HNC-8 System Function Commissioning Manual

V2.4 Series

Introduction

The manual may help you to quickly get familiar with the HNC-8 system, providing detailed information about commissioning, programming or application methods. Any updates or modification of the manual is not allowed without the written permission of Wuhan Huazhong Numerical Control Co., LTD (hereafter referred to as "HCNC"). Without HCNC's authorization or written permission, any units or individuals are not allowed to modify or correct the manual. HCNC will not be responsible for any losses thus incurred to customers.

In this manual we have tried as much as possible to describe all the various matters concerning of the system. However, we cannot describe all the matters which must not be done, or which cannot be done, because there are so many possibilities. Therefore, matters which are not especially described as possible in this manual should be regarded as "impossible" or "not allowed".

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Please favor me your instruction for shortages and inadequacies of the manual.

> **⚠ Note**
>
> ⚠ As to notes such as "Limitations" and "Usable functions", the specification provided by the machine tool manufacturer is superior to the manual. Please conduct dryrun before actual machining and confirm machining program, tool compensation volume and workpiece offset, and so on.
>
> ⚠ Please explain matters which are not described in the manual as "Infeasible".
>
> ⚠ The manual is prepared on the condition that all functions are configured. Please make a confirmation according to the specification provided by the machine tool manufacturer in use.
>
> ⚠ For relevant instructions for machine tools, please refer to the specification provided by the machine tool manufacturer.
>
> ⚠ Usable screens and functions differ with different NC systems (or versions). Please be sure to confirm specifications before use.

Contents

1 Commissioning Instructions for Basic Functions of Servo Spindle

Typical connection between HNC-808D CNC controller and bus I/O unit and bus servo drive unit is shown in Fig. 1.
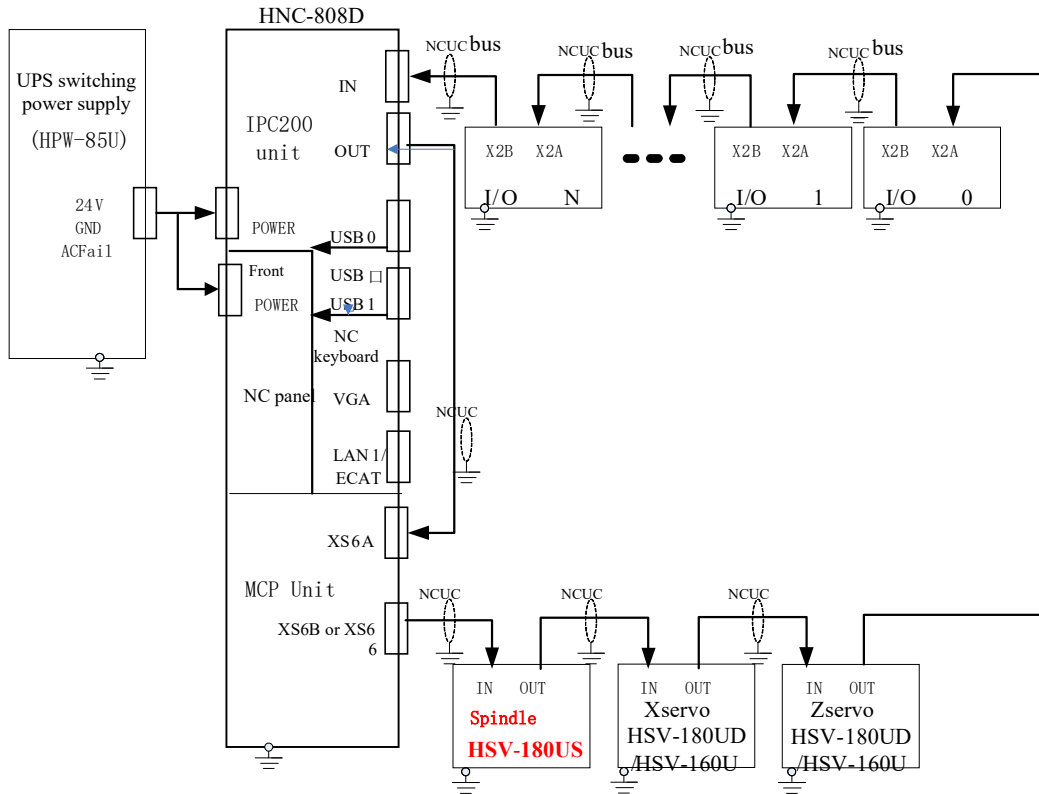
Fig. 1 Typical connection between CNC controller and bus I/O unit and bus servo drive unit

Default device parameter sequence is: MCP, I/O-NET, spindle servo drive, X axis drive and Z axis drive

Connection diagram 2 of spindle drive unit:
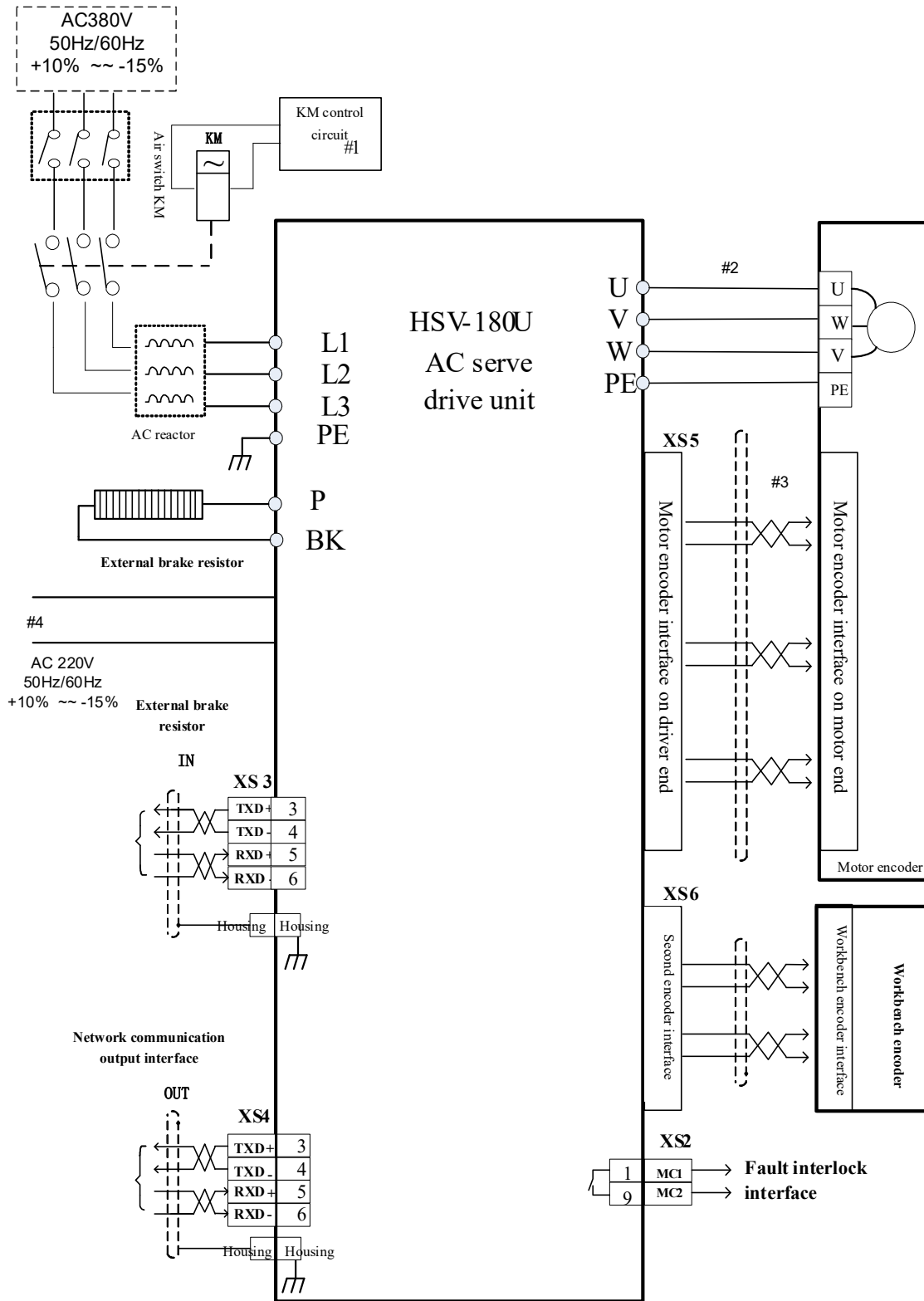
Fig. 2 Connection diagram of spindle drive

For detailed port definition and function adjustment, please refer to HSV-180US Series AC Spindle Drive Unit User Manual-V2.20

The following commissioning instructions are for the configurations of single channel, servos X and Z and servo spindle. See example in below table,

Axis	Channel 0
X	Logical axis 0
Z	Logical axis 2
Spindle	Logical axis 5

1.1 System Spindle Parameter Configuration

Parameter type	Parameter number	Set value	Remarks
Channel parameter	040010 (axis number of spindle 0)	5	
	040028 (displayed axis number of spindle)	5	
Coordinate axis parameter	105001 (axis type)	10	
	105004 (numerator of electronic gear ratio)	360000	The transmission ratio of the spindle is 1:1 by default. If there is reduction ratio, multiply 105005 parameter by reduction ratio
	105005 (denominator of electronic gear ratio)	Pulse count per revolution of spindle encoder	
	105067 (pulse count per axis revolution)	Pulse count per revolution of spindle encoder	
Device interface parameter	508010 (working mode)	3	
	508011 (logical axis number)	5	
	508014 (feedback position cycle mode)	1	
	508015 (pulse count of feedback position cycle)	Pulse count per revolution of spindle encoder	
	508016 (encoder type)	Based on field encoder type	

Parameters in the above table are key parameters of the spindle. For parameters of spindle speed and gear, refer to functional specification.

1.1.1 Spindle Speed Limit Setup

View spindle speed in below table by Maintain → User setup → P parameter:

Parameter number	Parameter name	Set value	Remarks
010420	Maximum spindle speed	×××	Maximum motor speed
010421	Minimum spindle speed at gear 1	×××	Minimum spindle speed at gear 1
010422	Maximum spindle speed at gear 1	×××	Maximum spindle speed at gear 1
010423	Numerator of gear ratio of spindle gear 1	×××	Reduction ratio of gear 1 on motor side
010424	Denominator of gear ratio of spindle gear 1	×××	Spindle side of reduction ratio of gear 1
010425	Minimum spindle speed at gear 2	×××	Minimum spindle speed at gear 2
010426	Maximum spindle speed at gear 2	×××	Maximum spindle speed at gear 2
010427	Numerator of gear ratio of spindle gear 2	×××	Reduction ratio of gear 2 on motor side
010428	Denominator of gear ratio of spindle gear 2	×××	Spindle side of reduction ratio of gear 2
010429	Minimum spindle speed at gear 3	×××	Minimum spindle speed at gear 3
010430	Maximum spindle speed at gear 3	×××	Maximum spindle speed at gear 3
010431	Numerator of gear ratio of spindle gear 3	×××	Reduction ratio of gear 3 on motor side
010432	Denominator of gear ratio of spindle gear 3	×××	Reduction ratio of gear 3 on spindle side

Gear 1 command M41, gear 2 command M42, gear 3 command M43
Default gear is gear 1. M41, M42 and M43 commands can be used to switch gear.

Speed Mode Parameter on Spindle Servo End

1.1.2 Parameters Relating to Servo Control

SN	Name	Range	Default value	Unit
PA--2	Speed control mode Speed proportional gain	25-32000	350	

Function and setup:

① Set proportional gain of speed regulator under speed control mode (PA--23=1,3).

② The larger the set value is, the higher gain is, the larger rigidity is. Parameter value is determined by type of specific spindle drive unit and load. Generally, the larger load inertia, the larger the set value is.

③ Try to set a larger value without system oscillation. The parameter will be set automatically after motor code (PA--59) is set.

SN	Name	Range	Default value	Unit
PA--3	Speed control mode Speed integral time constant	5-32767	30	1ms

Function and setup:

① Set integral time constant of speed regulator under speed control mode (PA--23=1,3). The parameter will be set automatically after motor code (PA--59) is set;

② The smaller the set value is, the larger the integral speed is. Parameter value is determined by type of specific spindle drive unit and load. Generally, the larger load inertia, the larger the set value is.

③ Try to set a smaller value without system oscillation.

SN	Name	Range	Default value	Unit
PA--4	Speed feedback filter coefficient	0-7	1	

Function and setup:

① Set characteristics of speed feedback lowpass filter.

② The larger the value is, the lower cut-off frequency is, the smaller noise produced by the motor is. If load inertia is very large, the set value can decrease appropriately. If the value is too large and consequently response slows down, vibration may be caused.

③ The smaller the value is, the higher cut-off frequency is, the faster speed feedback response is. If speed response is high, the set value can be decreased appropriately.

SN	Name	Range	Default value	Unit
PA--5	Deceleration time constant	1-1800	40	0.1s/8000r/min
PA--6	Acceleration time constant	1-1800	40	0.1s/8000r/min

Function and setup:

① PA--5 represents the time that the motor decelerates from 8000r/min to 0r/min; PA--6 represents the time that

the motor accelerates from 0r/min to 8000r/min.

② Acceleration and deceleration characteristics are linear.

SN	Name	Range	Default value	Unit
PA--11	Speed arrival range	0-1000	10	1r/min

Function and setup:

① Set speed arrival range.

② If motor speed tracking error is less than the set value under speed control mode (PA--23=1,3), speed arrival switch signal is ON; otherwise, it is OFF.

③ The parameter is valid under speed control mode (PA--23=1,3) and is unrelated to rotation direction.

SN	Name	Range	Default value	Unit
PA--20	Internal speed	-30000-32000	0	1r/min

Function and setup:

① Set internal speed.

② Select the value as speed command under internal speed control mode (PA--23=3).

SN	Name	Range	Default value	Unit
PA--21	JOG speed	0-500	300	1r/min

Function and setup:

① Set running speed of JOG operation.

SN	Name	Range	Default value	Unit
PA--23	Control mode selection	0-7	1	

Function and setup:

① Select control mode of drive unit:

0: Position control mode of C axis, to receive position command.

1: External speed control mode, to receive external speed command.

3: Internal speed control mode, to set internal speed by parameter PA--20

SN	Name	Range	Default value	Unit
PA--29	Zero speed arrival range	0-300	10	1r/min

Function and setup:

① Set zero speed arrival range.

② If motor speed is less than the set value under speed control mode (PA--23=1,3), zero speed output switch

signal is ON; otherwise, it is OFF.

③ The parameter is valid under speed control mode (PA--23=1,3).

④ The parameter is unrelated to rotation direction.

Parameter setup description: Under speed control mode (PA--23=1, 3), speed loop characteristics are adjusted with PA--2 speed proportional gain in speed control mode and PA--3 speed integral time constant in speed control mode, current characteristics is adjusted with PA--27 current control proportional gain and PA--28 current control integral time and flux current is set with PA--33 flux current.

When motion parameter PA--23=1, external speed command is received.

When motion parameter PA--23=3, the spindle drive unit moves at the speed set by motion parameter PA--20 in internal speed control mode (external command is not needed).

1.2   Spindle Orientation Function

The orientation commands: M19 (spindle orientation is enabled),   M20 (spindle orientation is disabled)

1.2.1   Servo Parameters Relating to Orientation Function

SN	Name	Range	Default value	Unit
PA--42	Position control mode of C axis /orientation mode Speed proportional gain	25-32000	450	

Function and setup:

① Set proportional gain of speed regulator under spindle orientation mode.

② The larger the set value is, the higher gain is, the larger rigidity is. Parameter value is determined by type of specific spindle drive unit and load. Generally, the larger load inertia, the larger the set value is.

③ Try to set a larger value without system oscillation. The parameter will be set automatically after motor code (PA--59) is set.

SN	Name	Range	Default value	Unit
PA--43	Position control mode of C axis /orientation mode Speed integral time constant	5-32767	20	1ms

Function and setup:

① Set integral time constant of speed regulator under spindle orientation mode. After motor code (PA--59) is set, the parameter will be set automatically.

② The smaller the set value is, the larger the integral speed is. Parameter value is determined by type of specific spindle drive unit and load. Generally, the larger load inertia, the larger the set value is.

Try to set a smaller value without system oscillation.

SN	Name	Range	Default value	Unit
PA--13	Numerator of transmission ratio between spindle and motor	1-32767	1	
PA--14	Denominator of transmission ratio between spindle and motor	1-32767	1	

Function and setup:

① Set the transmission ratio between spindle and motor.

② e.g.: If the spindle motor rotates 5 revolutions when the spindle rotates every 3 revolutions, PA--13=3, PA--14=5. If the spindle motor rotates 3 revolutions when the spindle motor rotates every 5 revolutions, PA--13=5, PA--14=3.

SN	Name	Range	Default value	Unit
PA--37	Spindle orientation completion range	0-100	10	Pulse

Function and setup:

① Set the allowable minimum position error range when spindle orientation is completed.

② When position error is less than the set value while the orientation position is arrived, orientation is completed. Meanwhile, the spindle drive unit outputs orientation completion signal.

SN	Name	Range	Default value	Unit
PA--38	Spindle orientation speed	10-600	100	1r/min

Function and setup:

① Set the speed of the spindle motor during spindle orientation.

SN	Name	Range	Default value	Unit
PA--39	Spindle orientation position	-32767-32767	0	Pulse

Function and setup:

① Set orientation position of the spindle motor. Pulse count per revolution of the motor corresponds to 360°.

② Zero pulse position of motor encoder or spindle encoder is used as a reference for the set value.

SN	Name	Range	Default value	Unit
PA--40	Incremental angle of indexing orientation	0-32767	0	

Function and setup:

① Set incremental angle of indexing orientation.

② Incremental angle of indexing orientation = PA-40 * 360/ppr0/8* Incremental angle magnification of indexing orientation,

ppr0: STA-13=0 optical encoder resolution of spindle motor *4

STA-13=1 spindle encoder resolution*4

Incremental angle magnification of indexing orientation: Determined by switching values INC_Sel1 and INC_Sel2

SN	Name	Range	Default value	Unit
PA--44	Orientation mode Position proportional gain	10-5000	200	0.1Hz

Function and setup:

① Set proportional gain of position regulator under orientation mode.

② The larger the set value is, the higher gain is, the larger rigidity is. Parameter value is determined by type of spindle drive system and load. Generally, the larger load inertia, the larger the set value is.

③ Try to set a larger value without system oscillation.

SN	Name	Range	Default value	Unit
PA--45	Orientation mode Percentage of flux current	30-150	110	%

Function and setup:

① Set flux current value of motor under orientation mode.

② The set value represents percentage of flux current (PA--33) when asynchronous motor is used under orientation mode.

SN	Name	Range	Default value	Unit
PA--47	Resolution of spindle encoder	1-32767	4096	Quadruple frequency

Function and setup:

① Set quadruple frequency of spindle encoder.

② PA--47=Spindle encoder resolution*4. If spindle encoder resolution=1200, PA--47=1200*4=4800. If spindle encoder is not used, it should be set as 4096.

SN	Name	Range	Default value	Unit
PA--48	Initial offset angle of orientation	0-18	0	$20°$

Function and setup:

① Set initial offset angle of spindle orientation.

② The parameter should be used when pulse count per spindle revolution is greater than 65536. Spindle orientation position is determined by parameters PA-48 and PA-39.

e.g.: Pulse count per revolution of spindle is $2^{17} = 131072$ pulses; expected orientation offset is 150°.

Set PA-48 = 7 (initial offset angle of orientation is $20° * 7 = 140°$);

Set PA-39 = 3641 (offset angle corresponding to 3641 is about 3641 * 3600/131072 = 100)

Parameter setup description: Under orientation mode, adjust position loop characteristics with position proportional gain PA--44, speed loop characteristics with speed proportional gain PA-42 and speed integral time constant PA--43, current characteristics with current control proportional gain PA—27 and current control integral time PA—28, and set flux current with flux current PA—33 and PA--45 flux current in orientation mode. Flux current equals to PA--53*PA--33*PA--46. e.g.: If PA--53=100 (10A), PA--33=60 (60％), PA--46=110 (110％), flux current is 100*60％*110％=66 (6.6A).

1.2.2 Orientation Using Motor Encoder

Orientation with motor encoder is suitable for the situation that the transmission ratio between the spindle motor and the spindle is 1:1.

When motor encoder is used for orientation, feedback of the motor encoder should be connected to input interface XS5 of the motor encoder of the drive unit. Motion parameters are set as below:

① Numerator of transmission ratio between spindle and motor PA--13 = 1;

② Denominator of transmission ratio between spindle and motor PA--14 = 1;

③ Set spindle orientation range PA--37 based on actual need;

④ Spindle orientation speed PA--38;

⑤ Spindle orientation position PA--39.

Set control parameters as below:

① Use feedback of motor encoder STA-13 = 0;

② Use orientation of motor encoder STA-15 = 0;

③ Set spindle orientation rotation direction STA-14 based on actual need.

1.2.3 Orientation Using Spindle Encoder

Orientation with motor encoder is suitable for the situation that the transmission ratio between the spindle motor and the spindle is not 1:1.

When motor encoder is used for orientation, feedback of the motor encoder should be connected to input interface XS5 of the motor encoder of the drive unit and feedback of the spindle encoder should be connected to input interface XS6 of the spindle encoder of the drive unit. Motion parameters are set as below:

① Set resolution of spindle encoder PA--47 based on the used spindle encoder;

② Spindle orientation completion range PA--37;

② Spindle orientation speed PA--38;

④ Spindle orientation position PA--39.

Set control parameters as below:

① Set parameter STA-9 based on type of the used spindle encoder;

② Use feedback of spindle encoder STA-13 = 1;

③ Use orientation of spindle encoder STA-15 = 1;

④ Set spindle orientation rotation direction STA-14 based on actual need.

1.2.4 Orientation Using Zero Switch

Orientation of zero switch is suitable for the situation that the transmission ratio between the spindle motor and the spindle is not 1:1.

When orientation of zero switch is used, A phase and B phase feedback of the spindle motor encoder should be connected to the input interface XS5 of spindle motor encoder of the drive unit, Z phase feedback of the spindle motor encoder should not be connected and Z phase feedback of zero switch should be connected to the input interface XS5 of Z phase feedback of spindle motor encoder of drive unit. Motion parameters are as below:

① PA-13 = ？ ; (numerator of transmission ratio between spindle and motor)

② PA-14 = ？ ; (denominator of transmission ratio between spindle and motor)

③ Spindle orientation completion range PA--37;

④ Spindle orientation speed PA--38;

⑤ Spindle orientation position PA-39.

