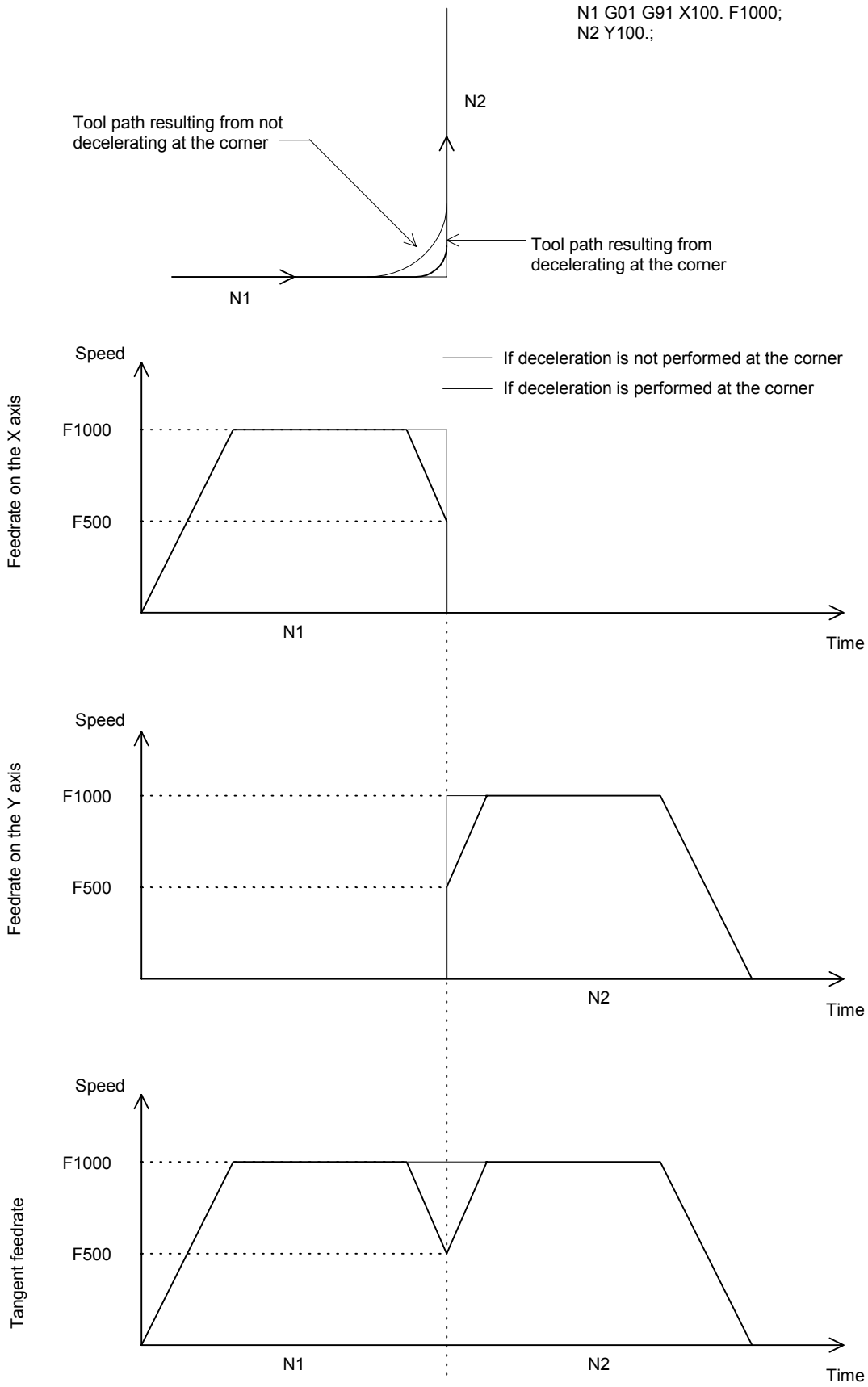
Using for reference the axis for which the ratio of the actual speed difference to the permissible speed difference is the largest of the axes for which the speed difference on each axis between blocks exceeds the setting (parameter No. 1783), this function calculates the speed at a corner as described below, and decelerates the tool to achieve that speed at the block joint.
The speed changes on the respective axes (Vx, Vy, ...) during movement at the specified speed F are compared with the settings of parameter No. 1783 (Vprm-x, Vprm-y, ...). If the speed change on any axis exceeds the corresponding parameter setting,

$$\mathrm{Rmax} = \max\left[\frac{\mathrm{Vx}}{\mathrm{Vprm-x}}, \frac{\mathrm{Vy}}{\mathrm{Vprm-y}}, \cdots\right]$$

the speed (Fc) is determined as given below and deceleration is performed at the corner.

where $\mathrm{Fc} = \mathrm{F} \times \dfrac{1}{\mathrm{Rmax}}$

For example, assuming that the specified feedrate is 1000 mm/min and the permissible speed difference (parameter No. 1783) is 500 mm/min, deceleration is performed as shown in the next figure if the tool movement direction changes by 90 degrees from X axis to Y axis.


N1 G01 G91 X100. F1000;
N2 Y100.;
N2
Tool path resulting from not decelerating at the corner
Tool path resulting from decelerating at the corner
N1
Speed
If deceleration is not performed at the corner
If deceleration is performed at the corner
Feedrate on the X axis
F1000
F500
N1
Time
Speed
Feedrate on the Y axis
F1000
F500
N2
Time
Speed
Tangent feedrate
F1000
F500
N1
N2
Time

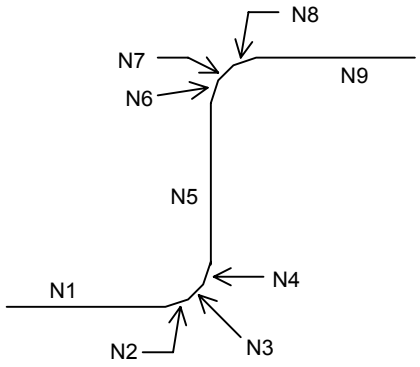
Feedrate clamp by acceleration

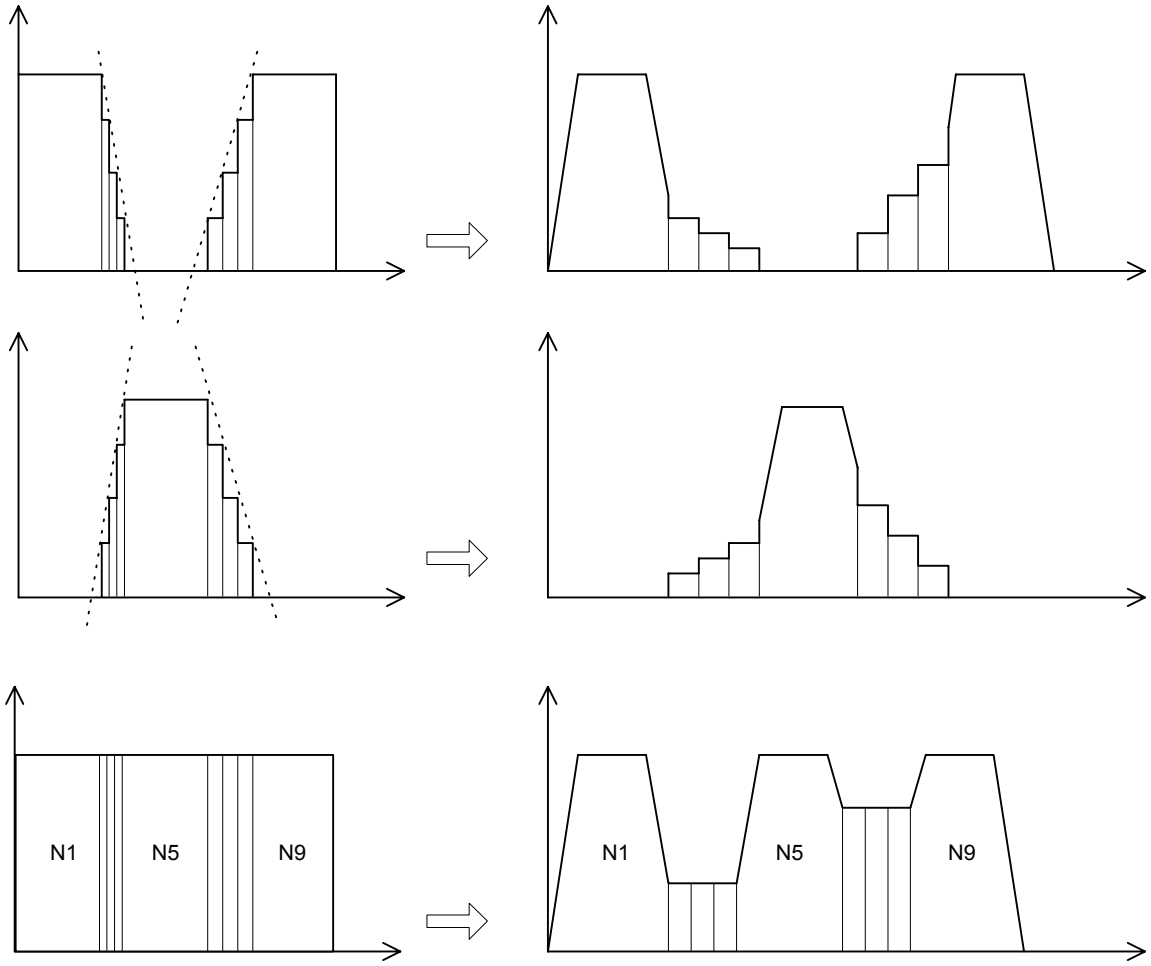
If consecutive, minute straight lines form a curve, as in the example shown in the figure below, the speed difference on each axis between corners is not very large. Deceleration by speed difference is not, therefore, effective. Consecutive, small speed differences, however, cause large acceleration on each axis as a whole.
In such a case, to hold down the shocks to the machine and machining errors that can result from increases in acceleration, deceleration can be performed. The speed to be attained by deceleration is such a feedrate that the acceleration on each axis, which can be determined with the formula shown below, does not exceed the permissible acceleration established for all axes.
The permissible acceleration is established with the maximum cutting feedrate (parameter No. 1432) and the time required to reach that feedrate (parameter No. 1785).

$$\text{Acceleration on each axis} = \frac{\text{Speed difference on that axis between corners}}{\max\left(\frac{\text{Travel distance in the previous block}}{E}, \frac{\text{Travel distance in the next block}}{F}\right)}$$

The deceleration speed is determined for each corner. Of the actual feedrate, the deceleration speed determined at the start point of the block, the deceleration speed determined at the end point, the smallest one is assumed.
(Example)

In the following example, deceleration is performed at N2 to N4 and at N6 to N8, because acceleration/deceleration (inclination of the dotted line in the speed graph) is large.





Feedrate clamp by arc radius

To ensure that the acceleration in an arc block does not exceed the permissible value, this function calculates the maximum permissible speed v for an arc with the program-specified radius r, using the arc radius R and the maximum permissible speed V (parameter setting) for this radius, as described below. If the specified feedrate exceeds the speed V, this function automatically clamps it to the speed v.
Assuming that

$$\text{Maximum permissible acceleration} = \frac{V^2}{R}$$

R: Arc radius V: Feedrate for the arc radius R
then, the maximum permissible speed v for an arc with the radius r can be determined with the following formula:

$$v = \sqrt{r/R} \times V$$

The smaller the specified arc radius, the lower the maximum permissible speed v. To prevent it from decreasing extremely, the maximum permissible speed v can be set to the setting of parameter No. 1732 (lower limit on the feedrate clamp by arc radius) when it decreases below the setting of parameter No. 1732.