Spindle orientation position ranges from 0 to 4096*n (transmission ratio between spindle motor and spindle). Set control parameters as below:

① STA-10 = 1; (zero switch orientation function is valid)

② Use feedback of motor encoder STA-13 = 0;

③ Use orientation of spindle encoder STA-15 = 0;

③ Set spindle orientation rotation direction STA-14 based on actual need;

⑤ STB-13 = 0. (Switch type selection, 0: 5V TTL differential output type, 1: 24V NPN type normally open output type)

Note: For stronger anti-interference capability, zero switch using differential output mode is recommended

1.2.5 Orientating Using Proximity Switch

Orientation with proximity switch is suitable for the situation that the transmission ratio between the spindle motor and the spindle is not 1:1, and external encoder cannot be installed for mechanical reason.

When orientation with proximity switch is used, feedback of the motor encoder should be connected to input interface XS5 of the motor encoder of the drive unit and the proximity switch should be connected to I/O interface XS2 of the drive unit.

Commissioning steps are as follows:

(1) Relevant parameters are set as below:

PA-13 = ？; (numerator of transmission ratio between spindle and motor)

PA-14 = ？; (denominator of transmission ratio between spindle and motor)

e.g.: If the reduction ratio between the spindle and the motor is 1:2, and the motor rotates 2 revolutions when spindle rotates one revolution, then PA-13 is set as 1 and PA-14 is set as 2.

STA-10 = 1; (proximity switch orientation function is valid)

STA-13 = 0; (use feedback of motor encoder)

STA-15 = 0; (use orientation of motor encoder)

STB-13 = 1; (Switch type selection, 0: 5V TTL differential output type, 1: 24V NPN type normally open output type)

STB-8 = 1; (external switching value input signal is valid)

Set PA-37 (spindle orientation completion range), PA-38 (spindle orientation speed) and STA-14 (spindle orientation rotation direction) based on actual need.

(2) Rotate the spindle manually for more than two revolutions and observe DP-LAT (motor offset pulse count relative to Z pulse). The value of DP-SPT should change between zero and the maximum value (motor feedback pulse count corresponding to a revolution of the spindle). Adjust the spindle manually to the exact stop position. If motor feedback pulse count corresponding to a revolution of the spindle does not exceed 32767, directly write the value of DP-SPT in parameter PA39 (spindle orientation position). If motor feedback pulse count corresponding to a revolution of the spindle exceeds 32767, set orientation position through the combination of parameters PA-39 (spindle orientation position) and PA-48 (orientation offset angle). Calculation is shown below:

Orientation position ＝ (PA-48 * motor feedback pulse count corresponding to a revolution of the spindle) / 18 + PA-39

(3) The CNC system controls the drive unit for spindle orientation. If the exact stop position has a small deviation and pulse count of motor feedback corresponding to a revolution of the spindle does not exceed 32767, adjust the value of parameter PA-39 (spindle orientation position). If pulse count of motor feedback corresponding to a revolution of the spindle exceeds 32767, adjust the values of parameters PA-39 (spindle orientation position) and PA-48 (orientation offset angle).

(4) Instructions for proximity switch

The drive unit supports only NPN type normally open proximity switch which uses 24V power supply such as Omron E2B and E2E series proximity switches. External 24V switching power supply supplies power to proximity switch, external 24V switching power supply ground is connected to command interface COM pin of the drive unit, and normally open signal of proximity switch is connected to switching input signal pin corresponding to I/O interface.

With Omron E2B series proximity switch as an example, the brown line should be connected to external switching power supply +24V, the blue line should be connected to the 7th pin or the 8th pin (COM) of XS2 I/O interface and external switching power supply ground and the black line should be connected to the 11th pin (PIN.2) of XS2 I/O interface.
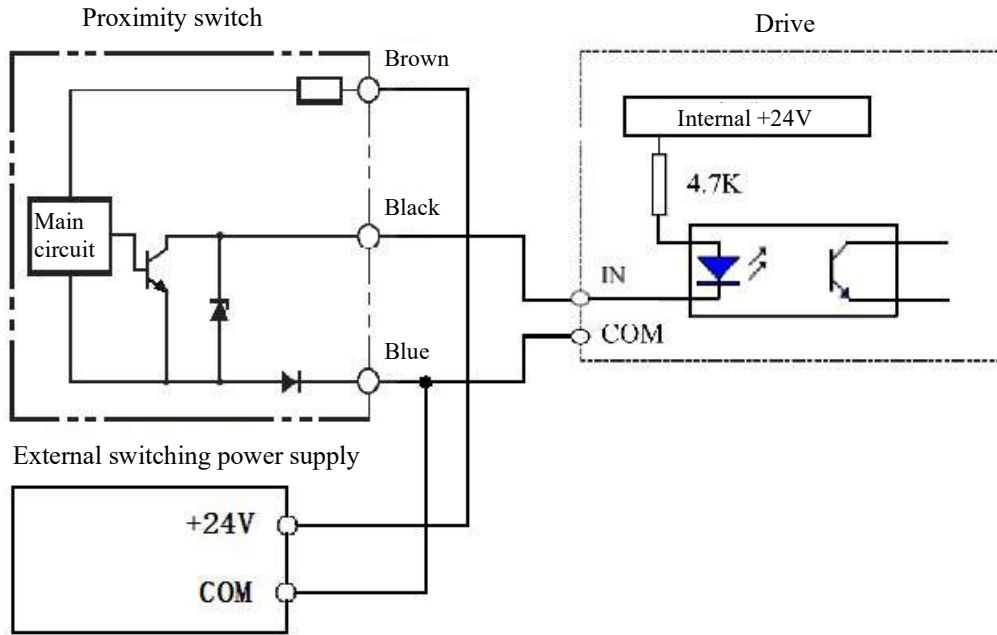
Connection diagram of proximity switch (Omron E2B series proximity switch is used)

1.3 Rigid Tapping of Spindle

In the position mode, the interpolation motion of spindle and Z axis or X axis is performed.

Before position mode is switched, relevant servo parameters of spindle need be set.

5.1. Parameters Relating to Position Control

SN	Name	Range	Default value	Unit
PA--0	Position control mode of C axis Position proportional gain	10-5000	200	0.1Hz

Function and setup:

① Set proportional gain of position regulator in the C axis position control mode (PA—23=0) or when in the speed control mode (PA—23=1, 3) it is switched to C axis position control mode by control mode switching switch.

② The larger the set value is, the larger gain is, the larger rigidity is, and the smaller position hysteresis is under equal frequency command pulse conditions. If the value is too large, vibration or overtravel may be caused.

③ Parameter value is determined by type of specific spindle drive unit and load.

SN	Name	Range	Default value	Unit
PA--12	Position tolerance detection range	1-32767	30	0.1rev

Function and setup:

① Set detection range of position out-of-tolerance of C axis.

② In the C axis position control mode (PA—23=0) or when in the speed control mode (PA—23=1, 3) it is switched to C axis position control mode by control mode switching switch, if the counting value of position offset counter exceeds the parameter value, the spindle drive unit gives an alarm for position out-of-tolerance.

e.g.: When the spindle motor encoder is 1024PPR, pulse count per revolution of motor is 4096. If the parameter is set as 30 and position tolerance exceeds 30 * 0.1 * 4096 = 12288 under position control mode of C axis

(PA--23=0), the drive unit will alarm (A12).

SN	Name	Range	Default value	Unit
PA--16	Feedforward control gain of C axis	0-100	0	

Function and setup:

① Set feedforward gain of position loop in the C axis position control mode (PA—23=0) or when in the speed control mode (PA—23=1, 3) it is switched to C axis position control mode by control mode switching switch.

② When it is set as 100%, it means that position hysteresis is 0 under command pulse of any frequency.

③ When feedforward gain of position loop increases, the high-speed response characteristic of control system improves, but position control of system is instable and oscillation is easily caused.

④ The parameter is often set as 0 when very high response characteristic is not needed.

SN	Name	Range	Default value	Unit
PA--23	Control mode selection	0-7	0	

Function and setup:

① Select control mode of drive unit:

   0: Position control mode of C axis, receive position command.

   1: External speed control mode, receive external speed command.

   3: Internal speed control mode, internal speed is set by parameter PA--20

SN	Name	Range	Default value	Unit
PA--42	Position control mode of C axis /orientation mode Speed proportional gain	25-32000	450	

Function and setup:

① Set proportional gain of position regulator in the C axis position control mode (PA—23=0) or when in the speed control mode (PA—23=1, 3) it is switched to C axis position control mode by control mode switching switch.

② The larger the set value is, the higher gain is, the larger rigidity is. Parameter value is determined by type of spindle drive and load. Generally, the larger load inertia, the larger the set value is.

③ Try to set a larger value without system oscillation.

SN	Name	Range	Default value	Unit
PA--43	Position control mode of C axis /orientation mode Speed integral time constant	5-32767	20	1ms

Function and setup:

① Set integral time constant of speed regulator in the C axis position control mode (PA—23=0) or when in the speed control mode (PA—23=1, 3) it is switched to C axis position control mode by control mode switching switch.

② The smaller the set value is, the larger the integral speed is. Parameter value is determined by type of specific spindle drive unit and load. Generally, the larger load inertia, the larger the set value is.

③ Try to set a large value without system oscillation.

SN	Name	Range	Default value	Unit
PA--46	Flux current in C axis position control mode	30-150	110	0-100%

Function and setup:

① Set flux current value of motor in the C axis position control mode (PA—23=0) or when in the speed control mode (PA—23=1, 3) it is switched to C axis position control mode by control mode switching switch. It corresponds to percentage of rated exciting current of asynchronous motor used in the mode of C axis.

SN	Name	Range	Default value	Unit
PA--49	Numerator of electronic gear ratio of C axis	1-32767	1	
PA--50	Denominator of electronic gear ratio of C axis	1-32767	1	

Function and setup:

① Electronic gear ratio of C axis position

② Under position control mode of C axis (PA--23=0), set PA--49 and PA--50 parameters to easily match various pulse sources in order to achieve the user's ideal control resolution (namely angle/pulse).

③ P×G=N×C

P: Pulse count of input command;

G: Electronic gear ratio

$$G = \frac{\text{Position command pulse frequency division numerator}}{\text{Position command pulse frequency division denominator}}$$

N: Number of motor rotations;

C: Pulse count per revolution of motor encoder;

④ [e.g.:] When input command pulse is 6000, the spindle motor rotates 1 revolution and the motor encoder is 2500PPR incremental photoelectric encoder:

$$G = \frac{N \times C}{P} = \frac{1 \times 2500 \times 4}{6000} = \frac{5}{3}$$

Then, parameter PA--49 is set as 5 and PA--50 is set as 3.

⑤ Recommended range of electronic gear ratio is $\dfrac{1}{50} \le G \le 50$

Parameter setup description: Under position control mode of C axis (PA--23=0), adjust position loop characteristics with position proportional gain PA--0, speed loop characteristics with speed proportional gain PA--42 and speed integral time constant PA--43, current loop characteristics with PA--27 current control proportional gain and PA--28 current control integral time, and set flux with PA--33 flux current and PA--46 position control mode flux current. Flux current equals to PA--53*PA--33*PA--46. e.g.: If PA--53=100 (10A), PA--33=50 (50％) and PA--46=110 (110％), flux current is 100*50％*110％=55 (5.5A).

5.2. Synchronous Error Commissioning of Rigid Tapping Interpolation Axis

During rigid tapping, machining quality and efficiency are related to synchronous error of two interpolation axes (spindle and feed axis), so the principal purpose is to minimize synchronous error of these two interpolation axes before machining.

The system end integrates "Servo diagnosis" tools to visually view synchronous error of tapping axis and adjust relevant parameters according to guide and suggestions in order to optimize servo.

Enter "Diagnosis"→"Servo adjustment"→"Rigid tapping"→"Configuration" interface

Fig. 3

(1) The "Configuration" interface is used to set tapping parameters including thread pitch, rotation speed, movedown distance, tapping depth and dwell time. The most important is to determine tapping axis. According to parameter configured, tapping is set as shown in Fig. 3.

Press "Code preview" to enter the generated code view state after setup, as shown in Fig. 4:

Fig. 4

Select G84 and G88. For specific programming command format, please refer to HNC-8 User Manual--programming

(2) The "Color setup" interface is used to configure and display line color for ease of observation, as shown in Fig. 5:
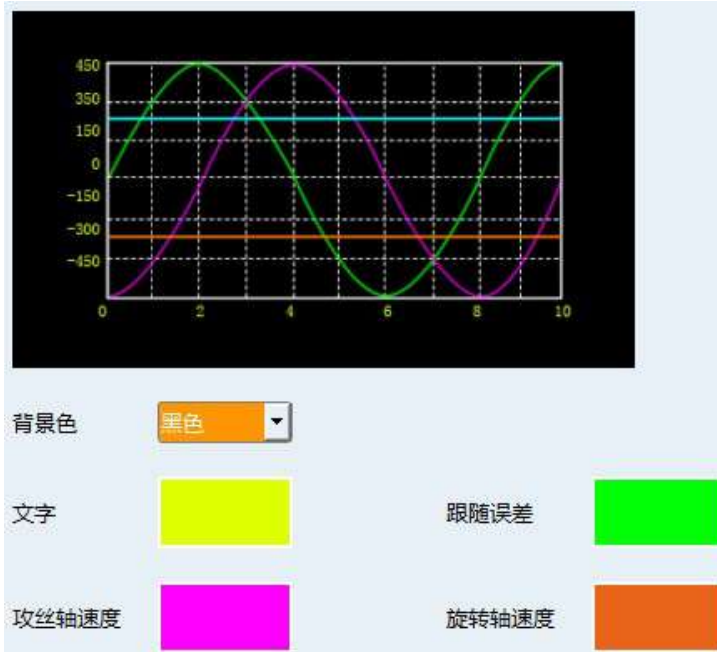
Fig. 5

(3) Display and adjustment of synchronous error. The system display interface is shown in Fig. 6:
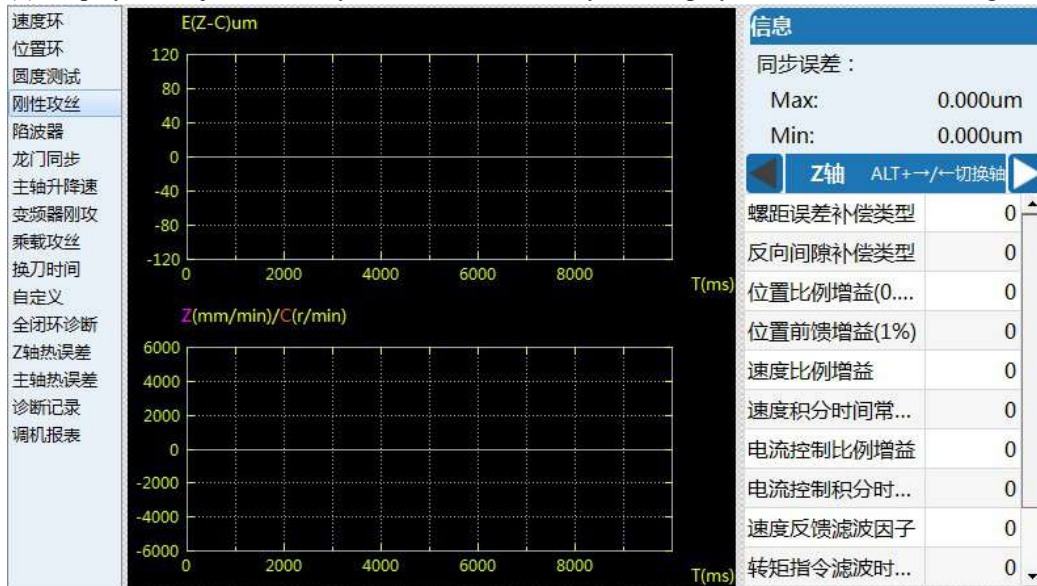
Fig. 6

Fig.6 displays synchronous error E (Z-C) um of tapping interpolation axis and speed of interpolation axis as well as servo gain parameter of interpolation axis, acceleration/deceleration time constant and jerk time constant. Increase or decrease gain of Z axis and C axis based on E after tapping program is executed and the system will give a prompt message in the interface. Normally, E value should be limited to +/-20um.

1.4 Automatic Gear Shift of Spindle

Spindle configuration: There is automatic gear shift device, including gear stage feedback signal (X input) and gear stage setup signal (Y output)

Gear shift parameter (default logical axis 5), see Table 1.

SN	Parameter number	Parameter name	Value
1	105155	S command requests for response	1
2	105156	Spindle output analog	0
3	105157	Maximum spindle motor speed	Set based on maximum motor speed on the site
4	105158	Number of gear stages	Number of gear stages on the site
5	105159	Minimum spindle speed at gear stage 1	Field configuration setups
6	105160	Maximum spindle speed at gear stage 1	
7	105161	Numerator of transmission ratio of gear stage 1 [motor speed]	
8	105162	Denominator of transmission ratio of gear stage 1 [spindle speed]	
9	1005163	Numerator of feedback transmission ratio of feedback of gear stage 1	
10	105164	Denominator of feedback transmission ratio of gear stage 1	
11	105165	Minimum spindle speed at gear stage 2	
12	105166	Maximum spindle speed at gear stage 2	
13	105167	Numerator of transmission ratio of gear stage 2 [motor speed]	
14	105168	Denominator of transmission ratio of gear stage 2 [spindle speed]	
15	105169	Numerator of feedback transmission ratio of gear stage 2	
16	105170	Denominator of feedback transmission ratio of gear stage 2	
17	105171	Minimum spindle speed at gear stage 3	
18	105172	Maximum spindle speed at gear stage 3	
19	105173	Numerator of transmission ratio of gear stage 3 [motor speed]	
20	105174	Denominator of transmission ratio of gear stage 3 [spindle speed]	
21	105175	Numerator of feedback transmission ratio of gear stage 3	
22	105176	Denominator of feedback transmission ratio of gear stage 3	
23	105177	Minimum spindle speed at gear stage 4	
24	105178	Maximum spindle speed at gear stage 4	
25	105179	Numerator of transmission ratio of gear stage 4 [motor speed]	
26	105180	Denominator of transmission ratio of gear stage 4 [spindle speed]	
27	105181	Numerator of feedback transmission ratio of gear stage 4	
28	105182	Denominator of feedback transmission ratio of gear stage 4	
29	105183	Enable rotation speed of shift point	
30	105184	Rotation speed of shift point between gear sage 1 and 2	
31	105185	Rotation speed of shift point between gear stage 2 and 3	

32	105186	Rotation speed of shift point between gear stage 3 and 4	
33	105187	Motor speed during gear shift	
34	105188	Reset spindle after gear shift	

Parameter Description:

1. "S command requests for response": Whether the system makes a response when S command is input separately, e.g.: The parameter should be set as "1" so that the spindle rotates when "S200" is input.

2. "Spindle output analog ": The parameter should be set as "1" when spindle is configured as DA PWM spindle.

3. "Maximum spindle motor speed": Set maximum motor speed, which is unrelated to maximum rotation speed of gear stage.

4. "Number of gear stages": Set number of gear stages for spindle.

5. "Minimum spindle speed at gear stage 1": Set minimum speed corresponding to the gear stage.

6. "Maximum spindle speed at gear stage 1": Set maximum speed corresponding to the gear stage.

7. "Numerator of transmission ratio of gear stage 1 [motor speed]": Set rotation speed on the motor side corresponding to the gear stage (the parameter has the same meaning for other 3 gears).

8. "Denominator of transmission ratio of gear stage 1 [spindle speed]": Set rotation speed on the spindle side corresponding to the gear stage 1 (the parameter has the same meaning for other 3 gears).

9. "Numerator of feedback transmission ratio of gear stage 1": Set feedback reduction ratio on the motor side of the gear (the parameter has the same meaning for other 3 gears). If spindle feedback is the first encoder, the value is set to be consistent with "Numerator of transmission ratio of gear stage 1 [motor speed]".

10. "Denominator of feedback transmission ratio of gear stage 1": Set reduction ratio on the encoder side of the gear (the parameter has the same meaning for other 3 gears). If spindle feedback is the first encoder, the value is set to be consistent with "Denominator of transmission ratio of gear stage 1 [spindle speed]". When spindle feedback is that the second encoder is directly connected to the spindle, the parameter should be set to 1.

11. "Enable rotation speed of shift point": When the speed range of each gear has overlapping speeds, the parameter should be set to 1. If the given speed at the time of gear shift is greater than the value and less than the minimum speed of the target gear stage, the gear shift is enabled.

12. "Rotation speed of shift point between gear stage 1 and 2": The parameter is valid when "Enable rotation speed of shift point" is set to 1. When there is an overlapping speed between speed ranges of gear stage 1 and 2, and the set speed is greater than the value, the gear shift is enabled.

13. "Rotation speed of shift point between gear 2 stage and 3": The parameter is valid when "Enable rotation speed of shift point" is set to 1. When there is an overlapping speed between speed ranges of gear stage 2 and 3 and the set speed is greater than the value, the gear shift is enabled.

14. "Rotation speed of shift point between gear stage 3 and 4": The parameter is valid when "Enable rotation speed of shift point" is set to 1. When there is an overlapping speed between speed ranges of gear stage 3 and 4 and the set speed is greater than the value, the gear shift is enabled.

15. "Motor speed during gear shift ": Set motor speed during gear shift of spindle.

16. "Reset spindle after gear shift":

Register Description (Axis Register Interface):

F474: Target gear stage. It is calculated based on speed range of different gear stages through NC analyzing S command. BIT0-BIT3 represents gear stages 1-4 respectively, namely gear stages 1-4 is 1, 2, 4 and 8 respectively.

G464: Current gear stage. It is gear stage number currently obtained when PLC acquires external signals. BIT0-BIT3 represents gear stages 1-4 respectively, namely gears 1-4 is 1, 2, 4 and 8 respectively.

G462.9: Enable shift speed. When this signal is valid, the motor runs at speed set by "Motor speed during gear shift ".