Rapid traverse

In rapid traverse, acceleration/deceleration is performed with acceleration/deceleration before interpolation and travel is performed with linear-type positioning. Either the linear or bell-shaped type can be selected as the acceleration/deceleration type. The speed during travel and the acceleration of acceleration/deceleration before interpolation can be determined as follows:

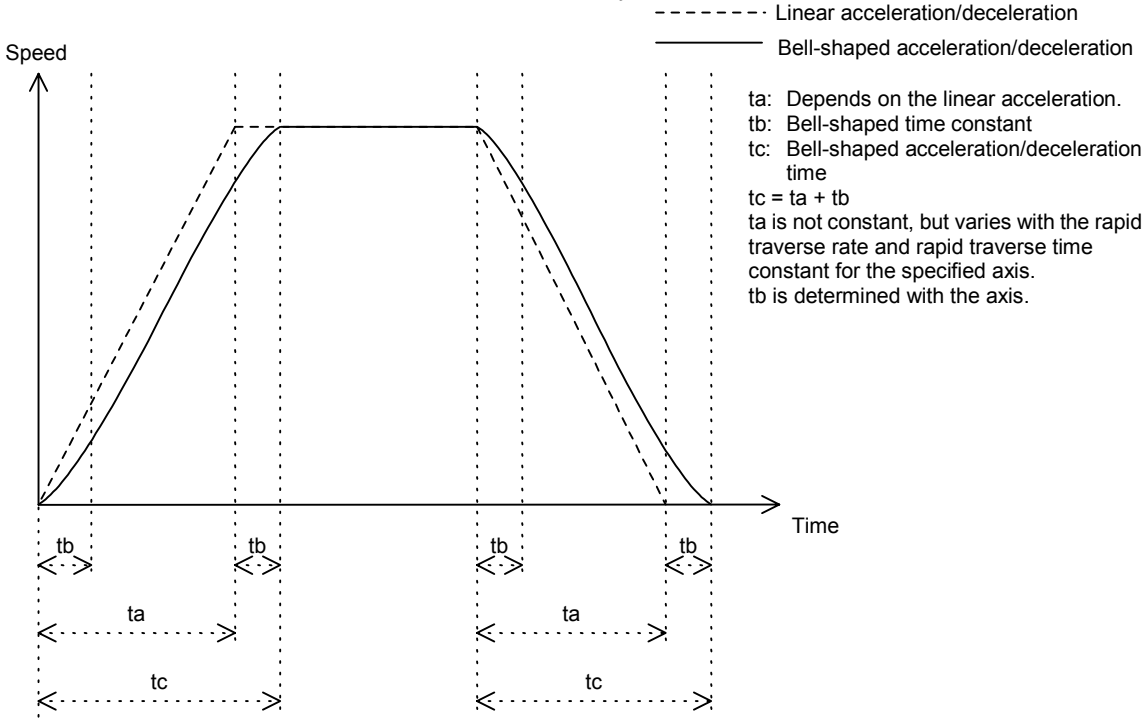
(1) Speed during travel
Of the axes of travel, the lowest value as calculated with the following formula is assumed the speed during travel.

$$\text{Feedrate on each axis (parameter No. 1420)} \times \frac{\text{Travel distance of the block}}{\text{Travel distance of each axis}}$$

(2) Acceleration of acceleration/deceleration before interpolation
- For the linear type
Of the axes of travel, the lowest value as calculated with the following formula is assumed the acceleration of linear acceleration/deceleration before interpolation during travel.

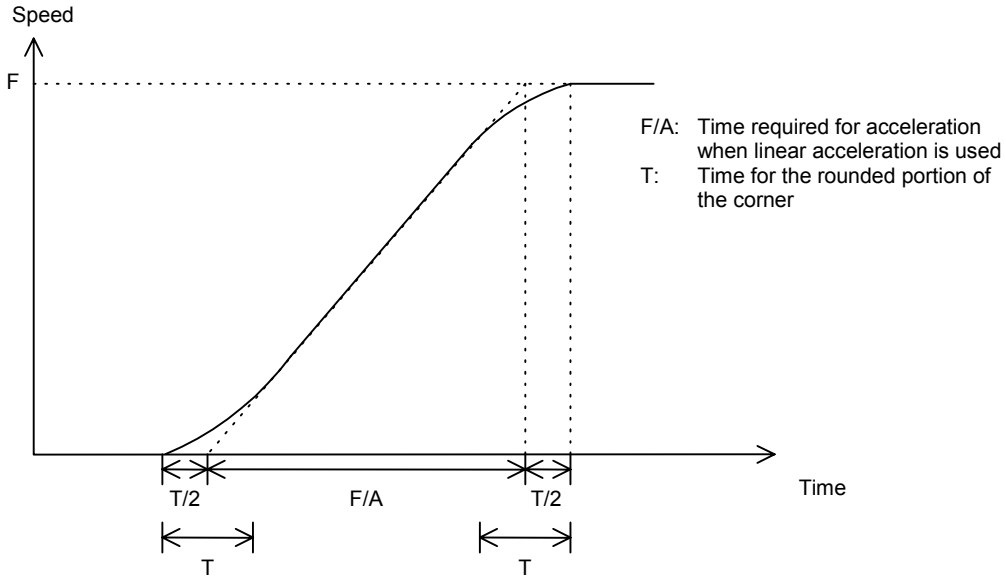
$$\frac{\text{Feedrate on each axis (parameter No. 1420)}}{\text{Time constant for each axis (parameter No. 1620)}} \times \frac{\text{Travel distance of the block}}{\text{Travel distance of each axis}}$$

- For the bell-shaped type
The speed determined from the acceleration described above is multiplied by the time constant specified in parameter No. 1621 (rapid traverse bell-shaped acceleration/deceleration time constant for each axis) for the axis that yields the smallest value with the above formula.



Assuming that the speed during travel is F, the acceleration assumed when linear acceleration/deceleration is used is A, and the bell-shaped acceleration/deceleration time constant is T, the time required for acceleration/deceleration is:

Time required for acceleration/deceleration=F/A (linear type)
=F/A+T (bell-shaped type)



NOTE
1 Rapid traverse block overlaps are disabled.
2 If bell-shaped acceleration/deceleration is to be used, the rapid traverse bell-shaped acceleration/deceleration option is required.

Signal

- AI contour control mode signal AICC＜F062#0＞

[Classification] Output signal
[Function] Notifies that the system is in AI contour control mode.
[Output condition] The signal is set to "1" if:
- The system enters AI contour control mode.

The signal is set to "0" if:
- The system leaves AI contour control mode.

Signal address

	#7	#6	#5	#4	#3	#2	#1	#0
F062								AICC

Parameter

- Parameters related to linear acceleration/ deceleration before interpolation

1770 **Maximum cutting speed during linear acceleration/deceleration before interpolation**

[Data type] 2-word

[Unit of data]
[Valid data range]

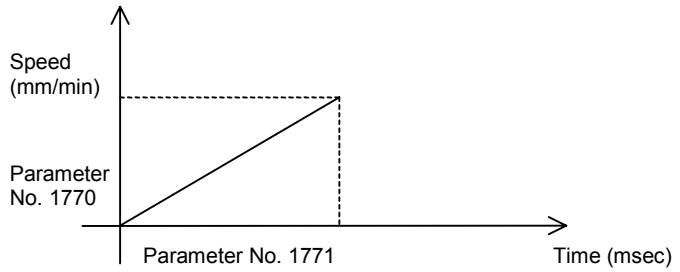
Input increment	Unit of data	Valid data range	
		IS-A, IS-B	IS-C
Millimeter machine	1 mm/min	6 to 240000	6 to 100000
Inch machine	0.1 inch/min	6 to 9600	6 to 4800

Specify the maximum cutting speed during linear acceleration/ deceleration before interpolation.
(Parameter 1 for specifying the acceleration of linear acceleration/ deceleration before interpolation)

1771 **Time required to reach the maximum cutting speed during linear acceleration/deceleration before interpolation (time constant)**

[Data type] Word
[Unit of data] 1 msec
[Valid data range] 0 to 4000
Specify the time (time constant) required to reach the speed specified in parameter 1.
(Parameter 2 for specifying the acceleration of linear acceleration/ deceleration before interpolation)

NOTE
1 If either parameter No. 1770 or 1771 is set to 0, no linear acceleration/deceleration before interpolation is applied.
2 The setting of parameter No. 1770 divided by the setting of parameter No. 1771 must be equal to or greater than 5.



1784 **Speed assumed when an overtravel alarm is raised during linear acceleration/deceleration before interpolation**

[Data type] Word

[Unit of data]
[Valid data range]

Input increment	Unit of data	Valid data range	
		IS-A, IS-B	IS-C
Millimeter machine	1 mm/min	6 to 15000	6 to 12000
Inch machine	0.1 inch/min	6 to 6000	6 to 4800

Specify the speed assumed when an overtravel alarm is raised during linear acceleration/deceleration before interpolation.
If an overtravel alarm is raised during linear acceleration/deceleration before interpolation, the tool decelerates and stops after the alarm is raised, so that it overruns by the deceleration distance. The overrun distance varies depending on the feedrate assumed when the overtravel alarm is raised. The overrun distance can be reduced by performing deceleration in advance to achieve the speed specified in parameter No. 1784 when an overtravel alarm is raised. In this case, deceleration may be completed sooner because deceleration is performed so that the feedrate assumed when an overtravel alarm is raised does not exceed the speed specified in the parameter. The feedrate assumed after the completion of deceleration is equal to the speed specified in the parameter.

NOTE
This parameter is not effective to rapid traverse blocks.

Deceleration is performed if the following condition is satisfied:

Distance to the stored stroke limit on each axis	<	Distance required for reduction from the current speed (tangent feedrate) to the speed of parameter No.1784

The overrun distance will be as follows:

$$\text{Overrun distance} \leqq \frac{\left[\text{FIX}\left(\frac{T_{OT}}{F} \times \frac{T}{8}\right) + 1.5\right]^2}{1875} \times \frac{F}{T}$$

F: Maximum cutting speed during linear acceleration/deceleration before interpolation (parameter No. 1770)
T: Time required to reach the maximum cutting speed during linear acceleration/deceleration before interpolation (parameter No. 1771)
F_{OT}: Speed assumed when an overtravel alarm is raised during linear acceleration/deceleration before interpolation (parameter No. 1784)
FIX: Rounds the value down to the nearest whole number.

NOTE
1 If 0 is set, the above control is not performed.
2 When the stroke check is disabled, the above control is also disabled.
3 The above control is effective to stored stroke check 1 only.

- Parameter related to automatic corner deceleration

1783	Permissible speed difference on each axis for the function for deceleration at corners by speed difference (for acceleration/deceleration before interpolation)

[Data type] Word axis

[Unit of data]

[Valid data range]

Input increment	Unit of data	Valid data range	
		IS-A, IS-B	IS-C
Millimeter machine	1 mm/min	6 to 15000	6 to 12000
Inch machine	0.1 inch/min	6 to 6000	6 to 4800
Rotation axis	1 deg/min	6 to 15000	6 to 12000

Specify the speed difference on each axis for the function for automatic deceleration at corners by speed difference when linear acceleration/ deceleration before interpolation is used.

- Parameter related to the feedrate clamp by acceleration

1785	Parameter for determining the permissible acceleration in speed clamp by acceleration

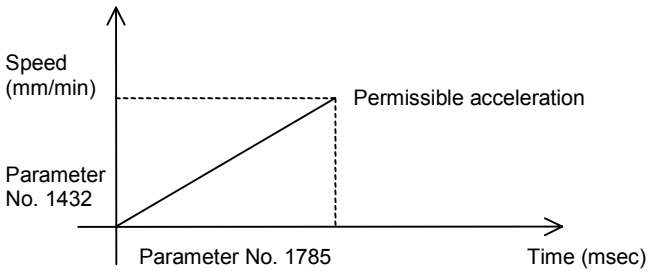
[Data type] Word axis

[Unit of data] 1 msec

[Valid data range] 0 to 32767

To determine the permissible acceleration used to perform speed clamp by acceleration, specify the time required to reach the maximum cutting feedrate.

The maximum cutting feedrate and the setting of this parameter are used to determine the permissible acceleration. Parameter No. 1432 (maximum cutting feedrate in AI contour control mode) is used as the maximum cutting feedrate parameter.



- Parameters related to feedrate clamp by arc radius

1731	Arc radius corresponding to the upper feedrate limit

[Data type] 2-word

[Unit of data]

Input increment	IS-A	IS-B	IS-C	Unit
Millimeter machine	0.01	0.001	0.0001	min
Inch machine	0.001	0.0001	0.00001	inch

[Valid data range] 1000 to 99999999

Specify the arc radius corresponding to the upper feedrate limit specified in parameter No. 1730.