F2562.12: Spindle 0 of channel 0 has S command
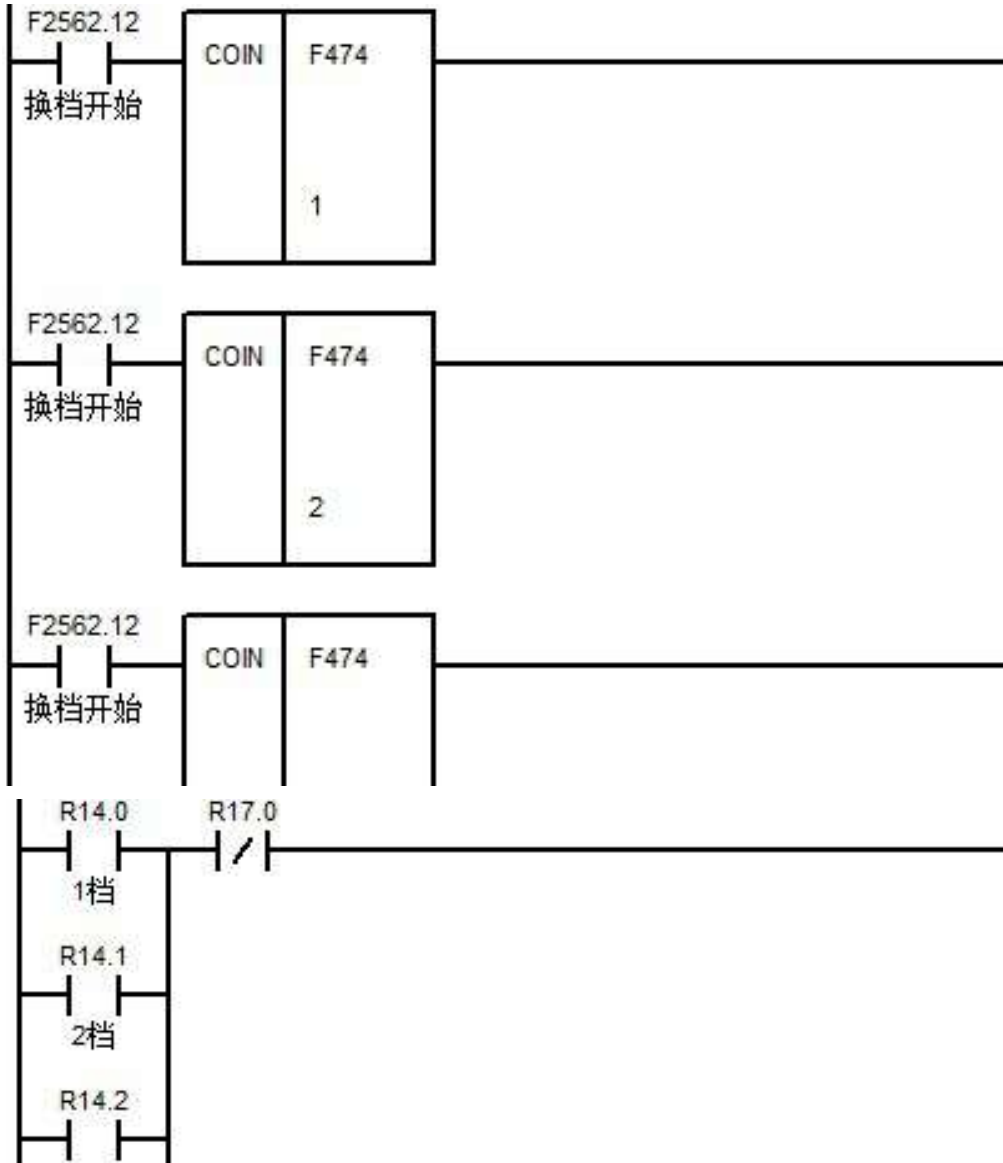
F2570-F2571: Command speed of spindle 0 in channel 0

G2562.0: S command response of spindle 0 in channel 0

G2570-G2571: Command output of spindle 0 in channel 0

PLC Gear Shift Control

Description: Gear stage feedback signal is input by external I/O. After acquiring the signal, PLC determines current gear stage number and assigns the value to G464 to notify the system.

Description: When the system requests for gear shift to execute M3/M4S×× or S×× command, F2562.12 is set. After NC analyzes S command and marks, the corresponding gear stage (F474) marker bit is turned on. PLC determines target gear number of command and turns Enable Gear Shift Speed (G462.9) on. The spindle will rotate and shift gears based on the set value of Motor Speed During Gear Shift.
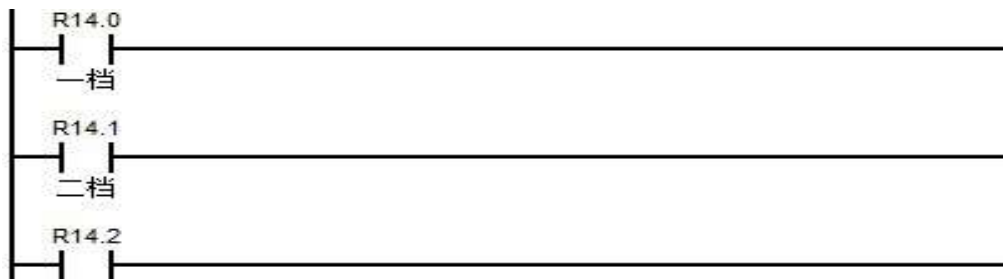
Description: After determining target gear number of command, PLC sets Y output register of corresponding gear stage for gear shift.
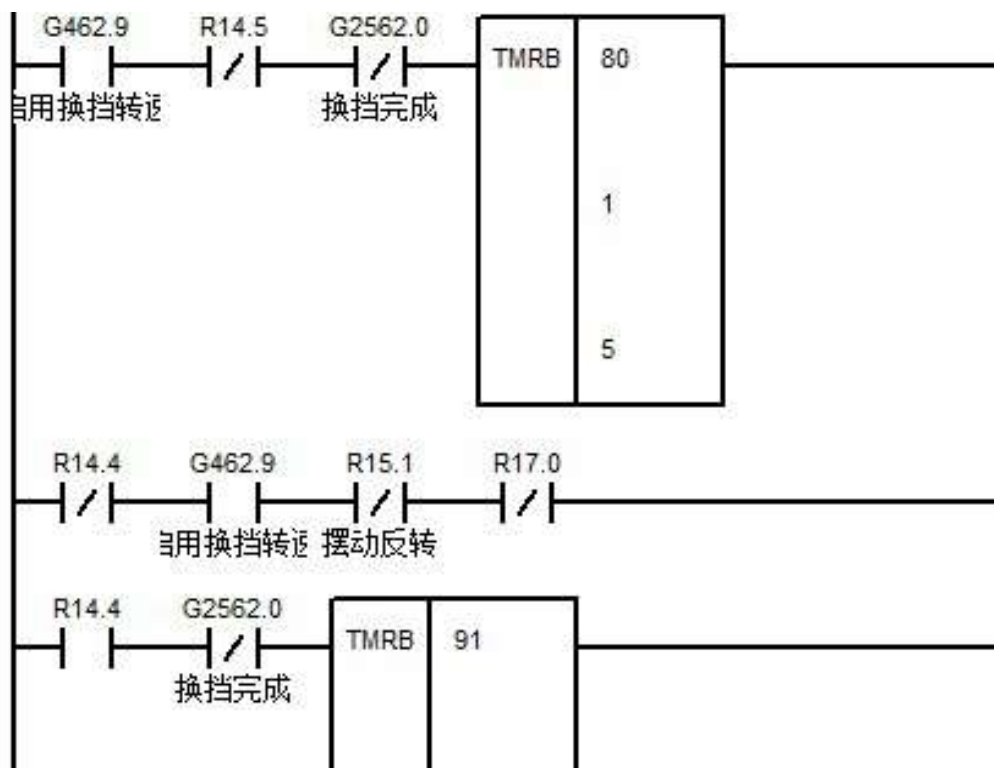
Description: CCW and CW rotation of spindle is realized by timer.
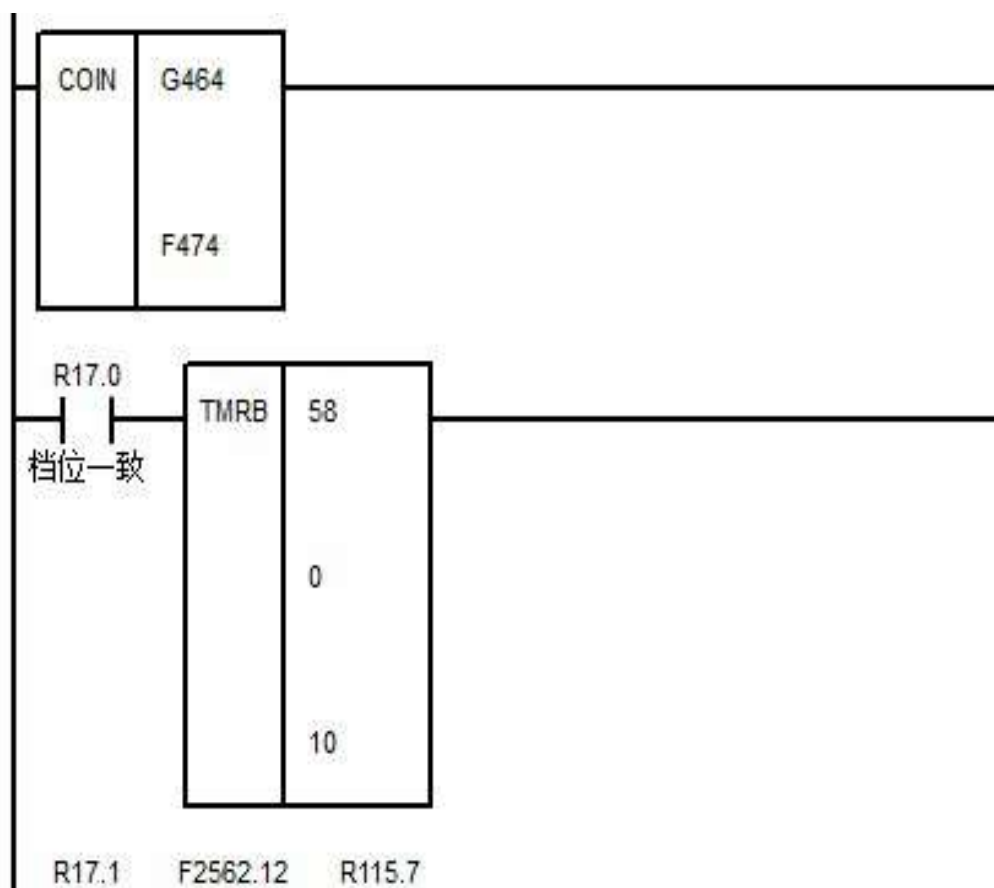
Description: PLC determines whether feedback gear stage number is consistent with target gear stage number. If so, delay and determine speed arrival signal and the gear stage changing completion marker bit G2562.0 is turned on after rotation speed increases.
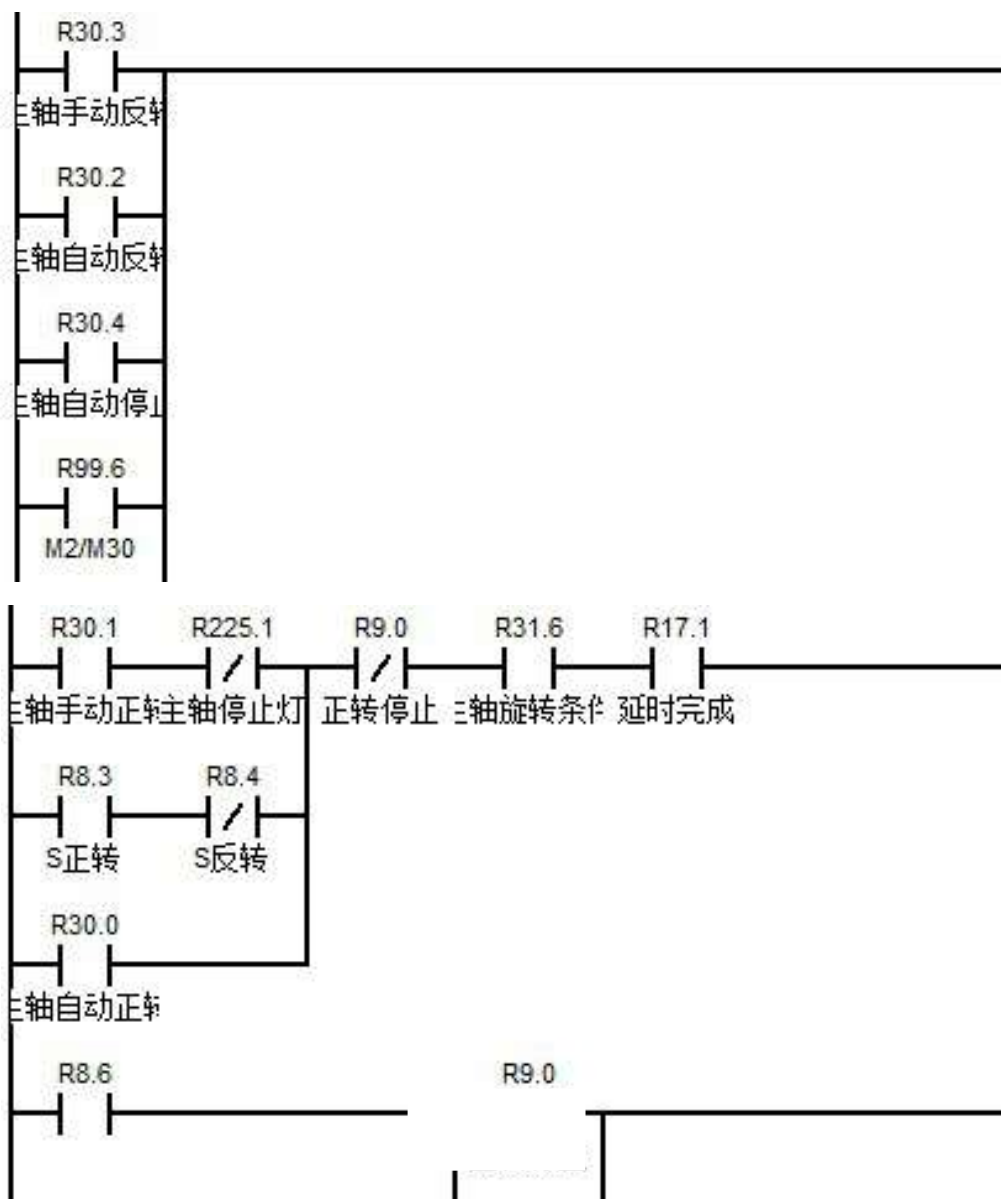
Description: Control of CW spindle rotation and realization of positive swing of spindle.

R30.0
主轴自动正转

R30.1
主轴手动正转

R30.4
主轴自动停止

R99.6
M2/M30

R30.3   R225.1   R31.6   R9.1   R17.1
主轴手动反转 主轴停止灯 主轴旋转条件 反转停止   延时完成

R8.4   R8.3
S反转   S正转

R30.2
主轴自动反转

R8.7   R9.1
                                            反转停止

R225.2   R30.5   R17.1
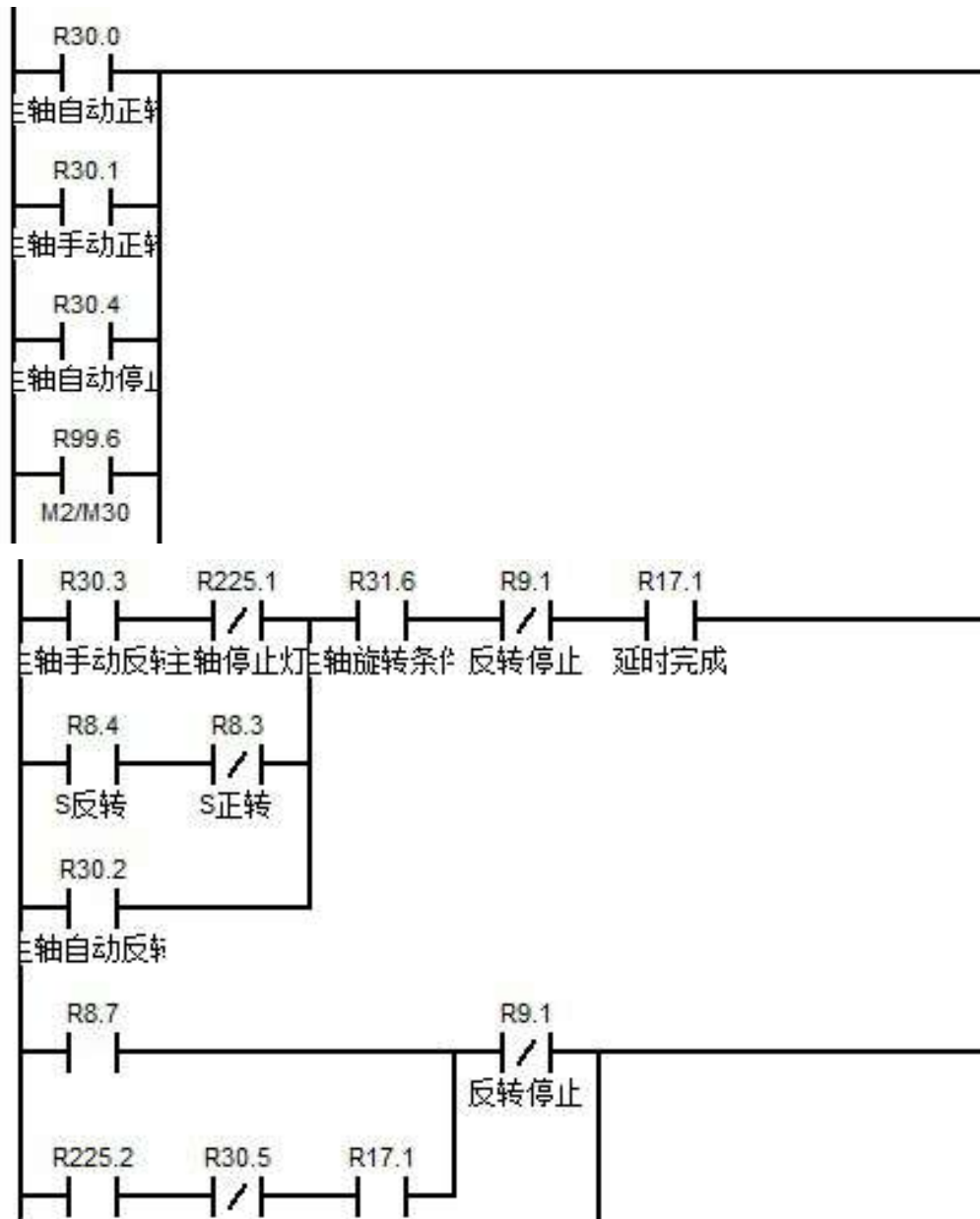
Description: Control of CCW spindle rotation and realization of negative swing of spindle.

R30.0   R17.0   R30.7   TMRB   24
主轴自动正转 档位一致 主轴速度到达

R30.2
主轴自动反转   0

R225.0

                                                    500
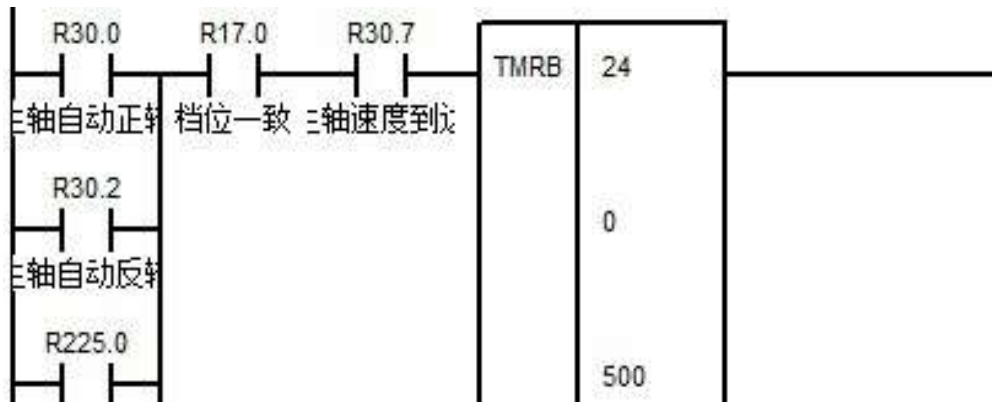
Determination of spindle speed arrival delay

Note: The aforesaid PLC spindle control is only applicable to CW and CCW spindle rotation and spindle stop in JOG or auto. The separate S command is to specify the gear stage changing. If more spindle actions are needed, PLC control should be modified.

1.5 Control of Conversion from Feed Axis to Spindle

When the feed axis servo drive is used as the spindle servo drive for the power head or tool post of turning center or turn-mill combination machine, or the axis control board (with pulse output function) is used with the third-party drive, feed axis should be used as spindle and should be set as below.

Converting feed axis to spindle is the internal processing of the CNC system and is unrelated to servo drive. To set parameters, this function can be realized by two parts of the ladder diagram.

Parameters

Parameters to be set include channel parameter, coordinate axis parameter and device interface parameter.

In channel parameter, it is just necessary to configure the unused physical axes in axis number parameter of spindle 1. Axis number configured in the parameter will be mapped to logical axis in coordinate axis parameter and "AX" in device interface parameter.

Here channel parameter is logical axis 3.

040011	主轴1轴号	3	重启

Logical axis 3 in coordinate axis parameter is the mapping coordinate axis of spindle 1.

参数号	参数名	参数值	生效方式
103000	显示轴名	A	保存
103001	轴类型	9	保存
103004	电子齿轮比分子[位移](um)	360000	重启
103005	电子齿轮比分母[脉冲]	10000	重启
103006	正软极限坐标(mm)	2000.0000	复位
103007	负软极限坐标(mm)	-2000.0000	复位
103008	第2正软极限坐标(mm)	2000.0000	复位
103009	第2负软极限坐标(mm)	-2000.0000	复位
103010	回参考点模式	1	保存

(NC参数 / 机床用户参数 / 通道参数 / 坐标轴参数 / 逻辑轴0 / 逻辑轴1 / 逻辑轴2 / 逻辑轴3 / 逻辑轴4 / 逻辑轴5 / 逻辑轴6 / 逻辑轴7)

Axis type is changed to 9, which is type of the axis used by the second spindle. Numerator of electronic gear ratio should be 360×1000 for rotary axis and denominator should be filled out based on resolution of encoder on the site. Other parameters in logical axis 3 are identical to parameters of the first spindle. Set axis 3 found in device parameters using normal configuration method and change feedback position cycle mode to 2.