1730 **Upper feedrate limit at the arc radius R**

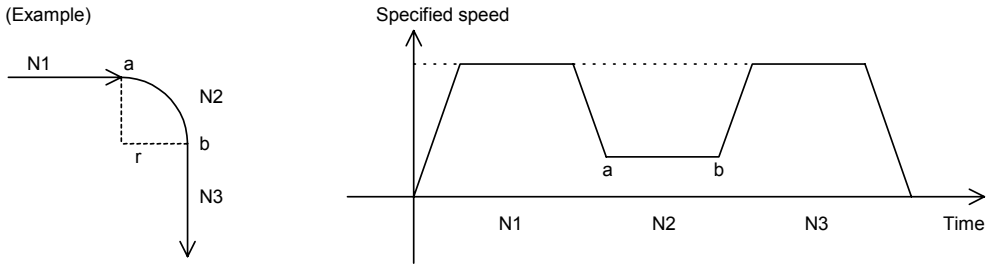
[Data type] Word

[Unit of data]

[Valid data range]

Input increment	Unit of data	Valid data range	
		IS-A, IS-B	IS-C
Millimeter machine	1 mm/min	8 to 15000	0 to 12000
Inch machine	0.1 inch/min	8 to 6000	0 to 4800

Specify the upper feedrate limit at the arc radius specified in parameter No. 1731.



1732 **Lower limit RVmin on feedrate clamp by arc radius**

[Data type] Word

[Unit of data]

[Valid data range]

Input increment	Unit of data	Valid data range	
		IS-A, IS-B	IS-C
Millimeter machine	1 mm/min	8 to 15000	0 to 12000
Inch machine	0.1 inch/min	8 to 6000	0 to 4800

With the "feedrate clamp by arc radius" function, the smaller the arc radius, the lower the upper feedrate limit. If the upper feedrate limit is lower than the lower limit RVmin on the feedrate clamp by arc radius, the upper feedrate limit is set to RVmin.

- Other parameters

1422 **Upper speed limit for cutting feed in AI contour control**

[Data type] 2-word

[Unit of data]

[Valid data range]

Input increment	Unit of data	Valid data range	
		IS-A, IS-B	IS-C
Millimeter machine	1 mm/min	6 to 240000	6 to 100000
Inch machine	0.1 inch/min	6 to 96000	6 to 48000

Specify the upper speed limit for cutting feed in AI contour control mode.

1432 **Maximum cutting feedrate in AI contour control mode (each axis)**

[Data type] 2-word

[Unit of data]

[Valid data range]

Input increment	Unit of data	Valid data range	
		IS-A, IS-B	IS-C
Millimeter machine	1 mm/min	0 to 240000	0 to 100000
Inch machine	0.1 inch/min	0 to 96000	0 to 48000
Rotation axis	1 deg/min	0 to 240000	0 to 100000

Specify the maximum cutting feedrate on each axis in AI contour control mode.

	#7	#6	#5	#4	#3	#2	#1	#0
1603		RBL						

[Data type] Bit

RBL In AI contour control mode, rapid traverse acceleration/deceleration is:

0: Linear acceleration/deceleration.

1: Bell-shaped acceleration/deceleration.

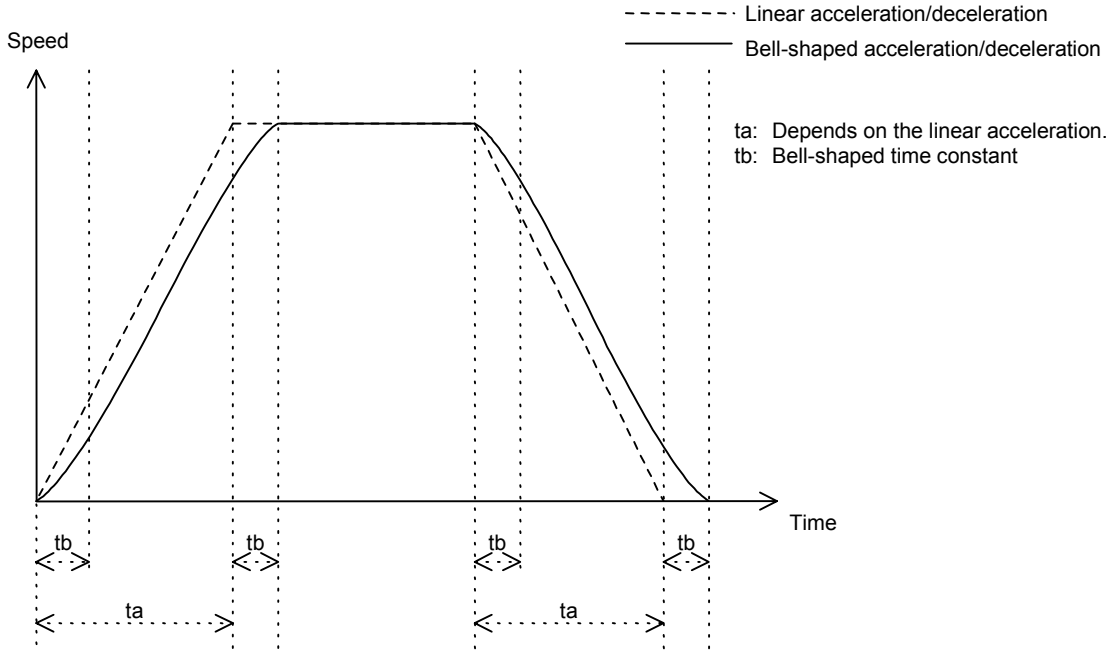
1621	Rapid traverse bell-shaped acceleration/deceleration time constant for each axis

[Data type] Word axis

[Unit of data] 1 msec

[Valid data range] 0 to 512

Specify tb, shown in the figure below, for each axis. If the setting is 0, linear acceleration/deceleration is assumed.



7061	Number of block overlaps

[Data type] Byte

[Unit of data] Blocks

[Valid data range] 0 to 40

To overlap multiple blocks, specify the maximum number of block overlaps. If the setting is 0, 5 fives are assumed.

	#7	#6	#5	#4	#3	#2	#1	#0
7050		MI1	MI0					

[Data type] Bit

MI1、MI0 Set the following values:

	MI1	MI0
Setting	0	1

	#7	#6	#5	#4	#3	#2	#1	#0
7052								NMI

[Data type] Bit axis

For a PMC controlled axis, tracing control axis, or optical path length compensation mirror axis, set this bit to 1.