参数号	参数名	参数值	生效方式
509010	工作模式	1	重启
509011	逻辑轴号	3	重启
509012	编码器反馈取反标志	0	重启
509013	伺服主轴转速单位	0	重启
509014	反馈位置循环方式	2	重启
509015	反馈位置循环脉冲数	10000	重启
509016	编码器类型	1	重启
509017	保留	0	重启
509018	保留	0	重启

(设备接口参数 / 设备0 / 设备1 / 设备2 / 设备3 / 设备4 / 设备5 / 设备6 / 设备7 / 设备8 / 设备9 / 设备10)

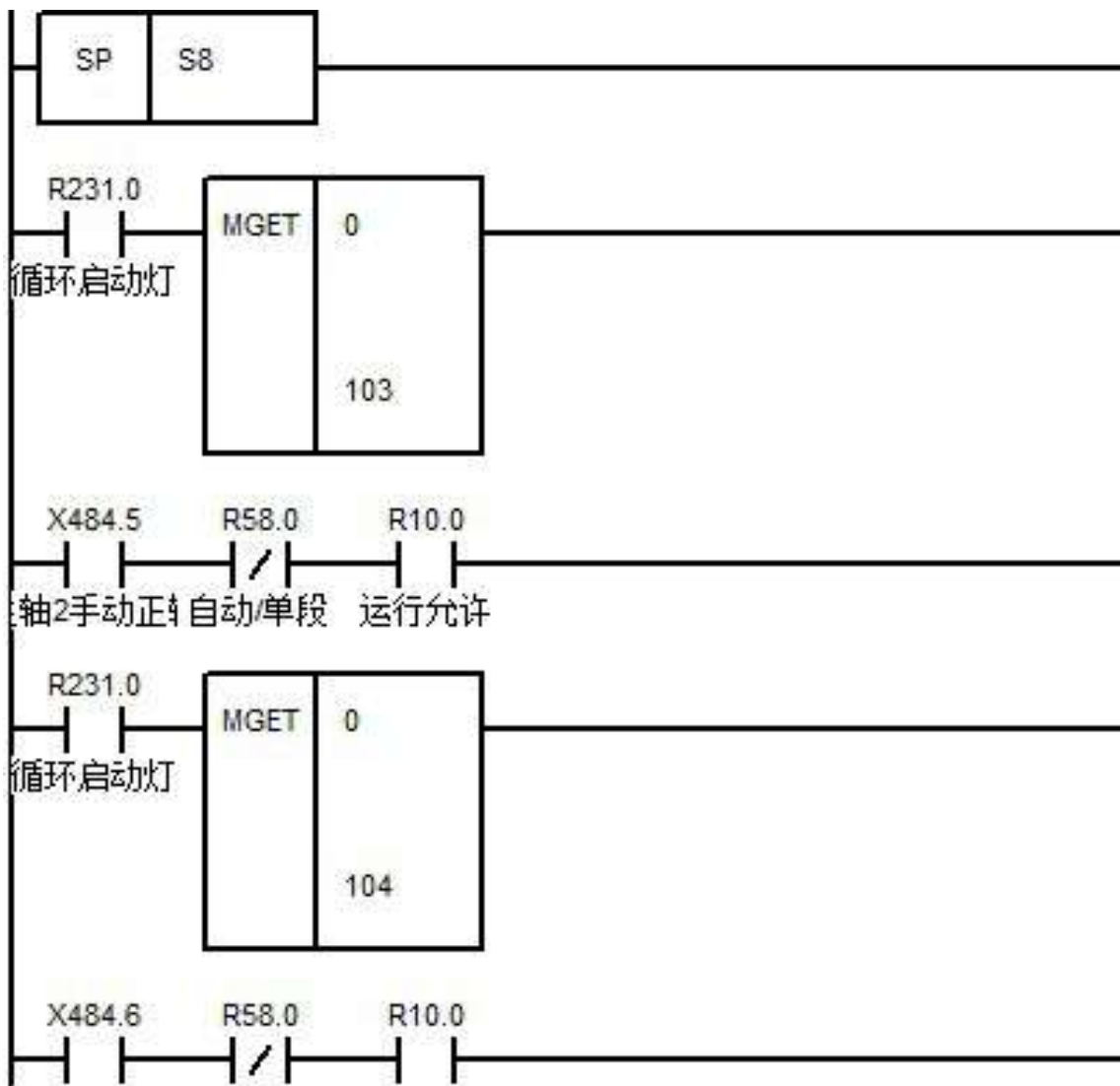Parameters of converting feed axis to spindle are configured.
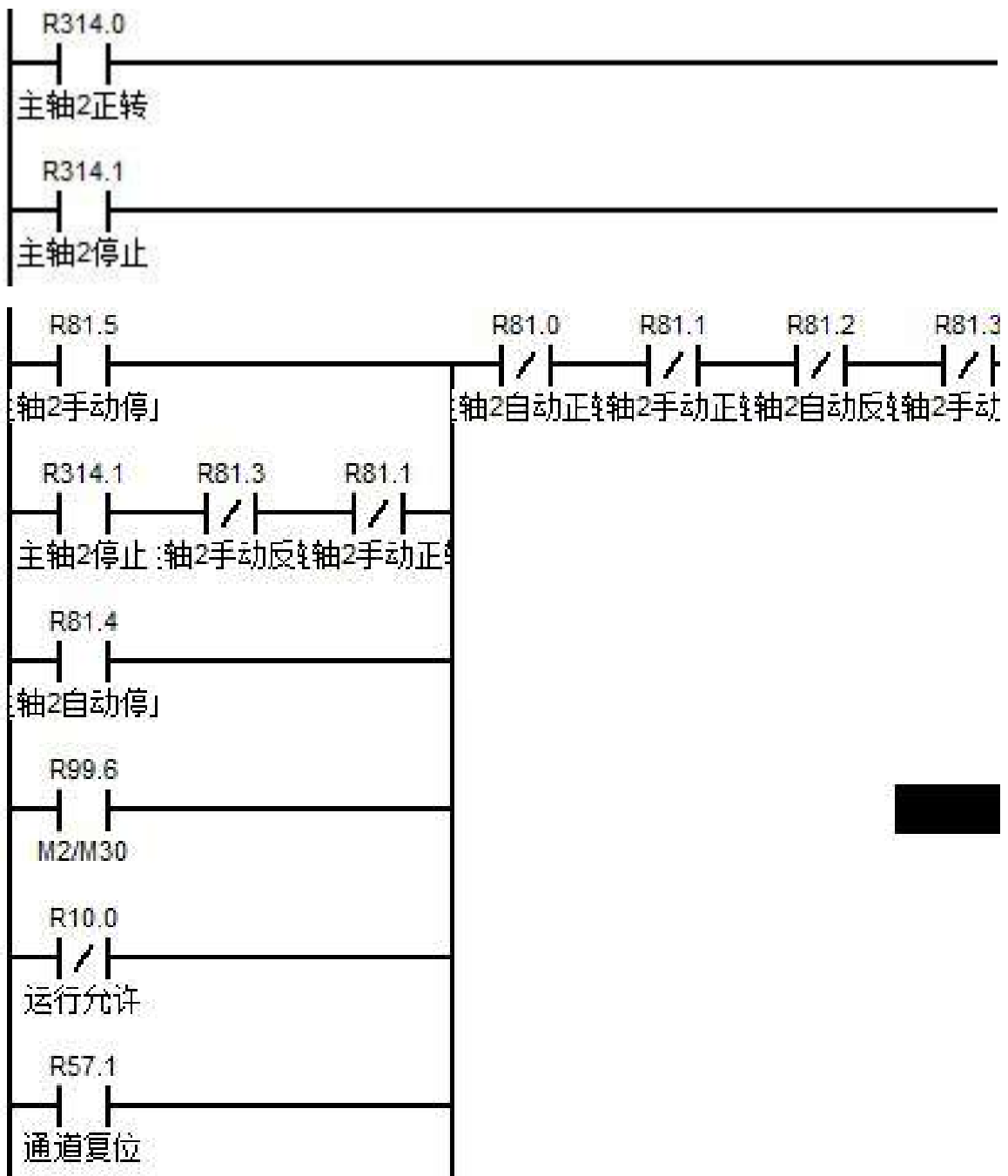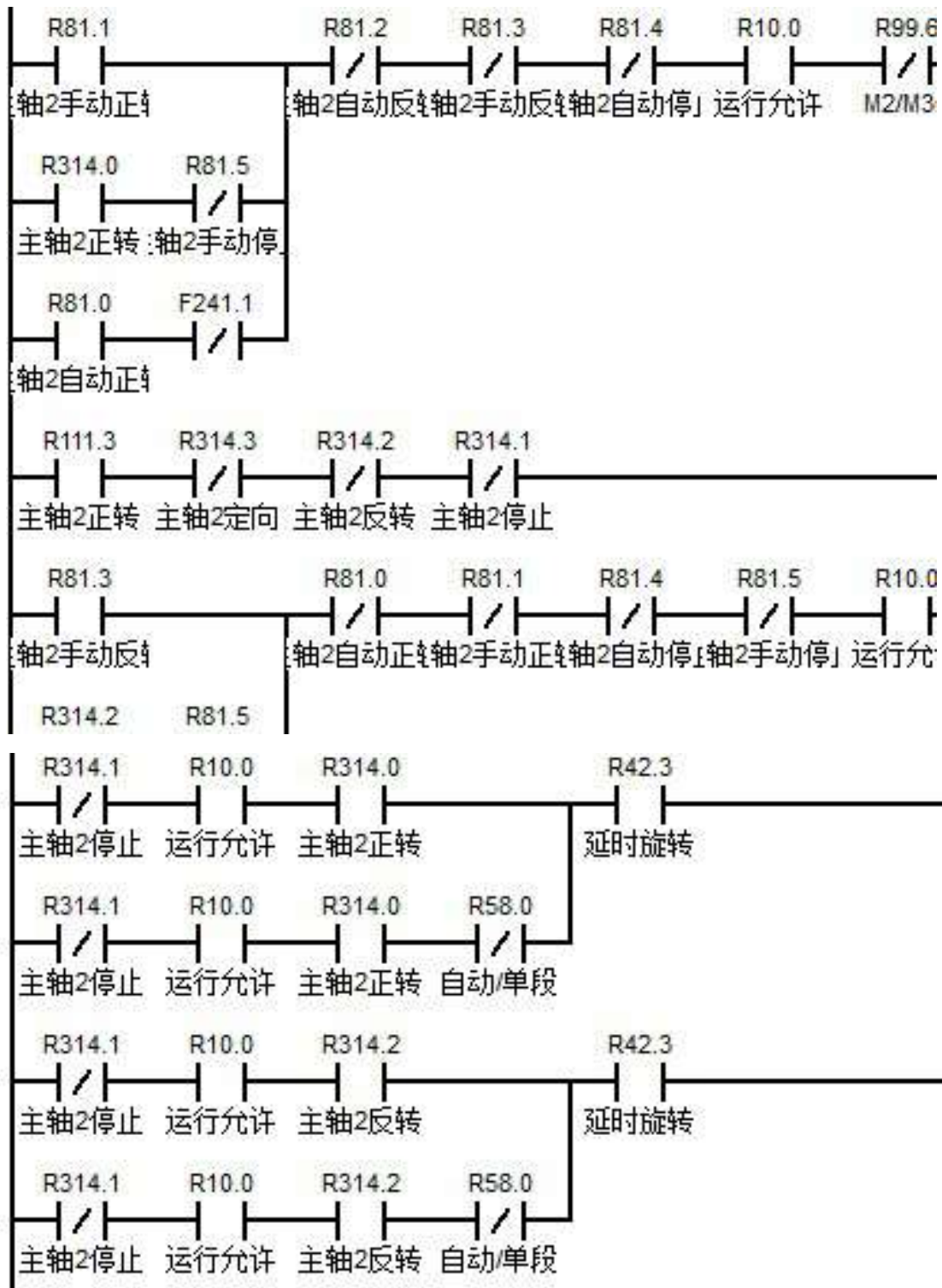
PLC And Register Are Shown in Table 1

Table 1

F1.5	Orientation completion	To correspond to different axes, please determine registers corresponding to axes by: Axis number ×80+1.5/1.6/1.7
F1.6	Zero speed completion	
F1.7	Rotation speed arrival	
G1.5	Orientation	
G1.6	CW rotation	
G1.7	CCW rotation	

When it is used as the second spindle, there is no big difference in PLC of the first spindle. Write the following program in a subprogram and place it in the ladder diagram.

Input M103 for CW rotation of the second spindle, M104 for CCW rotation and M105 for stop. Add 3 keys which have never been used on the panel for CW rotation, CCW rotation and stop of the second spindle (X484.5, X484.6 and X485.6 shown below). Automatic rotation indicates that the spindle rotation is specified with M command, and manual rotation indicates that the spindle rotation is specified with keys.

```
    R314.0
──┤ ├──────────────────────────────────────────────────
  主轴2正转

    R314.1
──┤ ├──────────────────────────────────────────────────
  主轴2停止


    R81.5                              R81.0      R81.1      R81.2      R81.3
──┤ ├─────────────────┬──────────────┤/├────────┤/├────────┤/├────────┤/├
  轴2手动停」          │             轴2自动正轴2手动正轴2自动反轴2手动

    R314.1    R81.3      R81.1        │
──┤ ├────────┤/├────────┤/├──────────┤
  主轴2停止:轴2手动反轴2手动正        │

    R81.4                            │
──┤ ├─────────────────────────────────┤
  轴2自动停」                          │

    R99.6                            │
──┤ ├─────────────────────────────────┤
  M2/M30                             │

    R10.0                            │
──┤/├─────────────────────────────────┤
  运行允许                            │

    R57.1                            │
──┤ ├─────────────────────────────────┤
  通道复位
```

CW rotation and CCW rotation of the second spindle are subject to commands G1.6 and G1.7. Whereas axis 3 is selected and every axis occupies 80 bits, CW rotation and CCW rotation of axis 3 are subject to commands G241.6 and G241.7.

Note: G241.6 and G2622.3 as well as G241.7 and G2623.3 should be outputted simultaneously (not added to the figure)
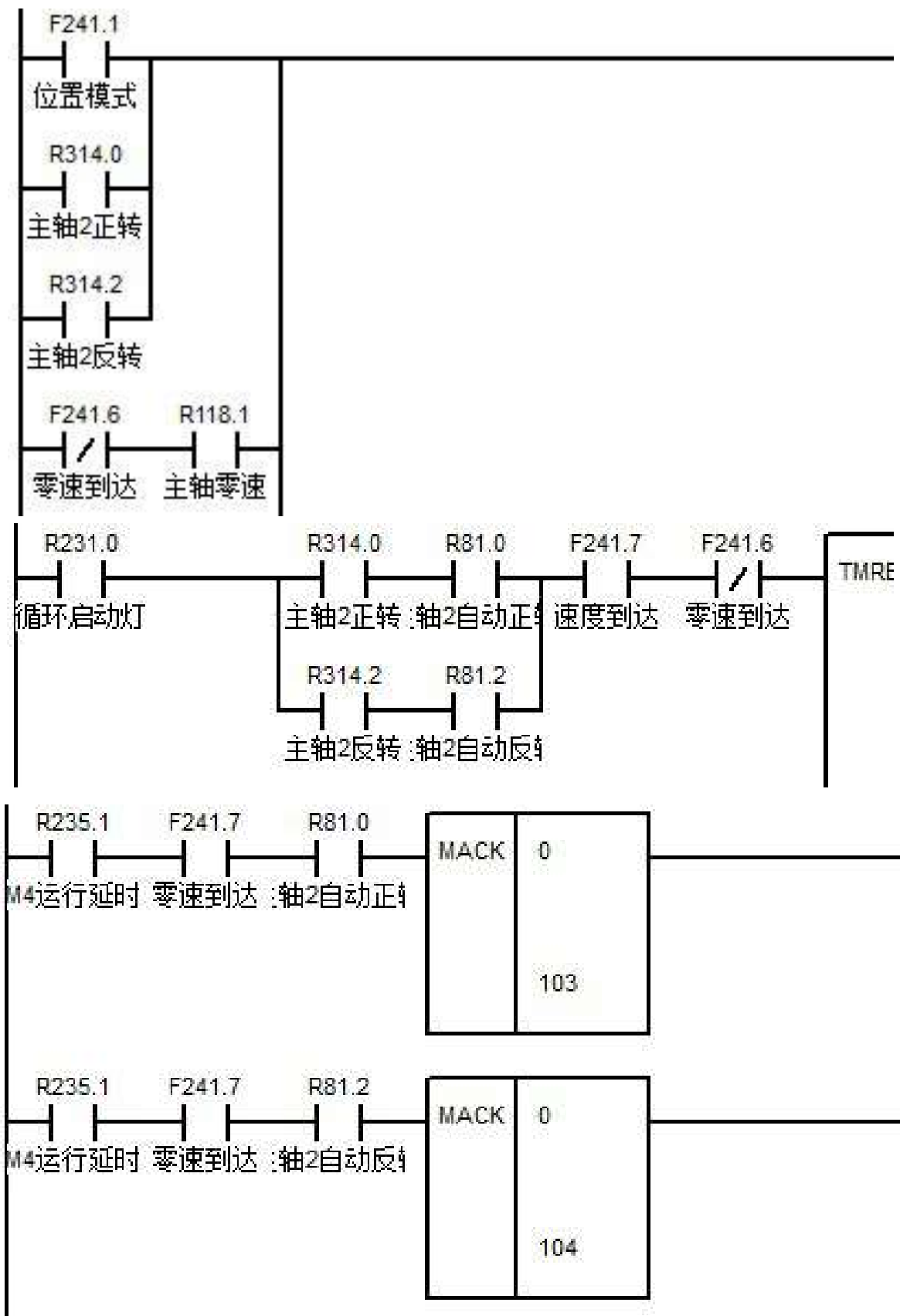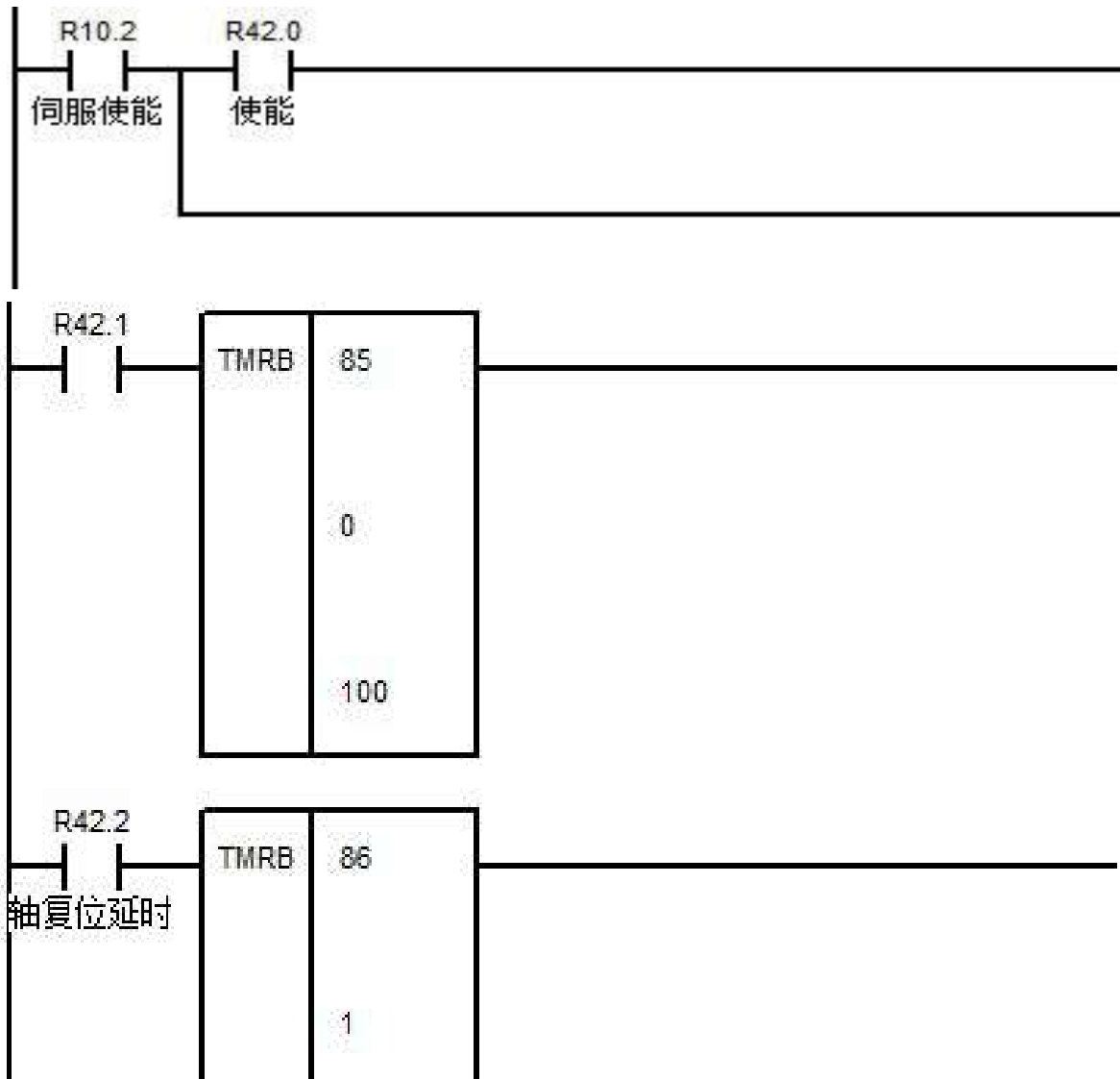
In the process of the spindle rotation, Enable signal G243.0 is activated, and Ready signal F242.8 and Axis Enable signal are detected. Then, delay Feed Axis Reset G240.15 and rotation command.

As the second spindle speed control

Add 1 key which has never been used on the panel for manual orientation of the second spindle (X482.5 shown below).