- Parameter numbers used in normal mode, advanced preview control mode, and AI contour control mode

(Parameters related to linear acceleration/deceleration before interpolation)

Parameter	Parameter number		
	Normal	Advanced preview control	AI contour
Acceleration/deceleration type (type A/B)	FWB/1602#0		None
Parameter 1 for specifying acceleration/deceleration	1630	1770	
Parameter 2 for specifying acceleration/deceleration	1631	1771	
Speed assumed if on overtravel alarm is raised	1784		

(Parameters related to automatic corner deceleration)

Parameter	Parameter number		
	Normal	Advanced preview control	AI contour
Automatic corner deceleration judgment method (angle/speed difference)	CSD/1602#4		None
Lower speed limit (control by angle)	1778	1777	None
Judgment angle (control by angle)	1740	1779	None
Permissible speed difference for all axes (control by speed difference)	1780		None
Permissible speed difference for each axis (control by speed difference)	1783		

(Parameter related to speed clamp by acceleration)

Parameter	Parameter number		
	Normal	Advanced preview control	AI contour
Parameter for determining permissible acceleration	None		1785

(Parameters related to speed clamp by arc radius)

Parameter	Parameter number		
	Normal	Advanced preview control	AI contour
Arc radius for the upper feedrate limit	1731		
Upper feedrate limit at the arc radius R	1730		
Lower clamp speed limit	1732		

(Others)

Parameter	Parameter number		
	Normal	Advanced preview control	AI contour
Radius error precision in circular interpolation	PCIRI/3403#0		None
Maximum cutting federate (common to all axes)	1422	1431	1422
Maximum cutting feedrate (for each axis)	1430	1432	
Rapid traverse bell-shaped acceleration/deceleration time constant	1621		RBL/1603#6 1621

Alarm and message

No.	Message	Description
5110	IMPROPER G-CODE (G05.1 G1 MODE)	An un-specifiable G code is specified in AI contour control mode.
5111	IMPROPER MODAL G-CODE (G05.1 G1)	When AI contour control mode is specified, an unusable G code is modal.
5112	G08 CAN NOT BE COMMANDED (G05.1 G1)	In AI contour control mode, the advanced preview control command (G08) is specified.
5113	CAN NOT ERROR IN MDI MODE (G05.1)	In MDI mode, the AI contour control command (G05.1) is specified.
5114	NOT STOP POSITION (G05.1 Q1)	At a restart after manual intervention, the coordinates have not returned to the stop position.
5156	ILLEGAL AXIS OPERATION (AICC)	In AI contour control mode, the controlled axis select signal (PMC axis control) changed. In AI contour control mode, the simple synchronous axis selection signal changed.
5157	FEEDRATE 0 (AICC)	The maximum cutting feedrate parameter (No. 1422 or 1532) is set to 0. The parameter for acceleration/deceleration before interpolation (No. 1770 or 1771) is set to 0.

Cautions

⚠ CAUTION

1 If the total distance of the advanced preview blocks decreases below the deceleration distance from the current speed, deceleration starts. If, at the end of deceleration, advanced preview has proceeded, increasing the total distance of blocks, acceleration is performed again. If blocks, especially those with small travel distances, are specified in succession, the speed may not become constant because deceleration and acceleration are performed alternately. If this occurs, decrease the specified speed.

2 If, during axial movement, the dry run signal changes from "0" to "1" or from "1" to "0," acceleration/deceleration is performed to the predetermined speed without deceleration to speed 0.

3 If, in AI contour control mode, there is a block without movement or a 1-shot G code command such as G04, the tool decelerates and stops temporarily in the previous block.

Notes

TE

1 Acceleration before interpolation used must be of the linear or bell-shaped type. Exponential acceleration/deceleration cannot be used.

2 During switching to AI contour control mode, manual handle interrupts are disabled.

3 This function is limited to X-Y plan machining. It cannot be used together with cylindrical interpolation, normal direction control, three-dimensional machining function, etc.

Reference item

Series 16*i*/160*i*/18*i*/180*i*	Operator's Manual (B-63524EN)	II.19.6	AI contour control
FANUC Series 16*i*/160*i*-LB	Operator's Manual (B-63664EN)	II.16.7	

APPENDIX

A INTERFACE BETWEEN CNC AND PMC (FOR C SERIES AND Y SERIES LASER)

A.1 LIST OF ADDRESSES

Interface addresses among CNC, PMC and Machine Tool are as follows:

(1) Standard signals
Refer to the FANUC Series 16*i*/160*i*-MODEL B Connection Manual (B-63523EN-1).

(2) FS16*i*-LB-specific signals

PMC→CNC

	#7	#6	#5	#4	#3	#2	#1	#0
G007								RVS
G220				*DU16	*DU8	*DU4	*DU2	*DU1
G221	AGRDY	CLRDY	BCAN	LCAN	PTE	PTS		
G222	HVON	RUN	AGST	BEMON	SHTON	SCLON	*BEMLC	*SHTLC
G223	PVO7	POV6	POV5	POV4	POV3	POV2	POV1	POV0
G224	OTPMX2						PWCTL	LRCS
G225		GAPG2	GAPG1	GAPG0	TCST	TRCKM	ZAPR	ZTRM
G226	RVSLSR	TBES			HNDCD	ALNAXS	REST2	NRSRH
G227	TRMLK	*TRIL						
G228	*FOV7	*FOV6	*FOV5	*FOV4	*FOV3	*FOV2	*FOV1	*FOV0
G229	*AOV7	*AOV6	*AOV5	*AOV4	*AOV3	*AOV2	*AOV1	*AOV0

CNC→PMC

	#7	#6	#5	#4	#3	#2	#1	#0
F082						RVSL		
F220	TRALM	MWRN	WKP	SHTONL	SHTOFL	TRCL	AGSLT	TRERS
F221	BEAM	LSTR	RFHV	CLON	WAIT	PURGE	LRDY	LARM
F222	PIRC	CW	PULSE	LPRC		AG3	AG2	AG1
F223	LONC						CSTP	LCIN
F224							PCMD	
F225				RVSG08	RVSERR	RVSSKE	LNSR	RVSARV
F226								
F227								
F228								
F229								

A.2 LIST OF SIGNALS

A.2.1 List of Signals (In Order of Functions)

Function	Signal name	Symbol	Address	Item
Assist gas pressure override	Assist gas pressure override signals	*AOV0 to *AOV7	G229	4.3
Assist gas control	Assist gas ready signal	AGRDY	G221#7	4.1
	Assist gas start signal	AGST	G225#5	
	Assist gas selection signal	AGSLT	F220#1	
	Machining pressure signal	WKP	F220#5	
	Assist gas select signals	AG1 to AG3	F222#0 to #2	
Approach feed	Approach feed function	ZAPR	G225#1	7.5
Retry processing function	Retracee signal	RVS	G007#0	8.6
	Retry processing mode selection signal	RVSLSR	G226#7	
	Retrace-in-progress signal	RVSL	F082#2	
	Retrace completion signal	RVSARV	F225#0	
	Skip completion signal	RVSSKE	F225#2	
	Machining condition impossible signal	RVSERR	F225#3	
	Advanced preview control resume signal	RVSG08	F225#4	
Guide light on	Guide light on signal	SCLON	G222#2	5.5
Proximity point search function	Proximity point search signal	NRSRH	G226#0	7.6
	Proximity point search progress signal	LNSR	F225#1	
Optical path length compensation	Optical path length compensation start signal	LRCS	G224#0	8.1
	Optical path length compensation signal	LCIN	F223#0	
	Optical path length compensation stop request signal	CSTP	F223#1	
Attitude control	Attitude control mode select signal	ALNAXS	G226#2	7.1.2
	Attitude control B speed clamp select signal	OTPMX2	G224#7	
Shutter open/lock control	Shutter lock signal	*SHTLC	G222#0	5.1
	Shutter open signal	SHTON	G222#3	
	Shutter ON/OFF signals	SHTONL SHTOFL	F224#4 F224#3	
Output override	Power override signals	POV0 to POV7	G223	5.3
	Frequency override signals	*FOV0 to *FOV7	G228	
	Duty override signals	*DU1 to *DU16	G220#0 to #4	
State output signal	Piercing signal	PIRC	F222#7	5.6
	Laser processing signal	LPRC	F222#4	
	Output drop alarm signal	MWRN	F220#6	
	Laser alarm signal	LARM	F221#0	
	Laser oscillator not connected signal	LONC	F223#7	
Teaching box interface	Teaching box exclusive right signal	TBES	G226#6	7.2
Tracing axis switching	Tracing axis switching signal	ZTRM	G225#0	7.4

Function	Signal name	Symbol	Address	Item
Tracing function	Tracing start signal	TCST	G225#3	6.1.1
	Tracing motion signal	TRCL	F220#2	
	Tracing alarm signal	TRALM	F220#7	6.1.5
	Trace check mode signal	TRCKM	G225#2	
	Tracing not avairable signal	TRERS	F220#0	
	Tracing gain override signals	GAPG0 to GAPG2	G225#4 to #6	6.1.6
	Tracing interlock signal	*TRIL	G227#6	6.2
	Tracing axis machine lock signal	TRMLK	G227#7	6.3
Power control function	Power control mode signal	PWCTL	G224#1	8.7
	Power control mode in progress signal	PCMD	F224#1	
Manual operation in hand coordinate system	Hand coordinate system mode select signal	HNDCD	G226#3	7.7
Piercing time external alteration function	Piercing time reduction signal	PTS	G221#2	5.4
	Piercing time extension signal	PTE	G221#3	
Beam on/off control	Beam on signal	BEMON	G222#4	5.2
	Beam lock signal	*BEMLC	G222#1	
	Beam output signal	BEAM	F221#7	
	Mode output signals	CW PULSE	F222#6 F222#5	
Program restart	Program restart signal	REST2	G226#1	2.4
	Proximity point search progress signal	LNSR	F225#1	
Laser gas mixer function	Leak check start signal	LCAN	G221#4	8.8
	Cylinder replacement signal	BCAN	G221#5	
Laser sequence control	Purge completion signal	PURGE	F221#2	3
	Oscillator start signal	RUN	G222#6	
	Oscillator ready signal	WAIT	F221#3	
	Chiller start request signal	CLON	F221#4	
	Chiller ready signa	CLRDY	G221#6	
	Discharge start ready signal	LRDY	F221#1	
	Discharge start signal	HVON	G222#7	
	Reference discharge start signal	RFHV	F221#5	
	Oscillator signal	LSTR	F221#6	

A.2.2 List of Signals (In Order of Symbols)

Group	Symbol	Signal name	Address	Item
*	*AOV0 to *AOV7	Assist gas pressure override signals	G229	4.3
	*BEMLC	Beam lock signal	G222#1	5.2
	*DU1 to *DU16	Duty override signals	G220#0 to #4	5.3
	*FOV0 to *FOV7	Frequency override signals	G228	5.3
	*SHTLC	Shutter lock signal	G222#0	5.1
	*TRIL	Tracing interlock signal	G227#6	6.2
A	AG1 to AG3	Assist gas select signals	F222#0 to #2	4.1
	AGRDY	Assist gas ready signal	G221#7	
	AGSLT	Assist gas selection signal	F220#1	
	AGST	Assist gas start signal	G225#5	
	ALNAXS	Attitude control mode select signal	G226#2	7.1.2
B	BCAN	Cylinder replacement signal	G221#5	8.8
	BEAM	Beam output signal	F221#7	5.2
	BEMON	Beam on signal	G222#4	
C	CLON	Chiller start request signal	F221#4	3
	CLRDY	Chiller ready signa	G221#6	
	CSTP	Optical path length compensation stop request signal	F223#1	8.1
	CW	Mode output signals	F222#6	5.1
G	GAPG0 to GAPG2	Tracing gain override signals	G225#4 to #6	6.1.6
H	HNDCD	Hand coordinate system mode select signal	G226#3	7.7
	HVON	Discharge start signal	G222#7	3
L	LARM	Laser alarm signal	F221#0	5.6
	LCAN	Leak check start signal	G221#4	8.8
	LCIN	Optical path length compensation signal	F223#0	8.1
	LNSR	Proximity point search progress signal	F225#1	7.6
	LONC	Laser oscillator not connected signal	F223#7	5.6
	LPRC	Laser processing signal	F222#4	
	LRCS	Optical path length compensation start signal	G224#0	8.1
	LRDY	Discharge start ready signal	F221#1	3
	LSTR	Oscillator signal	F221#6	
M	MWRN	Output drop alarm signal	F220#6	5.6
N	NRSRH	Proximity point search signal	G226#0	7.6
O	OTPMX2	Attitude control B speed clamp select signal	G224#7	7.1.2
P	PCMD	Power control mode in progress signal	F224#1	8.7
	PIRC	Piercing signal	F222#7	5.6
	POV0 to POV7	Power override signals	G223	5.3
	PTE	Piercing time extension signal	G221#3	5.4
	PTS	Piercing time reduction signal	G221#2	
	PULSE	Mode output signals	F222#5	5.2
	PURGE	Purge completion signal	F221#2	3
	PWCTL	Power control mode signal	G224#1	8.7