R231.0
循环启动灯 ── MGET ─ 0

119

R231.0
循环启动灯 ── MGET ─ 0

120

R314.0   R314.3
主轴2正转 主轴2定向

R314.2
主轴2反转

R61.0
主轴2自动

R61.2
主轴2自动

R31.2   R314.3   R10.0   R81.7   R10.1   R57.0
手动定向 主轴2定向 运行允许 轴2取消定 几床复位完成 复位开始

R314.3   R31.2
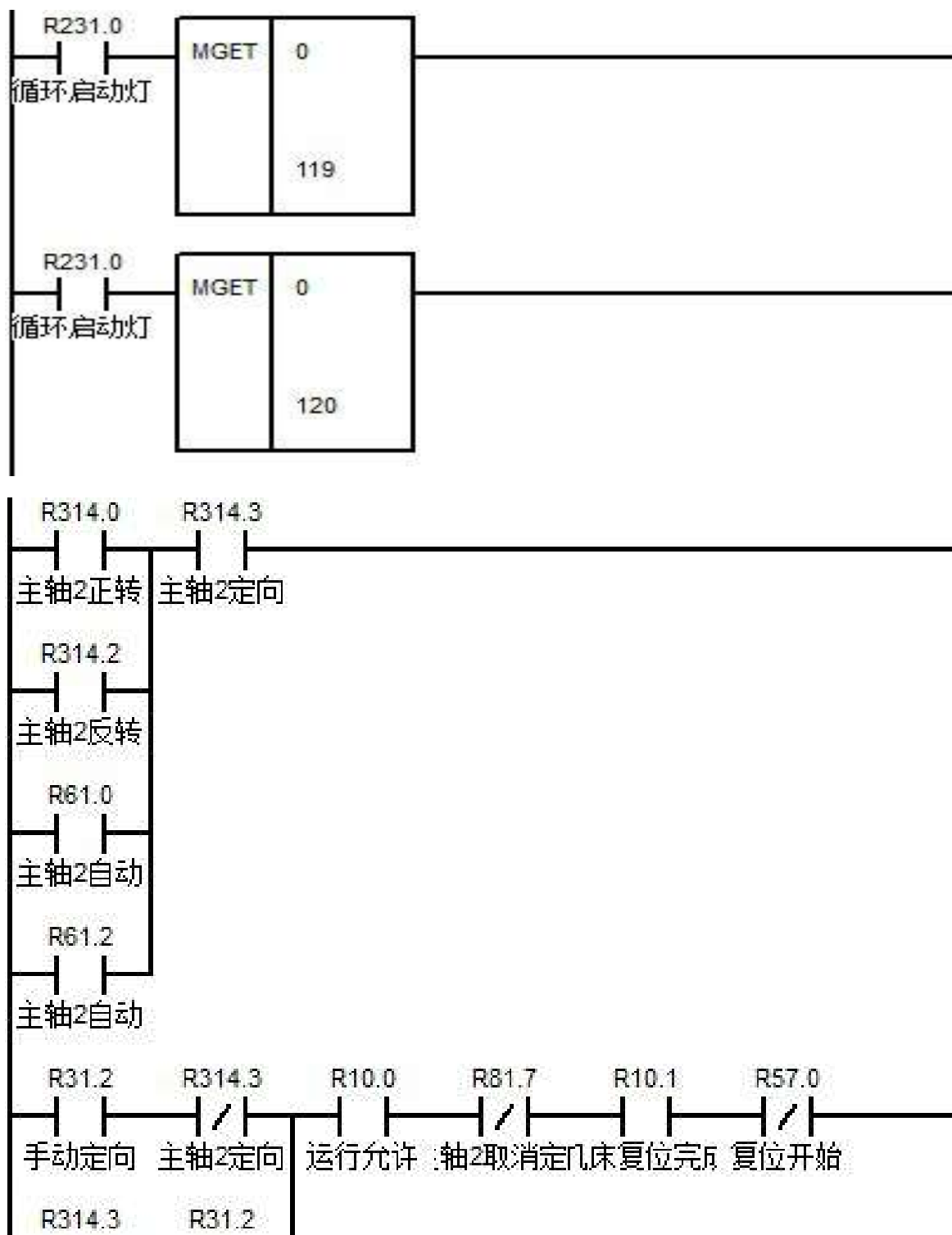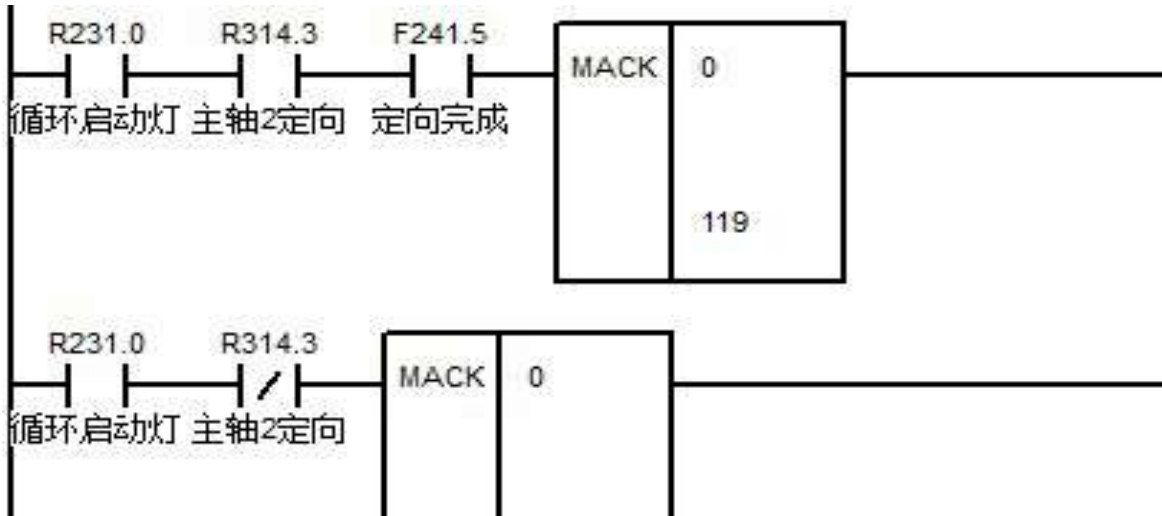
According to the aforesaid PLC modification, axes move after a few seconds delay after CW rotation, CCW rotation and orientation commands are issued. The reason is that the enable signal is activated only when axis is moving, and not activated when axis is not moving. The enable signal must be enabled before axis moves. Thus, axis movement command should be delayed. If it is enabled continuously, there will be no several seconds of delay in movement. PLC should be modified accordingly, and just delete the circled position in the following PLC.
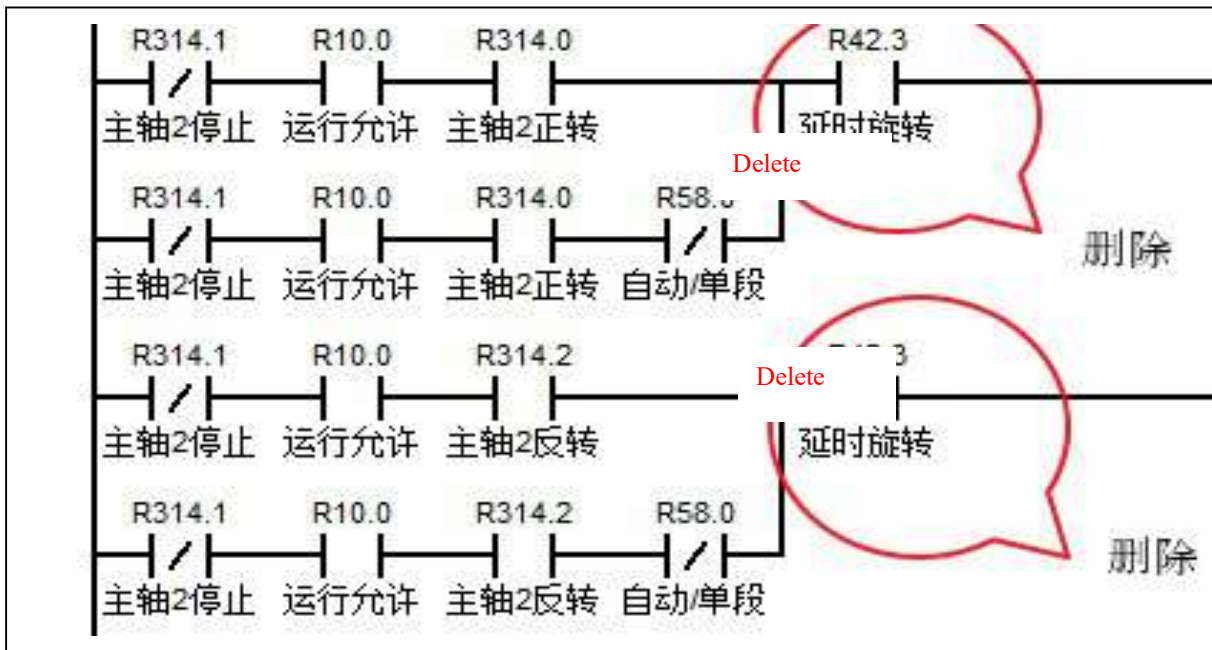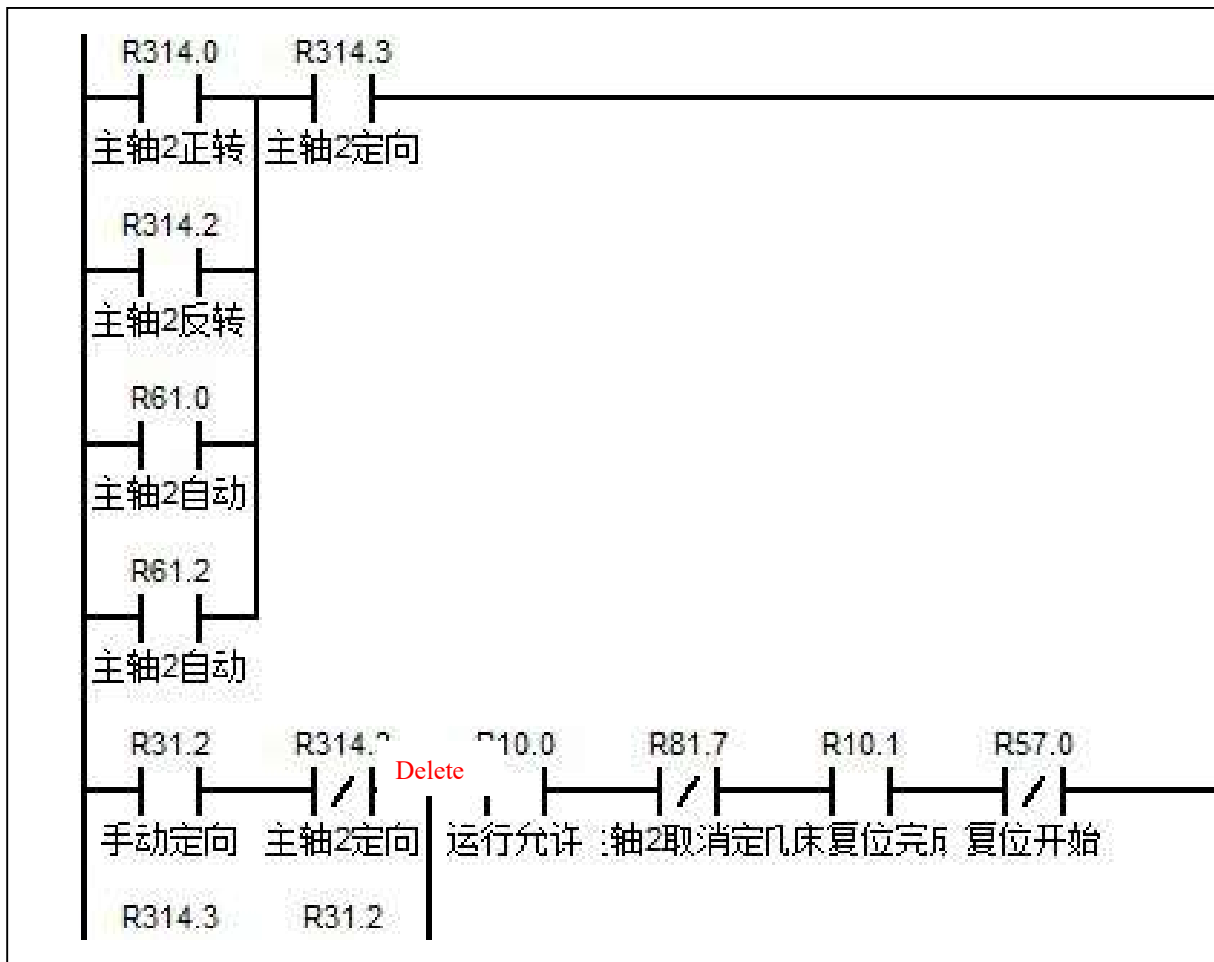
1.6 Dual Channel Spindle Sharing Function

Dual channel spindle sharing function G102.1 has two types of command formats and the usage is described as below:

Command Format 1:

Axis acquisition: G102.1 axis programming name=logical axis number

Programming name of axis: X/Y/Z/A/B/C/S (4 spindles are S, S1, S2 and S3 by default)

Logical axis number: 0, 1, 2, 3, 4, 5......

Function: The system acquires the axis specified by logical axis number in the current channel and goes to the axis designated to get the control right of the axis. After this command is executed, command can be issued or interpolation can be conducted for the acquired axes.

Configuration description: There is a spindle whose logical axis number is 5 in channel 0 and there is no spindle in channel 1 (as shown below)
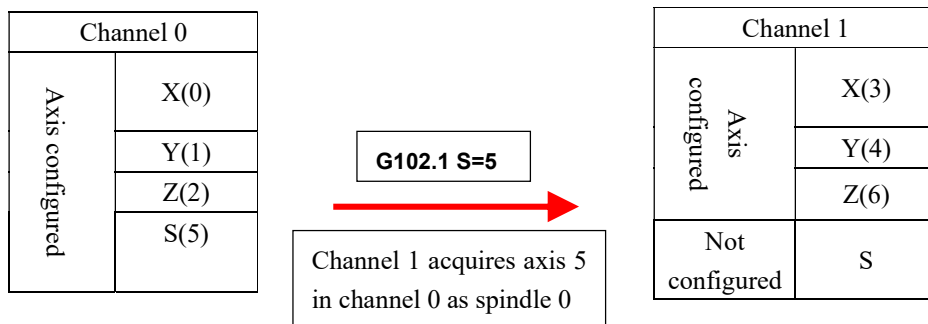
Application case 1: Configuration is shown above, input the following code in channel 1, spindle whose logical axis number is 5 can be captured from channel 0 and used in channel 1. Besides, PLC of spindle control should be modified accordingly:

    T0101

    G102.1 S=5; acquire the control right of logical axis 5 to channel 1 (programming name of spindle 0 is S)

    M03S300; logical axis 5 is spindle in channel 1 and its rotation speed is 300r/min

    G54 G00 X35 Z104; select coordinate system G54, move to starting point of thread machining cycle

    G82 X29.2 Z18.5 P180 F3; cyclic threading, depth is 0.8mm

    M30

PLC modified: Whereas spindle 0 is captured from channel 0 to channel 1, a set of M codes for spindle movement should be edited in channel 1, e.g.: M03 for spindle rotation CW, M04 for spindle rotation CCW and M05 for stop. Specific logical relation control can be shared with control spindle in channel 0 and PLC should be modified according to site condition.

Application case 2: Configuration is shown above, if need to capture logical axis 0 [feed axis X] from channel 0 to channel 1, then edit the following codes in channel 1 and PLC of axis control doesn't need to be modified:

    T0101

    G102.1 X=0; acquire the control right of logical axis 0 from channel 0 to channel 1 【programming name is X】

    G54 G01 X100 F1000; control the actual motion of logical axis 0 of channel 0 in channel 1

    G01 X-100

    M30

Note:

(1) Axes must belong to a channel. After acquiring feed axes from other channels, a channel stays at acquisition sate. Axes cannot be released through reset. Acquisition right of axes in current channel can be released only through emergency stop. After axes are released, the use right of axes will be restored to the original channel.

(2) A logical axis must belong to a channel, which can be a feed axis or a spindle;

(3) After a channel acquires an axis, G5X zero point of the axis should be set. If G5X zero point of the axis cannot be set in the setup interface, user can consider set the origin of the workpiece coordinate system using G10 programmable data input command;

(4) Axes cannot be acquired or released in the movement process.

(5) The only difference between G102.1 and G102 commands is that the axes acquired using G102.1 need not be released using G101 in order to simplify programming and operation. Other functions are consistent with G102.

Command Format 2:

Build spindle mapping: G102.1 spindle programming name = initial address of mapping channel + spindle number to be mapped

Programming name of spindle: Programming name of spindles (S, S1, S2 and S3 by default) in current channel

Initial address in mapping channel: (number of channel where spindle to be mapped is + 1) ×1000

e.g.: Channel 0 is 1000, channel 1 is 2000 and channel 2 is 3000......

Spindle number to be mapped: 0, 1, 2 and 3 (4 spindle numbers in the channel). e.g.: 1001 represents the spindle of the second 【No. 1】 in channel 0 and 2003 represents the spindle of the fourth 【No. 3】 in channel 1;

Function: Build a mapping spindle in current channel, share feedback of the spindle. e.g.: Service condition of G95 and G99.

Application case:

Configuration description: The system is configured with dual channel. There is a spindle in channel 0, channel 1 has no spindle, and feed axes (X, Y and Z) should follow spindle S in channel 0 to complete the feed in the mode of feed per revolution when processing is performed in channel 1.
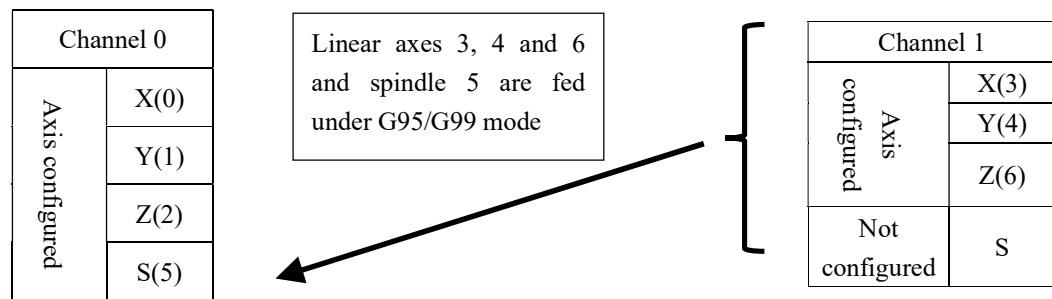
Input M03 S1000 in channel 0 to enable spindle rotation CW;

Input the following program codes in channel 1:

    T0101
    G102.1 S=1000; map feedback amount of spindle 0 【(0+1)×1000+0】 in channel 0 to channel 1
    G95G01X200F2; specify G95 for feed mode per revolution of spindle
    G94 ; cancel feed per revolution, recover feed per minute G94
    G1X0Z0
    M30

PLC modified: Whereas this function is used to acquire feedback of axes only, pay attention to setups of

registers selected for spindles in channels in PLC when feed per revolution mode is used. Register description is shown below (The offset in other channels is based on "Channel number ×80+2562"):

G2562.3	G2562.4	G2562.5	G2562.6	Description
1	0	0	0	Channel 0 selects feedback of spindle 0
0	1	0	0	Channel 0 selects feedback of spindle 1
0	0	1	0	Channel 0 selects feedback of spindle 2
0	0	0	1	Channel 0 selects feedback of spindle 3

Note:

(1) This command is intended for mapping of spindles only instead of other types of axes.

(2) Programming name of spindle is subject to programming name set on the site.

1.7 Double Speed Motor Type Spindle Commissioning

When double speed motor is used on the site, S command is followed by gear stage number such as S1, S2 and S3. After determining gear stage number, the system outputs corresponding Y signal in PLC and the spindle motor starts to rotate. Then, the system writes actual spindle speed in the command. (e.g.: Motor speed should be 1500r/min at M3S1. Write the feedback 1500 in the command speed to complete thread machining and rigid tapping)

PLC process chart is shown below

The spindle has 4 gears in the example.
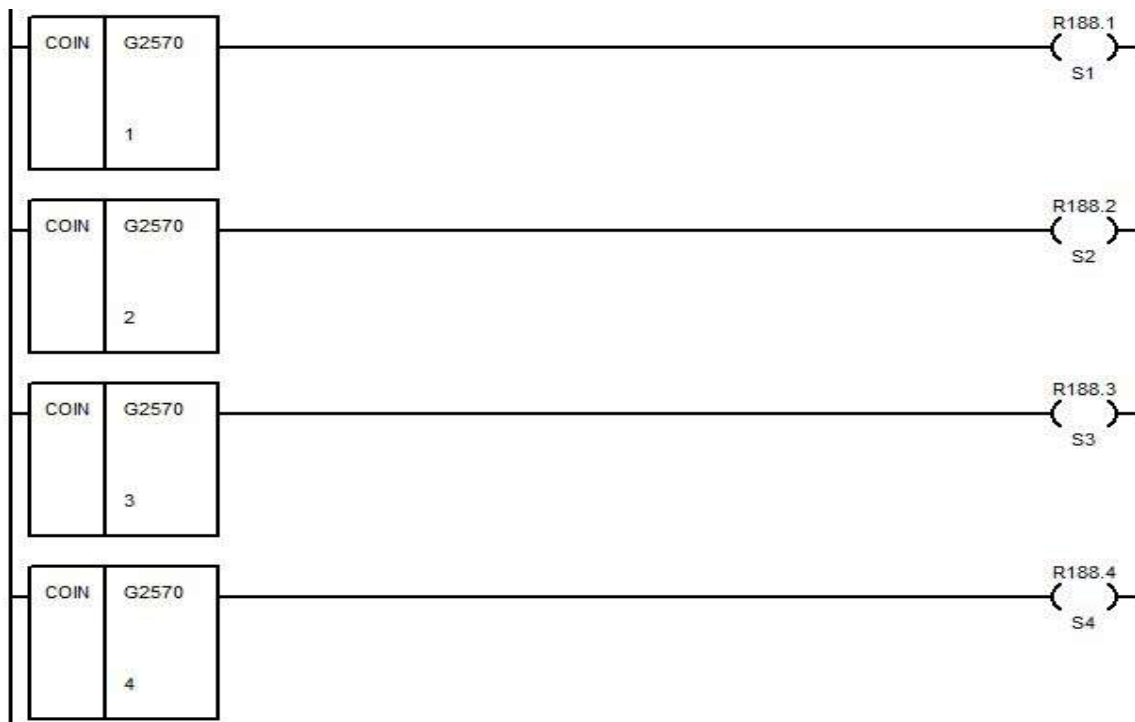
Determine the currently executed S command of channel 0 and mark it.
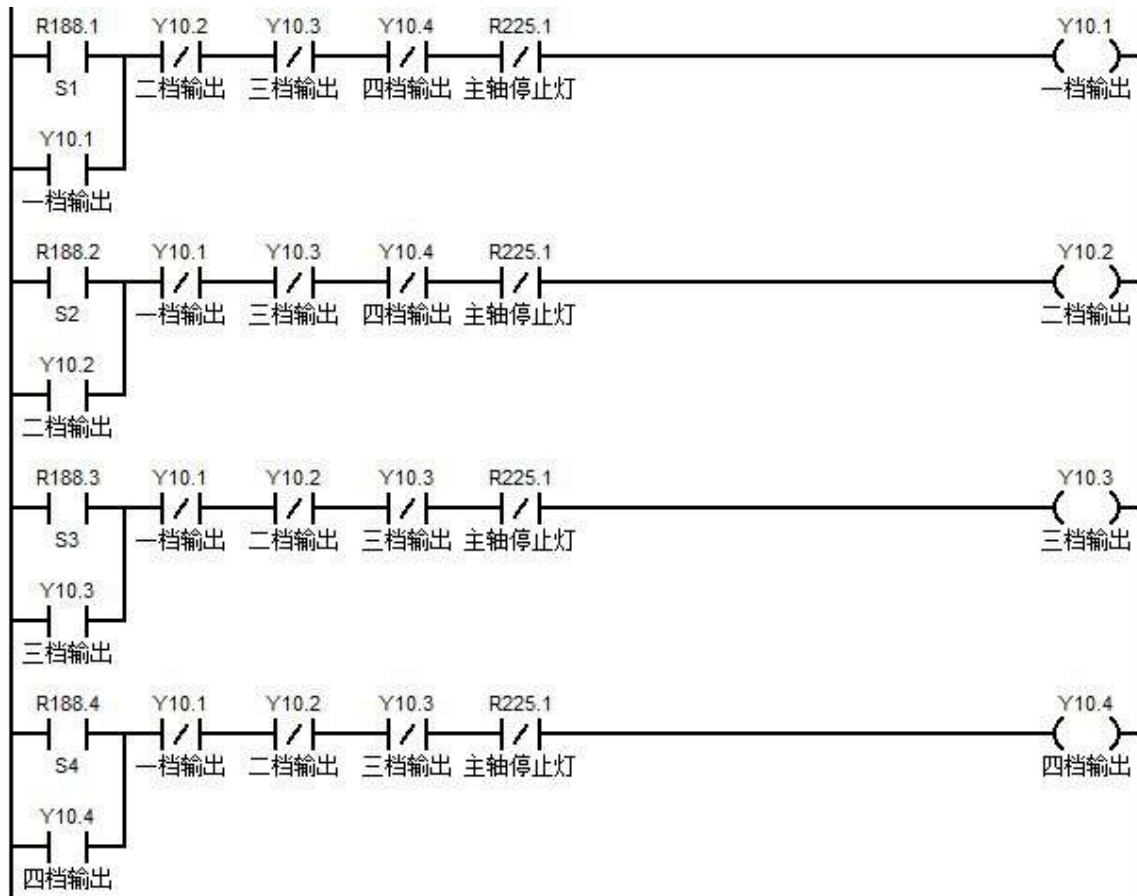
Output corresponding Y signal according to S command.

The system writes actual spindle speed in the command.

2   Analog Spindle Instruction

There are five basic conditions essential for analog spindle. Here use logical Axis 5 in channel 0 as sn example.

Enable of spindle: axial enable G400.7

The ladder diagram is shown below:

Spindle direction: logical axis 5 G2622.5 positive direction; G2623.5- negative direction

The ladder diagram is shown below:

SPDA Module

Parameter 1 channel number 0

Parameter 2 spindle number 0

Parameter 3 corresponding gear register (such as R39)

Parameter 4 invalid (any unused register such as R280)

Parameter 5 corresponding P parameters (such as P40 or P50, parameters correspond to P40-P44 or P50-P54)

The ladder diagram is shown below:

Remarks: To use current spindle of SPDA, SPDLBUS or SPDLBUS1 control of the spindle should be disabled.

Spindle command output: G2570 and G2571 of spindle 0

The ladder diagram is shown below:

Spindle override: G2566 of spindle 0

The ladder diagram is shown below:
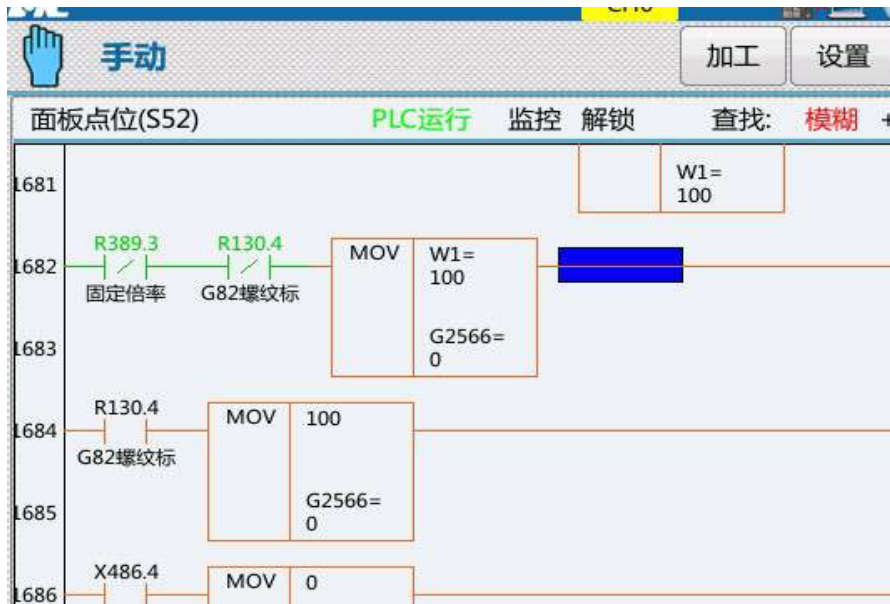
2.1 Commissioning of HIO-1073 Analog Module with Frequency Converter

HI0-1073 analog input/output (A/D-D/A) submodule is responsible for A/D signal input from machine tool to CNC system and D/A signal output from CNC system to machine tool. Every A/D-D/A submodule provides 4-channel 12-bit differential/single-ended analog signal input and 4-channel 12-bit differential/single-ended analog signal output.

HI0-1073 does not support spindle encoder function, D/A (XB interface) outputs analog voltage and controls PWM spindle, A/D input interface XA: (green); D/A output interface XB: (orange). Interface definition is shown below:
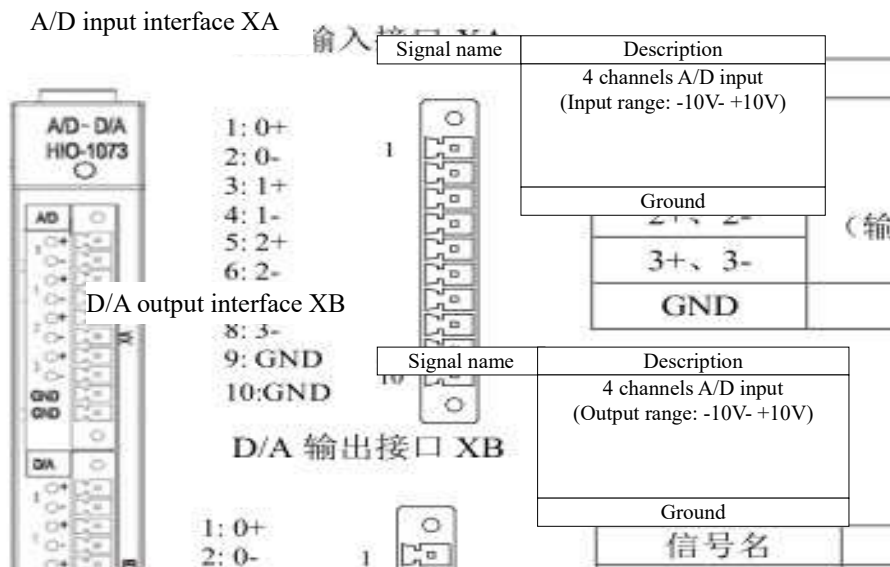
With lathe as an example (logical axis 0, logical axis 2 and logical axis 5):

The bus passes through HI0-1061 NCUC communication submodule (furnished a 1011 input submodule, a 1021 output submodule and a 1073 analog input/output submodule) and X and Z axes successively, then returns to the system. The module connection diagram is shown below:

Configuration of devices identified by the system is as below:

IO watchdog corresponds to X19 and Y19, as shown below:

2.1.1 Important Parameters Corresponding to Analog Spindle

Machine Tool User Parameters

010000	Maximum number of channels	1 (1 channel)
010001	Cutting type of channel 0	1 (lathe)
010009	Channel 0 selection marker	1 (channel 0 corresponds to 1)
010017	Display axis marker of channel 0	0x5 (logical axis 0 and logical axis 2)
010033	Load current display customization of channel 0	0, 2 (logical axis 0 and logical axis 2)

Channel Parameter
Channel 0

040001	X coordinate axis number	0 (logical axis 0)
040003	Z coordinate axis number	2 (logical axis 2)
040010	Axis number of spindle 0	5 (logical axis 5)
040023	Programming name of spindle 0	S (programming code)
040027	Display mode of spindle speed	1 (spindle encoder is not supported, command value is set)
040028	Display of spindle axis number	5 (logical axis 5)

Coordinate Axis Parameter

Logical axis 5

105000	Display axis name	S
105001	Axis type	10 (spindle)

Device Interface Parameter

Device 4

504010	Working mode	3 (speed mode)
504011	Logical axis number	5 (logical axis 5)
504013	Spindle DA output type	0 or 1 (0 corresponds to 0 - 10V and 1 corresponds to +10 - -10V)
504014	Zero drift adjustment amount of spindle DA output (mv)	200 (recommended value)
504016	Spindle encoder feedback device number	-1 (encoder is not supported)
504017	Spindle DA output device number	7 (corresponding to device number of I0_NET)
504019	Spindle DA output port number	1 (corresponding to offset of initial group number output by device of I0_NET, 1 corresponds to group 0 of XB and 2 corresponds to group 1 of XB, and so on)

Device 7

507012	Initial group number of input point	0
507013	Number of input point groups	10
507014	Initial group number of output point	0
507015	Group number of output point	10

Device 8

508012	Initial group number of input point	10
508013	Group number of input point	10
508014	Initial group number of output point	10
508015	Number of output point groups	10

2.2 Commissioning of HIO-1200 Analog Module with Frequency Converter

With HI0-1200-M2 panel as an example (consisting of HIO-1200 baseplate and IO expansion board of HIO-1200-31).

Hardware appearance is shown below:

Analog spindle interface XS3:

Pin	Signal name	Description
1	DA+	DA output (support 0-10V and -10V- +10V)
2	DA-	
3	AG1	Analog PE

Encoder feedback interface XS4:

Pin	Signal name	Description
1	+5V	5V output
2	GND	
3	PA1+	A+
4	PA1-	A-
5	PB1+	B+
6	PB1-	B-
7	PZ1+	Z+
8	PZ1-	Z-
9	-	Null
10	-	Null

With Lathe As An Example (Logical Axis 0, Logical Axis 2 And Logical Axis 5):
The Bus Passes through HI0-1200 Panel and X and Z Axes Successively, then Returns To The System. The board card connection diagram is shown below:

Configuration of Devices Identified By The System Is As Below:

IO Watchdog Corresponds To X19 And Y19, As Shown Below:

2.2.1 Important Parameters Corresponding to Analog Spindle

Machine Tool User Parameters

010000	Maximum number of channels	1 (1 channel)
010001	Cutting type of channel 0	1 (lathe)
010009	Channel selection marker	1 (channel 0 corresponds to 1)
010017	Display axis marker of channel 0	0x5 (logical axis 0 and logical axis 2)
010033	Load current display customization of channel 0	0, 2 (logical axis 0 and logical axis 2)

Channel Parameter
Channel 0

040001	X coordinate axis number	0 (logical axis 0)
040003	Z coordinate axis number	2 (logical axis 2)
040010	Axis number of spindle 0	5 (logical axis 5)
040023	Programming name of spindle 0	S (programming code)
040027	Display mode of spindle speed	0 or 1 (based on whether there is spindle encoder)
040028	Display of spindle axis number	5 (logical axis 5)

Coordinate Axis Parameter

Logical axis 5

105000	Display of axis name	S
105001	Axis type	10 (spindle)

Device Interface Parameter

Device 4

504010	Working mode	3 (speed mode)
504011	Logical axis number	5 (logical axis 5)
504012	Inverted encoder feedback marker	0 or 1 (determined according to revolutions feedback display and actual speed direction)
504013	Spindle DA output type	0 or 1 (0 corresponds to 0 - 10V and 1 corresponds to +10 - -10V)
504014	Zero drift adjustment amount of spindle DA output (mv)	200 (recommended value)
504015	Pulse count of feedback position cycle	4096 (determined according to pulse count per spindle encoder revolution *4)
504016	Spindle encoder feedback device number	8 (support encoder, corresponding to device number of I0_NET)
504017	Spindle DA output device number	8 (corresponding to device number of I0_NET)
504018	Spindle encoder feedback interface number	0
504019	Spindle DA output port number	0

Device 7

507012	Initial group number of input point	0
507013	Number of input point groups	10
507014	Initial group number of output point	0
507015	Number of output point groups	10

Device 8

508012	Initial group number of input point	10
508013	Number of input point groups	10
508014	Initial group number of output point	10
508015	Number of output point groups	10
507016	Encoder A type	0 or 1 or 3 (set according to actual type of spindle encoder)
507017	Pulse count per revolution of encoder A	4096 (determined based on pulse count per spindle encoder revolution *4)

2.3 Commissioning of HIO-1041 (without Pulse) Analog Module with Frequency Converter

HIO-1041 submodule can offer 2-way spindle analog interface and 2-way spindle encoder interface.

Interfaces XA and XB: (26-core high-density), interface definition is shown below:

Axis control interfaces XA, XB

Plug pin
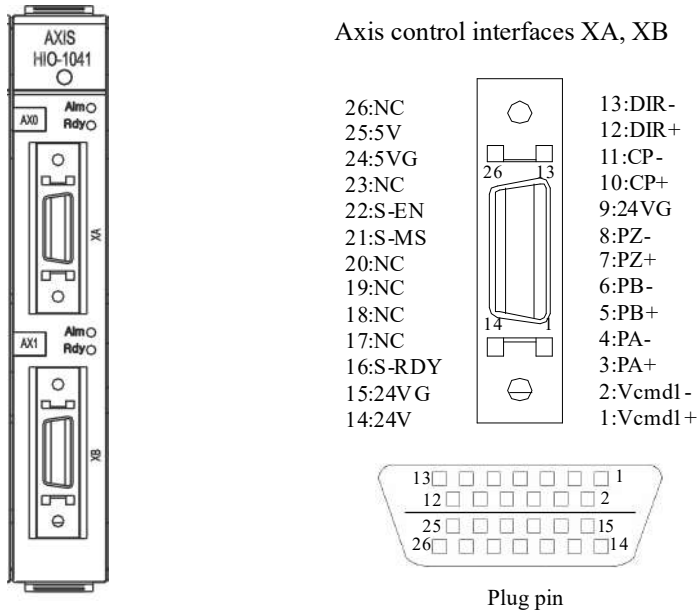
Signal name	Description
Vcmd1+, Vcmd1-	Analog output (-10V- +10V)
PA+, PA-	Encoder A phase feedback signal
PB+, PB-	Encoder B phase feedback signal

PZ+, PZ-	Encoder Z phase feedback signal
24V, 24VG	DC24V power supply
CP+, CP-	Not support
DIR1+, DIR1-	
24VB	DC24V
S-RDY	Ready
S-MS	Mode switching
S-EN	Enable
5V, 5VG	DC5V power supply
NC	Null

With lathe as an example (logical axis 0, logical axis 2 and logical axis 5):

The bus passes through HI0-1061 NCUC communication submodule (furnished a 1011 input submodule, a 1021 output submodule and a 1041 analog input/output submodule) and X and Z axes successively, then returns to the system. The board card connection diagram is shown below:
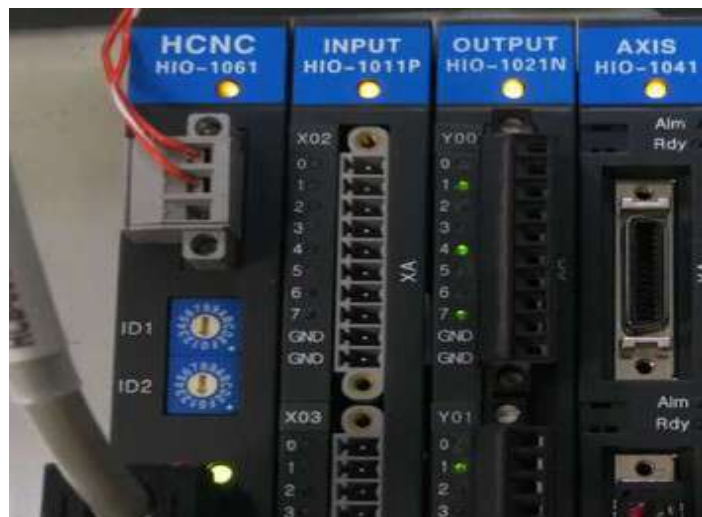
Configuration of devices identified by the system is as below,
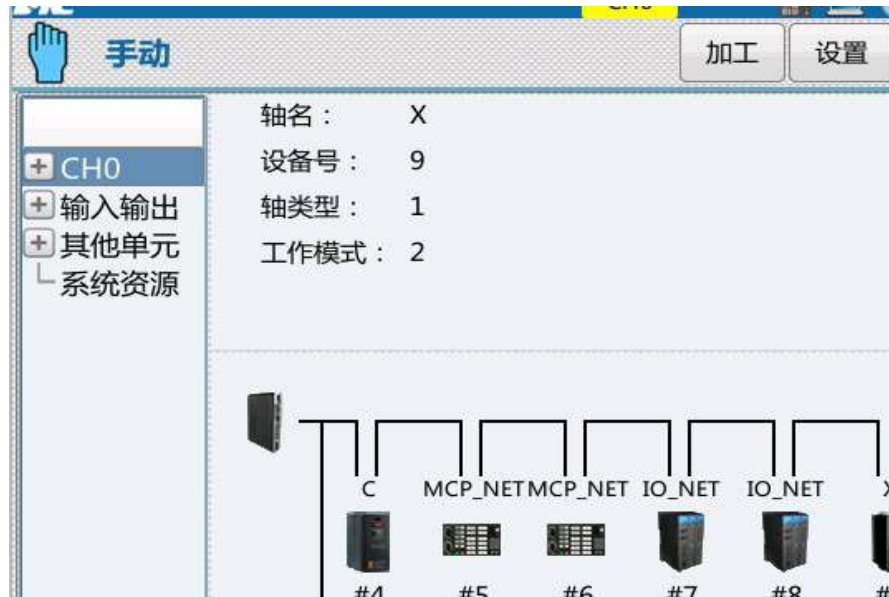
IO Watchdog Corresponds To X9 and Y9, As Shown Below:

2.3.1 Important Parameters Corresponding to Analog Spindle

Machine Tool User Parameters

010000	Maximum number of channels	1 (1 channel)
010001	Cutting type of channel 0	1 (lathe)
010009	Channel 0 selection marker	1 (channel 0 corresponds to 1)
010017	Display axis marker of channel 0	0x5 (logical axis 0 and logical axis 2)

| 010033 | Load current display customization of channel 0 | 0, 2 (logical axis 0 and logical axis 2) |

Channel Parameter
Channel 0

040001	X coordinate axis number	0 (logical axis 0)
040003	Z coordinate axis number	2 (logical axis 2)
040010	Axis number of spindle 0	5 (logical axis 5)
040023	Programming name of spindle 0	S (programming code)
040027	Display mode of spindle speed	0 or 1 (according to whether there is spindle encoder)
040028	Display axis number of spindle	5 (logical axis 5)

Coordinate Axis Parameter
Logical axis 5

| 105000 | Display of axis name | S |
| 105001 | Axis type | 10 (spindle) |

Device Interface Parameter
Device 4

504010	Working mode	3 (speed mode)
504011	Logical axis number	5 (logical axis 5)
504012	Inverted encoder feedback flag	0 or 1 (determined based on revolutions feedback display and actual speed direction)
504013	Spindle DA output type	0 or 1 (0 corresponds to 0~10V and 1 corresponds to +10 - -10V)
504014	Zero drift adjustment amount of spindle DA output (mv)	200 (recommended value)
504015	Pulse count of feedback position cycle	4096 (determined according to pulse count per spindle encoder revolution *4)
504016	Spindle encoder feedback device number	7 (support encoder, corresponding to device number of I0_NET)
504017	Spindle DA output device number	8 (corresponding to device number of I0_NET)
504018	Spindle encoder feedback interface number	0 or 1 (0 corresponds to A interface, 1 corresponds to B interface, B interface is recommended)
504019	Spindle DA output port number	1 (1 corresponds to A interface and 2 corresponds to B interface)

Device 7

507012	Initial group number of input point groups	10
507013	Number of input point groups	10
507014	Initial group number of output point	10
507015	Number of output point groups	10
507016	Encoder A type	0 or 1 or 3 (set according to actual type of spindle encoder)
507017	Pulse count per revolution of encoder A	4096 (determined based on pulse count per spindle encoder *4)
507018	Type of encoder B	0 or 1 or 3 (set according to actual type of spindle encoder)
507019	Pulse count per revolution of encoder B	4096 (determined based on pulse count per spindle encoder revolution *4)

Device 8

508012	Initial group number of input point	0
508013	Group number of input point	10
508014	Initial group number of output point	0
508015	Number of output point groups	10

2.4 Additional Multiple Analog Spindle

With lathe as an example, two analog spindles (logical axis 0, logical axis 2, logical axis 5 and logical axis 6):

The bus passes through HI0-1061 NCUC communication submodule (furnished a 1011 input submodule, a 1021 output submodule and a 1073 analog input/output submodule) and X and Z axes successively, then returns to the system. The board card connection diagram is shown below,

Configuration of devices identified by the system is as below,

IO watchdog corresponds to X19 and Y19, as shown below,

Set interface parameters through modification.