Group	Symbol	Signal name	Address	Item
R	REST2	Program restart signal	G226#1	2.4
	RFHV	Reference discharge start signal	F221#5	3
	RUN	Oscillator start signal	G222#6	
	RVS	Retrace signal	G007#0	8.6
	RVSARV	Retrace completion signal	F225#0	
	RVSERR	Machining condition impossible signal	F225#3	
	RVSG08	Advanced preview control resume signal	F225#4	
	RVSL	Retrace-in-progress signal	F082#2	
	RVSLSR	Retry processing function mode selection signal	G226#7	
	RVSSKE	Skip completion signal	F225#2	8
S	SCLON	Guide light on signal	G222#2	5.5
	SHTOFL SHTONL	Shutter ON/OFF signals	F224#3 F224#4	5.1
	SHTON	Shutter open signal	G222#3	
T	TBES	Teaching box exclusive right signal	G226#6	7.2
	TCST	Tracing start signal	G225#3	6.1.1
	TRALM	Tracing alarm signal	F220#7	
	TRCKM	Trace check mode signal	G225#2	6.1.5
	TRCL	Tracing motion signal	F220#2	6.1.1
	TRERS	Tracing not avairable signal	F220#0	6.1.5
	TRMLK	Tracing axis machine lock signal	G227#7	6.3
W	WAIT	Oscillator ready signal	F221#3	3
	WKP	Machining pressure signal	F220#5	4.1
Z	ZAPR	Approach feed function	G225#1	7.5
	ZTRM	Tracing axis switching signal	G225#0	7.4

A.2.3 List of Signals (In Order of Addresses)

Addresses	Signal name	Symbol	Item
G007#0	Retrace signal	RVS	8.6
G220#0 to #4	Duty override signals	*DU1 to *DU16	5.3
G221#2	Piercing time reduction signal	PTS	5.4
G221#3	Piercing time extension signal	PTE	
G221#4	Leak check start signal	LCAN	8.8
G221#5	Cylinder replacement signal	BCAN	
G221#6	Chiller ready signa	CLRDY	3
G221#7	Assist gas ready signal	AGRDY	4.1
G222#0	Shutter lock signal	*SHTLC	5.1
G222#1	Beam lock signal	*BEMLC	5.2
G222#2	Guide light on signal	SCLON	5.5
G222#3	Shutter open signal	SHTON	5.1
G222#4	Beam on signal	BEMON	5.2
G222#5	Assist gas start signal	AGST	4.1
G222#6	Oscillator start signal	RUN	3
G222#7	Discharge start signal	HVON	
G223	Power override signals	POV0 to POV7	5.3
G224#0	Optical path length compensation start signal	LRCS	8.1
G224#1	Power control mode signal	PWCTL	8.7
G224#7	Attitude control B speed clamp select signal	OTPMX2	7.1.2
G225#0	Tracing axis switching signal	ZTRM	7.4
G225#1	Approach feed function	ZAPR	7.5
G225#2	Trace check mode signal	TRCKM	6.1.5
G225#3	Tracing start signal	TCST	6.1.1
G225#4 to #6	Tracing gain override signals	GAPG0 to GAPG2	6.1.6
G226#0	Proximity point search signal	NRSRH	7.6
G226#1	Program restart signal	REST2	2.4
G226#2	Attitude control mode select signal	ALNAXS	7.1.2
G226#3	Hand coordinate system mode select signal	HNDCD	7.7
G226#6	Teaching box exclusive right signal	TBES	7.2
G226#7	Retry processing function mode selection signal	RVSLSR	8.6
G227#6	Tracing interlock signal	*TRIL	6.2
G227#7	Tracing axis interlock signal	TRMLK	6.3
G228	Frequency override signals	*FOV0 to *FOV7	5.3
G229	Assist gas pressure override signals	*AOV0 to *AOV7	4.3
F082#2	Retrace-in-progress signal	RVSL	8.6
F220#0	Tracing not avairable signal	TRERS	6.1.5
F220#1	Assist gas selection signal	AGSLT	4.1
F220#2	Tracing motion signal	TRCL	6.1.1
F224#3 F224#4	Shutter ON/OFF signals	SHTOFL SHTONL	5.1
F220#5	Machining pressure signal	WKP	4.1
F220#6	Output drop alarm signal	MWRN	5.6
F220#7	Tracing alarm signal	TRALM	6.1.1
F221#0	Laser alarm signal	LARM	5.6
F221#1	Discharge start ready signal	LRDY	3
F221#2	Purge completion signal	PURGE	
F221#3	Oscillator ready signal	WAIT	
F221#4	Chiller start request signal	CLON	

Addresses	Signal name	Symbol	Item
F221#5	Reference discharge start signal	RFHV	3
F221#6	Oscillator signal	LSTR	
F221#7	Beam output signal	BEAM	5.2
F222#0 to #2	Assist gas select signals	AG1 to AG3	4.1
F222#4	Laser processing signal	LPRC	5.6
F222#5	Mode output signals	PULSE	5.2
F222#6	Mode output signals	CW	5.1
F222#7	Piercing signal	PIRC	5.6
F223#0	Optical path length compensation signal	LCIN	8.1
F223#1	Optical path length compensation stop request signal	CSTP	8.1
F223#7	Laser oscillator not connected signal	LONC	5.6
F224#1	Power control mode in progress signal	PCMD	8.7
F225#0	Retrace completion signal	RVSARV	8.6
F225#1	Proximity point search progress signal	LNSR	7.6
F225#2	Skip completion signal	RVSSKE	8.6
F225#3	Machining condition impossible signal	RVSERR	
F225#4	Advanced preview control resume signal	RVSG08	

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Revision Record

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