Device 6

506019	Number of additional analog spindles	1 (add an analog spindle)

2.4.1 Important Parameters Corresponding to Analog Spindle

Machine tool user parameter

010000	Maximum number of channels	1 (1 channel)
010001	Cutting type of channel 0	1 (lathe)
010009	Channel 0 selection marker	1 (channel 0 corresponds to 1)
010017	Display axis marker of channel 0	0x5 (logical axis 0 and logical axis 2)
010033	Load current display customization of channel 0	0, 2 (logical axis 0 and logical axis 2)

Channel Parameter
Channel 0

040001	X coordinate axis number	0 (logical axis 0)
040003	Z coordinate axis number	2 (logical axis 2)
040010	Axis number of spindle 0	5 (logical axis 5)
040011	Axis number of spindle 1	6 (logical axis 6)
040023	Programming name of spindle 0	S (programming code)
040024	Programming name of spindle 1	S1 (programming code)
040027	Display mode of spindle speed	3 (spindle encoder is not supported, command value is set)

| 040028 | Display of spindle axis number | 5, 6 (logical axis 5 and logical axis 6) |

Coordinate Axis Parameter

Logical axis 5

| 105000 | Display of axis name | S |
| 105001 | Axis type | 10 (spindle) |

Logical axis 6

| 106000 | Display of axis name | S1 |
| 106001 | Axis type | 10 (spindle) |

Device Interface Parameter

Device 4

504010	Working mode	3 (speed mode)
504011	Logical axis number	5 (logical axis 5)
504013	Spindle DA output type	0 or 1 (0 corresponds to 0 - 10V and 1 corresponds to +10 - -10V)
504014	Zero drift adjustment amount of spindle DA output (mv)	200 (recommended value)
504017	Spindle DA output device number	7 (corresponding to device number of I0_NET)
504019	Spindle DA output port number	1 (corresponding to offset of initial group number output by device of I0_NET, 1 corresponds to group 0 of XB and 2 corresponds to group 1 of XB, and so on)

Device 7

507012	Initial group number of input point	0
507013	Number of input point groups	10
507014	Initial group number of output point	0
507015	Number of output point groups	10

Device 8

508012	Initial group number of input point	10
508013	Number of input point groups	10
508014	Initial group number of output point	10
508015	Number of output point groups	10

Device 11

511010	Working mode	3 (speed mode)
511011	Logical axis number	6 (logical axis 6)
511013	Spindle DA output type	0 or 1 (0 corresponds to 0 - 10V and 1

		corresponds to +10 - -10V)
511014	Zero drift adjustment amount of spindle DA output (mv)	200 (recommended value)
511017	Spindle DA output device number	7 (corresponding to device number of I0_NET)
511019	Spindle DA output port number	2 (corresponding to offset of initial group number output by device of I0_NET, 1 corresponds to group 0 of XB and 2 corresponds to group 1 of XB, and so on)

After parameters are set, Configuration Of Devices Identified By The System Is As Below:
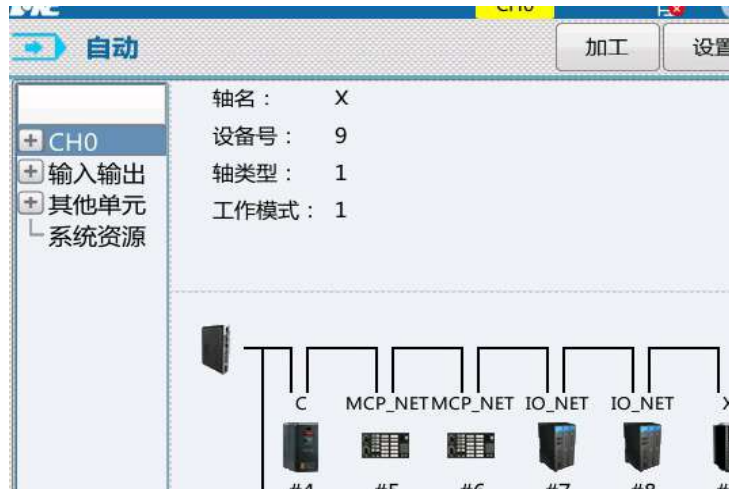
Note: Add an analog spindle and five conditions essential for the logical axis corresponding to the analog spindle in the ladder diagram.

3　Function of Feed Axis

3.1 Commissioning of Connection of HIO-1041 Board to Pulse Interface Drive

The new version of HIO-1041 board card supports 2-way analog voltage and 2-way incremental pulse output function. It can not only support analog PWM spindle configuration but also feed axis configuration of third-party drive with pulse interface.
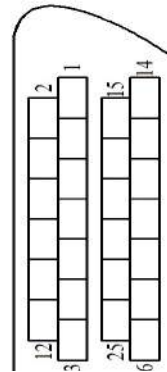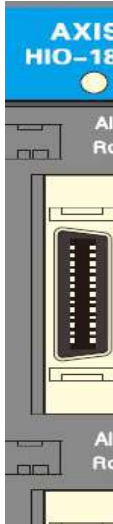
Plug pin

Interface pin description:

Pin	Definition	Pin number	Definition
Pin1	Vcmd1+ Analog output positive	Pin2	Vcmd1- Analog output negative
Pin3	PA+ Encoder phase A feedback signal positive	Pin4	PA- Encoder phase A feedback signal negative
Pin5	PB+ Encoder phase B feedback signal positive	Pin6	PB- Encoder phase A feedback signal negative
Pin7	PZ+ Encoder phase A feedback signal positive	Pin8	PZ- Encoder phase A feedback signal negative
Pin9	Power supply ground	Pin10	CP+ Command pulse output positive (A phase)
Pin11	CP- Command pulse output negative (A phase)	Pin12	DIR1+ Command direction output positive (B phase)
Pin13	DIR1- Command direction output negative (B phase)	Pin14	24V DC24V power supply
Pin15	Power supply ground	Pin16	Axis alarm bit (low level is effective)
Pin17-20	NC Null	Pin21	S_MS mode switching
Pin22	S_EN Enable	Pin23	NC Null
Pin24	Power supply ground	Pin25	5V　DC5V power supply
Pin26	NC Null		

Note: Pin9, 15 and 24 should be shorted to each other and connected to the shielding layer.

Pin16 is axis alarm flag bit which can be connected to external drive or frequency converter alarm signal. If there is no alarm signal, it can be connected to Pin15. When there is an alarm, it is high level (24V). When there

is no alarm, it is low level (0V).

3.1.1 Planning of Input/Output Words of 1000 Series Axis Control Unit

The board card has two axis control interfaces (XA corresponds to axis 0 and XB corresponds to axis 1). Every interface contains encoder feedback signal, spindle analog output signal and incremental pulse output signal. Two axes occupy 10 groups of input and 10 groups of output (occupy an I/O-NET device address).

X input:

Word	Address	Description
0	X0	Low byte of encoder feedback value of axis 0
	X1	High byte of encoder feedback value of axis 0, bit7 is the symbol bit
1	X2	Low byte of encoder Z pulse latch value of axis 0
	X3	High byte of encoder Z pulse latch value of axis 0, bit7 is the symbol bit
2	X4	Low byte of encoder feedback value of axis 1
	X5	High byte of encoder feedback value of axis 1, bit7 is the symbol bit
3	X6	Low byte of encoder Z pulse latch value of axis 1
	X7	High byte of encoder Z pulse latch value of axis 1, bit7 is the symbol bit
4	X8	Bit0: Alarm flag bit of axis 0 Bit1: Mode switching completion of axis 0 Bit6-Bit2: Reserved as 0 Bit7: Encoder z pulse latch completion of axis 0
	X9	Bit0: Alarm flag bit of axis 1 Bit1: Mode switching completion of axis 1 Bit6-Bit2: Reserved as 0 Bit7: Encoder Z pulse latch completion of axis 1

Y output:

Word	Address	Description
0	Y0	Low byte of analog command output value of axis 0
	Y1	High byte of analog command output value of axis 0
1	Y2	Low byte of pulse command output value of axis 0
	Y3	High byte of pulse command output value of axis 0 A frame period supports no more than 2000 pulses
2	Y4	Low byte of analog command output value of axis 1
	Y5	High byte of analog command output value of axis 1
3	Y6	Low byte of pulse command output value of axis 1
	Y7	High byte of pulse command output value of axis 1 A frame period supports no more than 2000 pulses
4	Y8	Bit0: Axis 0 enable Bit1: Axis 0 mode switching request 0: Analog output 1: Pulse output Bit2-Bit3: Axis pulse output mode setup <table><tr><th>Bit3</th><th>Bit2</th><th>Mode</th></tr><tr><td>0</td><td>0</td><td>Pulse + direction</td></tr><tr><td>0</td><td>1</td><td>Positive and negative pulse</td></tr><tr><td>1</td><td>0</td><td>Orthogonal pulse</td></tr></table>Bit4: Axis 0 Z pulse latch request 0: No request 1: Request for z pulse latch Bit7-Bit5: Reserved as 0

		Bit0: Axis 1 enable
		Bit1: Axis 1 mode switching request
		      0: Analog output
		      1: Pulse output
		Bit3-Bit2: Axis pulse output mode setup		

Y9		Bit3	Bit2	Mode
		0	0	Pulse + direction
		0	1	Positive and negative pulse
		1	0	Orthogonal pulse
		Bit4: Axis 1 Z pulse latch request Bit7-Bit5: Reserved		

Note:

1) X8.0 and X9.0 are axis alarm signals. If the state is 1, control pulse or analog corresponding to the system cannot be output normally.

2) Y8.1 and Y9.1 are port output mode switching status bits and should be set as 1 in PLC when pulse output is used.

3) Y8.2, Y8.3, Y9.2 and Y9.3 are axis pulse output mode setups and should be set or reset according to acceptance mode of drive.

4) Other output bits need not be set in PLC.

5) Whereas the board card address occupies an I/O-NET device address, there is no splicing address during field configuration. It is inserted into the first slot behind communication board card during installation. The first I/O-NET that appears in the devices is the board card device.

6) When stepping motor is used, it is just necessary to set to 2 "Encoder type" in I/O-NET device interface parameters corresponding to the board card.

✧ The above Y address is 1041 board card address, which is allocated as 0-9. The application is subject to field configuration.

Function Description:

1) Axis 0 and axis 1 can use analog output mode or pulse output mode respectively and both are independent.

2) Analog output, pulse output and encoder feedback signal must be differential mode.

3) Level of pulse output signal and encoder feedback signal is S422.

4) Axis alarm status signal is that low level is valid (24V-).

5) Please refer to the chart below for the comparison curve between the voltage value of the analog output and the digital value

Comparison curve
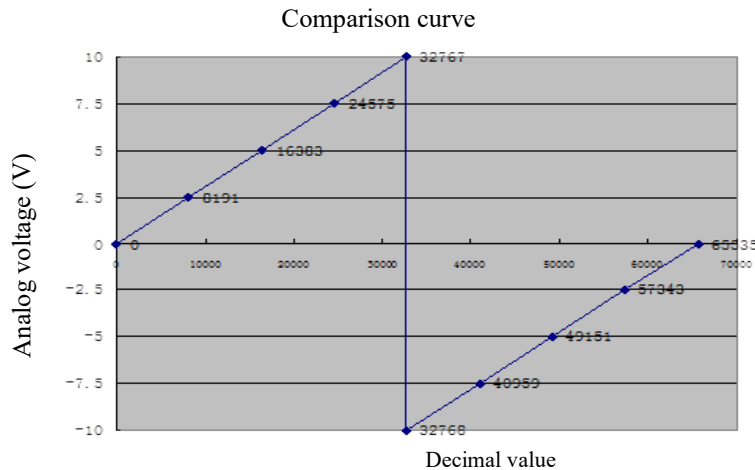
Hexadecimal	0000	1FFF	3FFF	5FFF	7FFF	8000	9FFF	BFFF	DFFF	FFFF

Decimal	0	8191	16383	24575	32767	32768	40959	49151	57343	65535
Analog (V)	0	2.5	5	7.5	10	-10	-7.5	-5	-2.5	0

3.1.2 System Software Parameter Setup

Drives supporting pulse board card are integrated into the software package of HCNC-V2.01 standard. When other versions use the board card, drive files corresponding to system version should be updated.

After drive is upgraded, "Device 0"-"Device 3" virtual axes (device type is 1002) will appear in system device interface parameters. When matching a third-party pulse drive, it is necessary to match the axis to device 0 - device 3. See the figure below,

3.1.3   Newly Added Parameters

Parameter	Description
Command pulse output type (50*013)	Not in use
Pulse output and feedback device number (50*017)	1041 board card device number (1041 board card should be inserted into the first slot other than communication board for ease of address assignment)
Encoder feedback port number (50*019)	The first interface is 0 and the second interface is 1. Set according to field connection
Pulse output port number (50*018)	The first interface is 0 and the second interface is 1. Set according to field connection

3.1.4   PLC Port Output Mode Switching Setup

Output pulse mode setting:
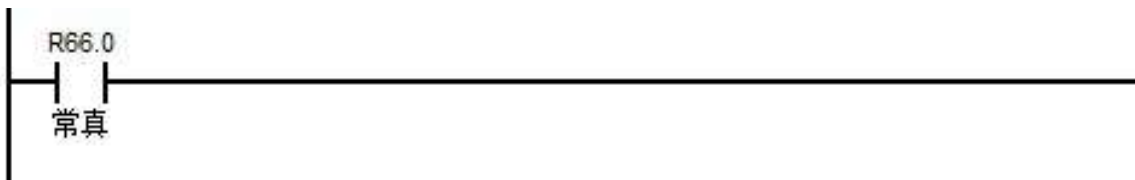
Output analog voltage mode setting:
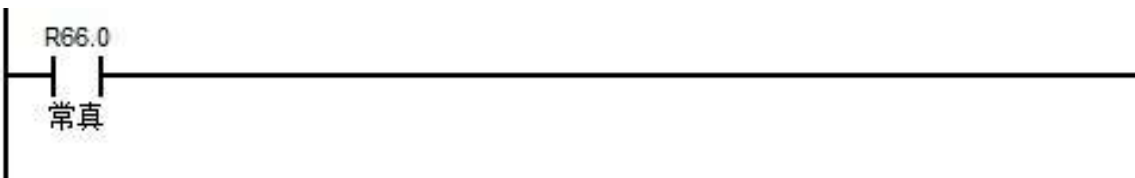
Note:

The above Y address is 1041 board card address, which is allocated as 0-9. The application is subject to field configuration.

3.1.5 Notes for PWM Spindle Configurations

1)   While configuring PWM spindle, output mode of port in PLC should be changed to analog voltage mode.
2)   Change Device 4 – Spindle DA output type (504013) in device interface parameters, as shown below:

Parameter	Value	Description
Spindle DA output type (504013)	0	Old version of 1041 board card 0-10V output
	1	Old version of 1041 board card -10- 10V output
	2	New version of 1041 board card 0-10V output
	3	New version of 1041 board card -10- 10V output

3.1.6 Drive Version Selection Setup

Register G2963 (decimal)	Drive description	Note
0	Devices 0-3 are devices reserved by the system	Default configuration
1	Devices 0-4 are virtual axes which can be assigned to system axes.	Configurable
2	Mix virtual axis and virtual MCP panel. Devices 0-3 are virtual axes which can be allocated to system axes and used during simulation operation. Device 4 is virtual MCP, and after it is enabled, keyboard can be used as MCP function and this function can be used if there is no MCP panel.	Configurable
4	Virtual pulse axis drive. Devices 0-3 are virtual axes and this function is used when pulse axis card is used.	Configurable

3.2 NCUC Bus Servo

NCUC industrial field bus technology is a technology with proprietary intellectual property rights owned by full-digital bus CNC devices of HNC-8 series products. It supports bus full-digital servo drive unit, absolute servo motor and bus remote I/O unit.

3.2.1 NCUC Bus Interface

1) Interface definition:

NCUC live wire interface
（IEEE-1394-6）

6:RXD-
4:TXD-
2:GND

5:RXD+
3:TXD+
1:+24V
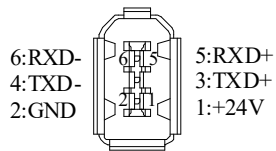
Signal name	Description
24V	DC 24V power
GND	
TXD+	Data transmission
TXD-	
RXD+	Data receiving
RXD-	

2) Connection diagram of NCUC bus cable

Shielding layer

24V 1
GND 2
TXD+ 3
TXD- 4
RXD+ 5
RXD- 6

1 24V
2 GND
5 RXD+
6 RXD-
3 TXD+
4 TXD-
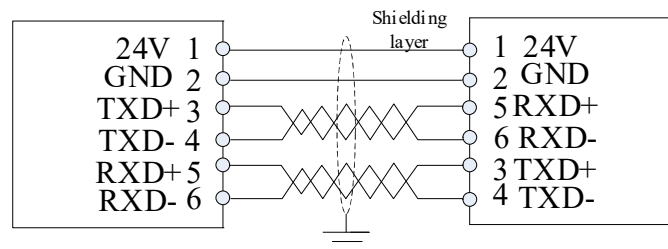
3.2.2 Connection Between CNC Controller and Bus Servo Drive Unit

CNC device is connected in series using NCUC bus, as shown below.
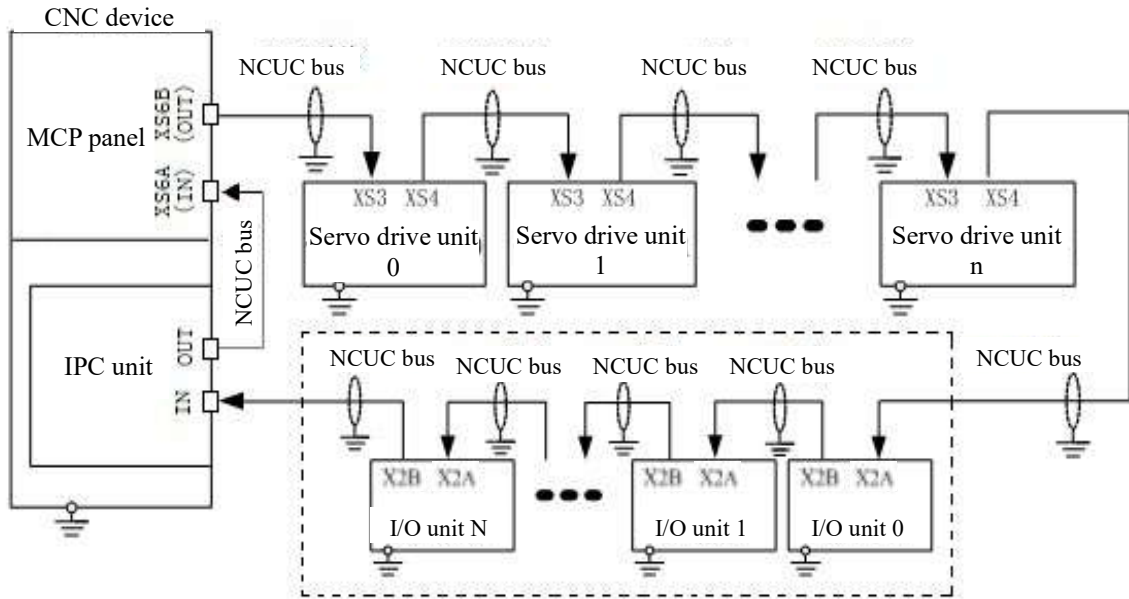
Fig. 2.5.1 Connection diagram of CNC device and bus servo drive unit

3.2.3 Parameter Setup

With the following configuration as an example (logical axis 0-X axis, logical axis 2-Z axis):
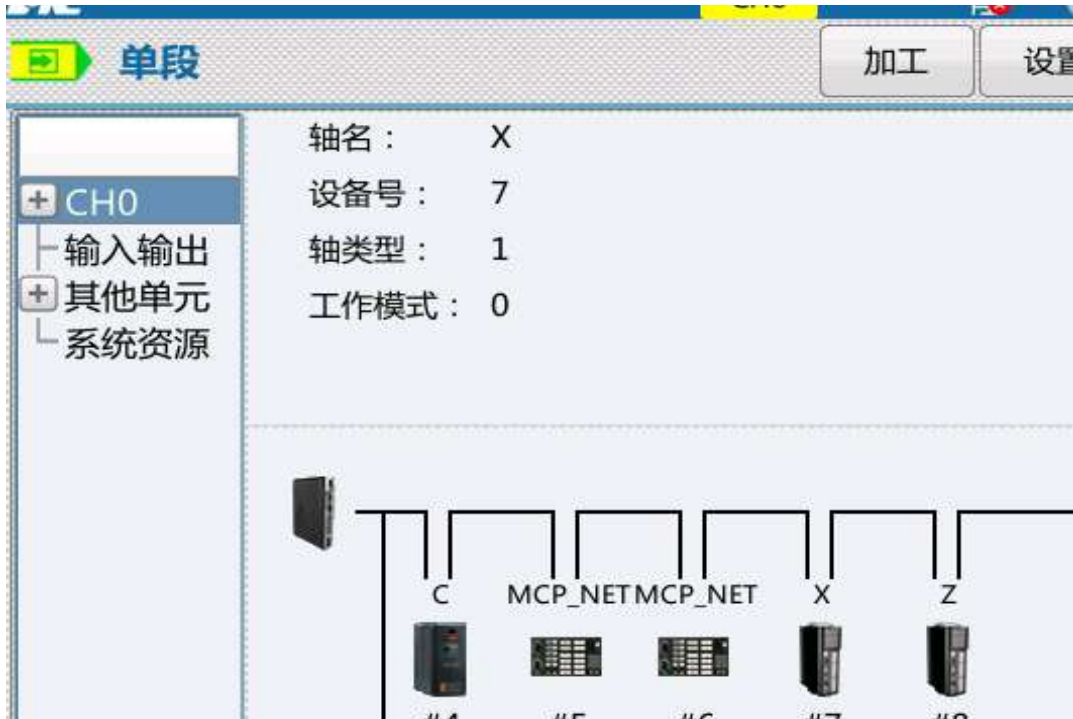
Important parameters are set as below:

1) Machine tool user parameters

   010017 display axis marker of channel 0   OX5 (logical axis 0 and logical axis 2)

2) Channel parameters

   040001 X coordinate axis number   0

   040003 Z coordinate axis number   2

040014 X coordinate programming name   X

040016 X coordinate programming name   Z

3) Coordinate axis parameters

With logical axis 0 (X axis) as an example:

100000 display of axis name	X
100001 axis type	1 (linear axis)
100004 Numerator of electronic gear ratio [displacement] (um)	10000 (screw pitch is set based on actual situation)
100005 Denominator of electronic gear ratio [pulse]	131072 (set based on actual situation)
100032 Low speed jog speed (mm/min)	2000 (set based on actual need)
100033 High speed jog speed (mm/min)	6000 (set based on actual need)
100034 Maximum rapid traverse speed (mm/min)	6000 (set according to actual need)
100035 Maximum machining speed (mm/min	5000 (set based on actual need)
100036 Acceleration and deceleration time constant in rapid traverse (ms)	8 (set based on actual need)
100037 Acceleration and deceleration jerk time constant in rapid traverse (ms)	8 (set based on actual need)
100038 Machining acceleration and deceleration time constant (ms)	8 (set based on actual need)
100039 Machining acceleration and deceleration jerk time constant (ms)	8 (set based on actual need)
100067 Pulse count per revolution of axis (pulse)	131072 (set based on actual situation)
100068 lead screw (mm)	10 (set based on actual situation)

4) Device interface parameters

With device 7 (X axis) as an example:

507010 working mode	1(working mode of feed axis is often set as 1)
507011 logical axis number	0
507012 Inverted encoder feedback marker	0 (set based on actual need)
507014 feedback position cycle mode	0 (linear feed axis is set as 0)
507015 feedback position cycle pulse count	131072 (100067 parameter of corresponding coordinate axis)
507016 encoder type	3 (set based on actual situation)

3.2.4 Register

1) Axis enable (G [Logical axis number *80+0].7]):

When axis enable register is valid, axis enable can be turned on.

2) Servo enable (G[Logical axis number*80+3].0):

When servo enable register is effective, servo drive can be turned on.

3) Axis feed override (G2564):

Assignment register can control machining (G01) movement speed of axis.

4) Rapid traverse override of axis (G2565):

Assignment register can control rapid traverse (G00) movement speed of axis.

5) Axis operation control (G2622-G2623):

Positive direction G[2622]. Logical axis number, negative direction G[2623]. Logical axis number,

When JOG mode, incremental mode and reference point return are needed for axis, the activation of corresponding register is set.

Axis enable

Before feed axis function is used, axis enable should be turned on.
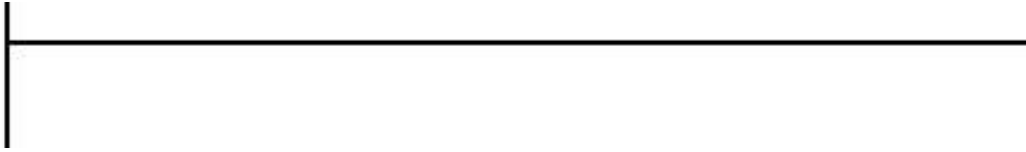
Servo Enable

Servo drive can be enabled only when servo enable is effective.
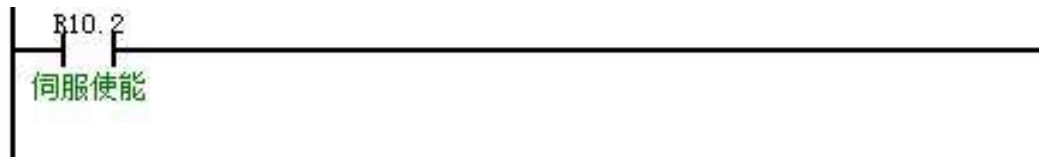
Feedrate Override

When the feed axis moves, feedrate override can control movement (G01) speed of axis. In the following example, feedrate override of feed axis is set as 100:
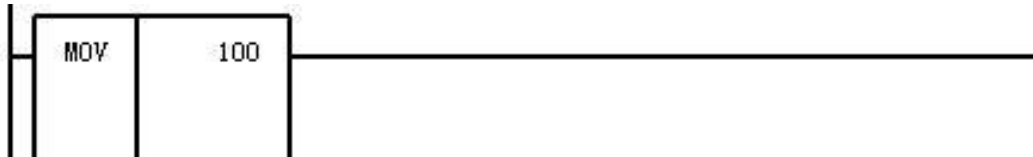
Rapid Traverse Override

When the feed axis moves, rapid traverse override can control movement (G00) speed of axis. In the following example, rapid traverse override of feed axis is set as 50:
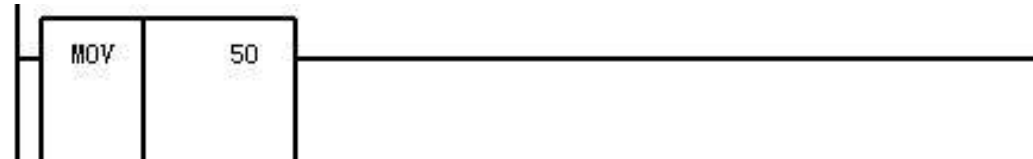
Servo Axis Operations

Press X483.1 and X axis moves in the positive direction;

Press X485.1 and X axis moves in the negative direction;

Press X483.1 and X485.1 simultaneously and X axis does not move.

Press X484.2 and Z axis moves in the positive direction;

Press X484.0 and Z axis moves in the negative direction;

Press X484.2 and X484.0 simultaneously and Z axis does not move.
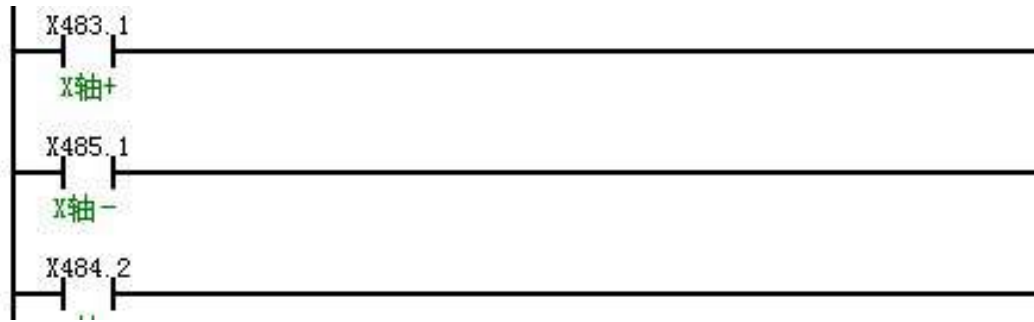
3.3 EtherCAT Configuration Tools and Axis Configuration

This chapter uses EtherCAT Config Tool 2.00.00.109 version as an example.

Servo drive and motor supporting EtherCAT, configuration manual for the EtherCAT configuration, XML file of the servo, PUTTY software (for ease of viewing backstage information), and a piece of ordinary network cable (to connect IPC to computer).

Device connection: EtherCAT network often consists of a master station (such as IPC) and a series of slave stations (such as servo controller and bus terminal). Every EtherCAT slave station has two standard Ethernet interfaces.

Backstage information: View drive information, manufacturer number and product number with dmesg command using PUTTY software.

With 808DM system connected to 150E drive as an example (EtherCat configuration file is not configured).

Power on the system and enter the system interface to view device configuration.
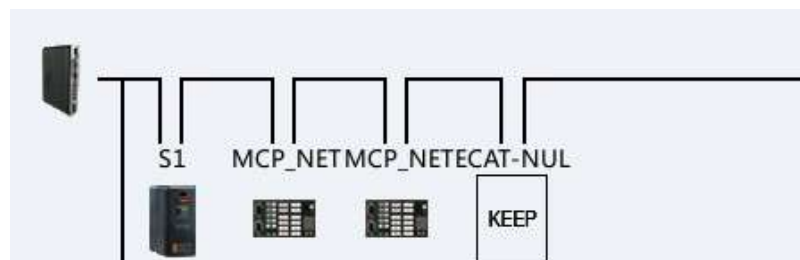
An EtherCat device is not recognized.

Check whether physical connection between the computer and the CNC device is normal as below:

Network cable is connected to computer and CNC device (for LAN, please ensure there are no IP conflicts);

Check IP setups of CNC controller, as shown below
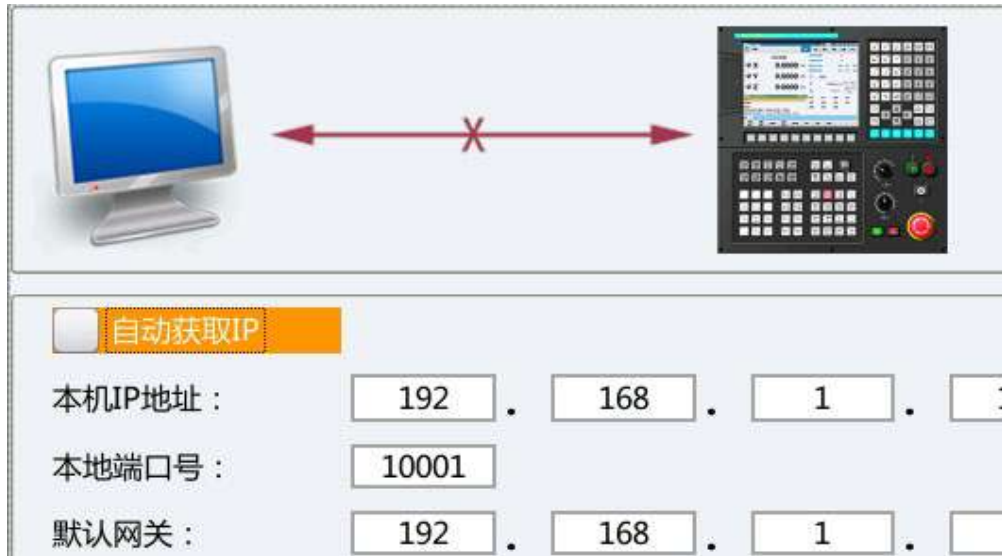
Note: A. The number larger than 10000 is recommended to be set for local port number;

B. After local IP address and local port number in Fig. 1 are modified, CNC controller should be restarted.

Check IP Setups of computer, As Shown Below:
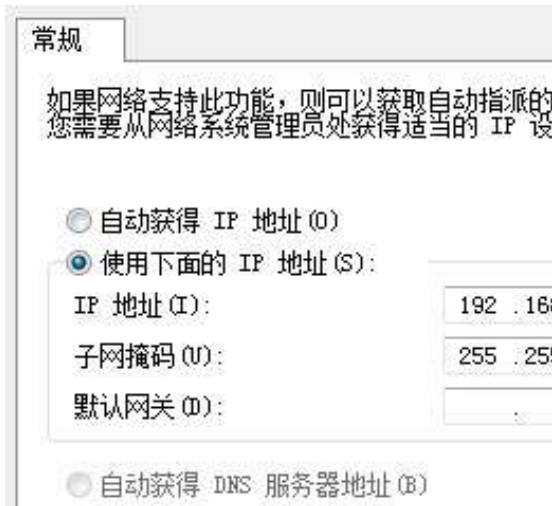
Please ensure computer IP and CNC device IP are in the same IP block (namely the first three numbers are the same and the last number is different).

Check Using ping Command

Click on computer 【Start】->【Run】, input "cmd" and press Enter, Input "ping 192.168.1.114 -t" and press Enter.
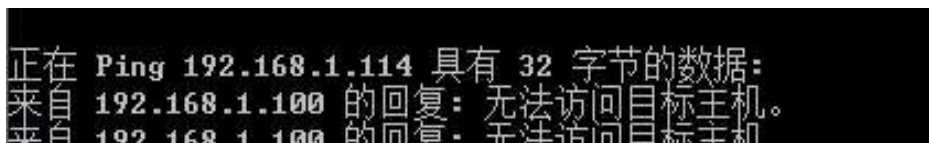
If the result shown above appears, communication between the computer and CNC device fails. Please replace the network cable or check whether the network interfaces of the computer and the CNC device are normal.

The above figure shows the normal communication between the computer and the CNC device.

Use of PUTTY software

Double click on "PuTTYPortable.exe" to start the software interface.
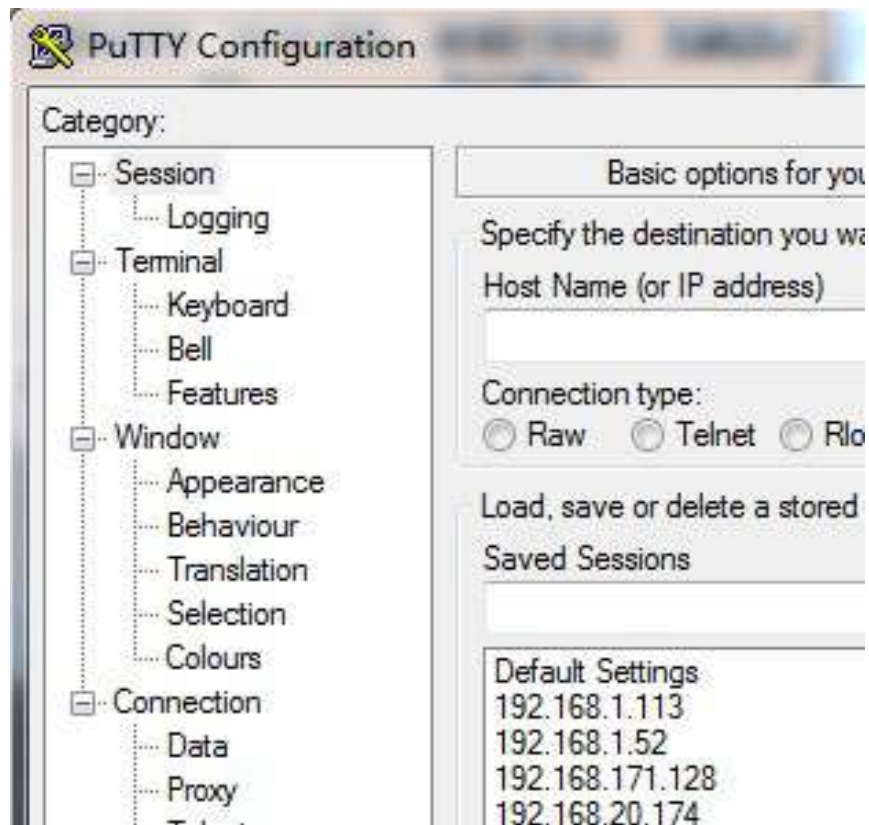
Fill in IP address of the system and IP address shown in the figure is "192.168.1.114".
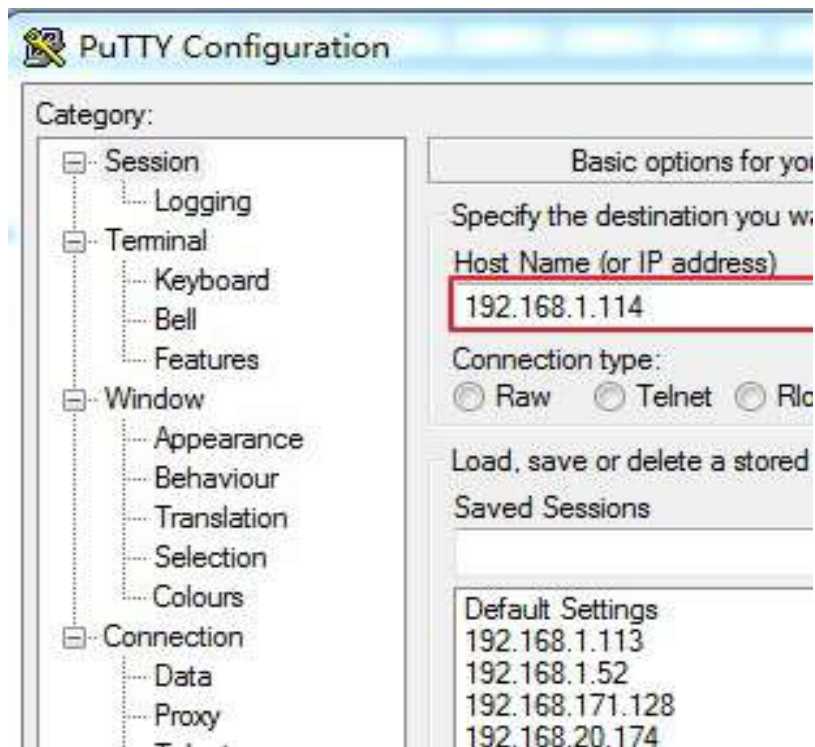
Select connection type, select "Telnet"
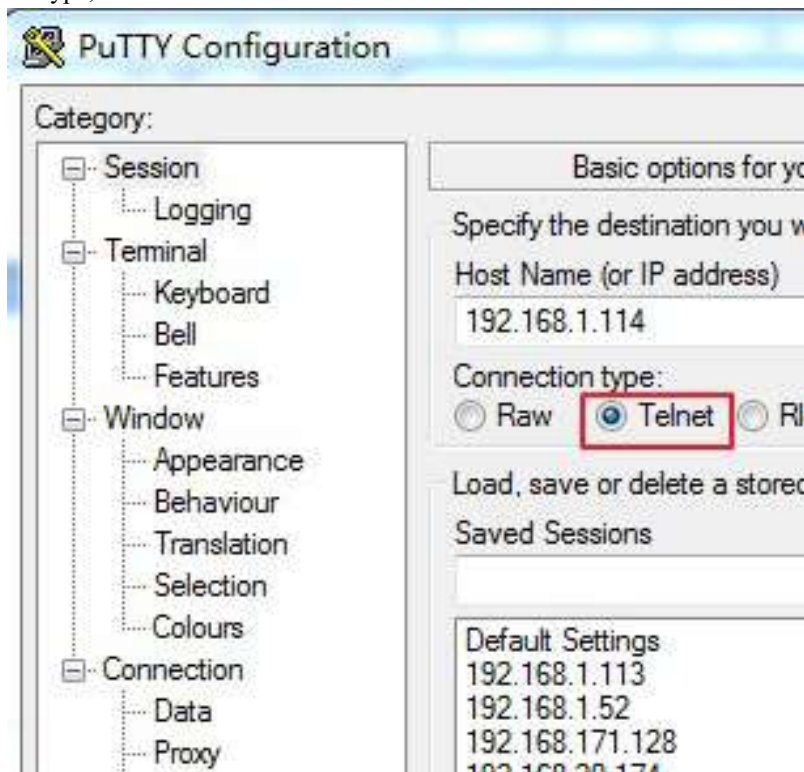
Click on Open to enter the interface.
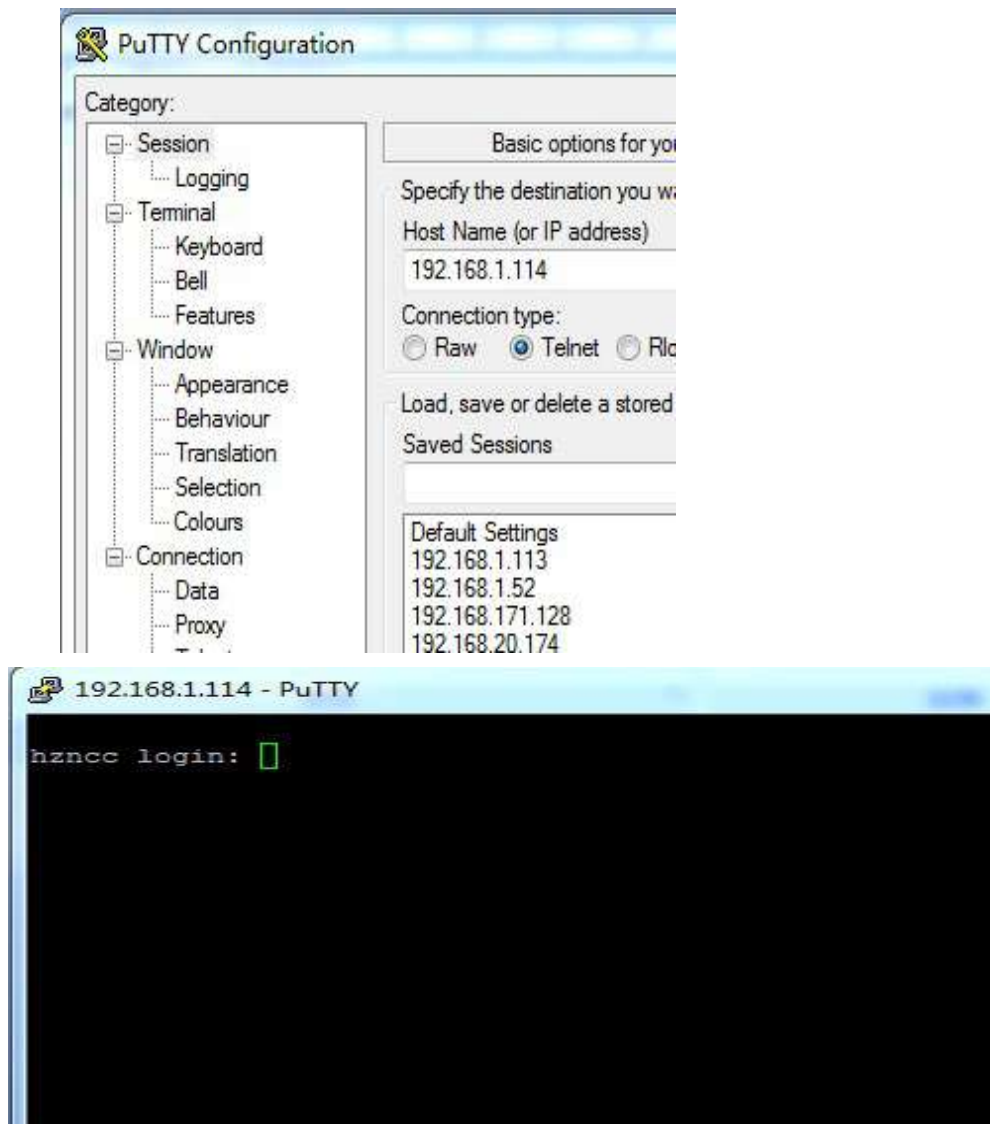
Input "root" and press enter.
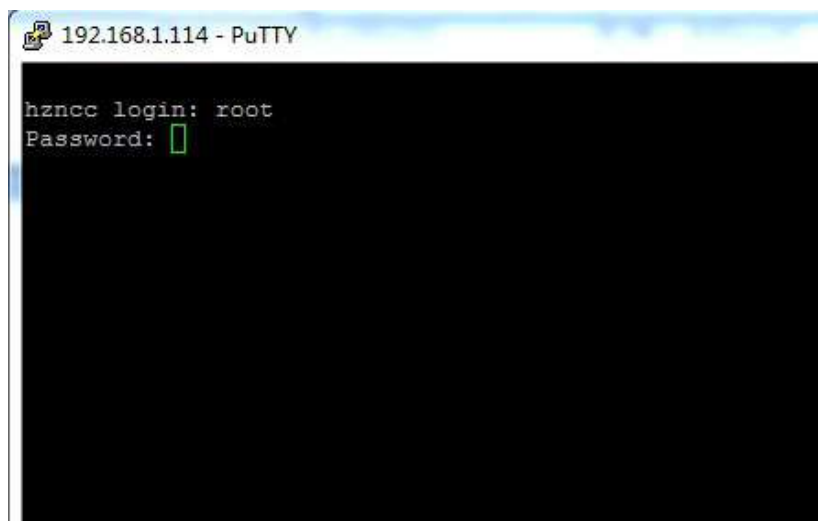
Input password "111111" and press Enter.
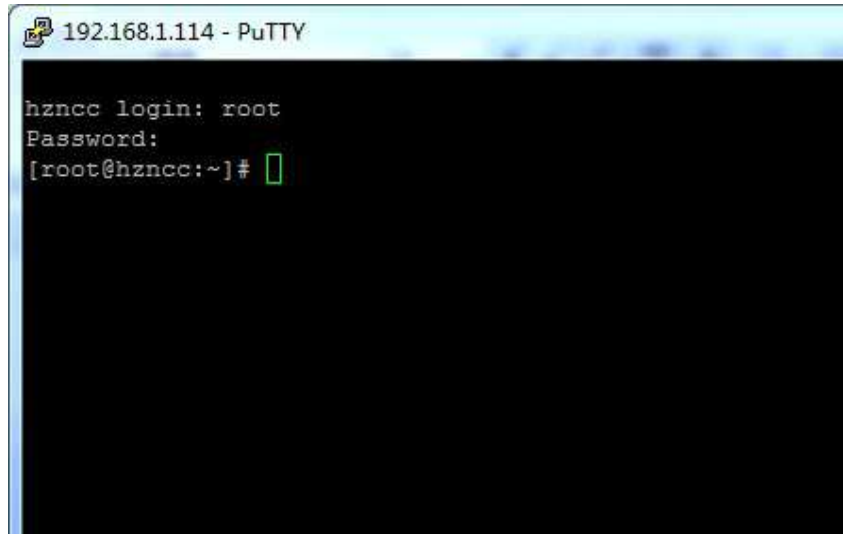
Input instruction "dmesg" and press Enter.

Vendor_id:0x2E1 corresponds to device manufacturer number

Product_code:0x0 corresponds to device product number

3.4 Use of EtherCAT Config Tool Tool

3.4.1 Add Devices

Open EtherCAT configuration software, right click on "Device"→ select "Add devices", as shown in the figure
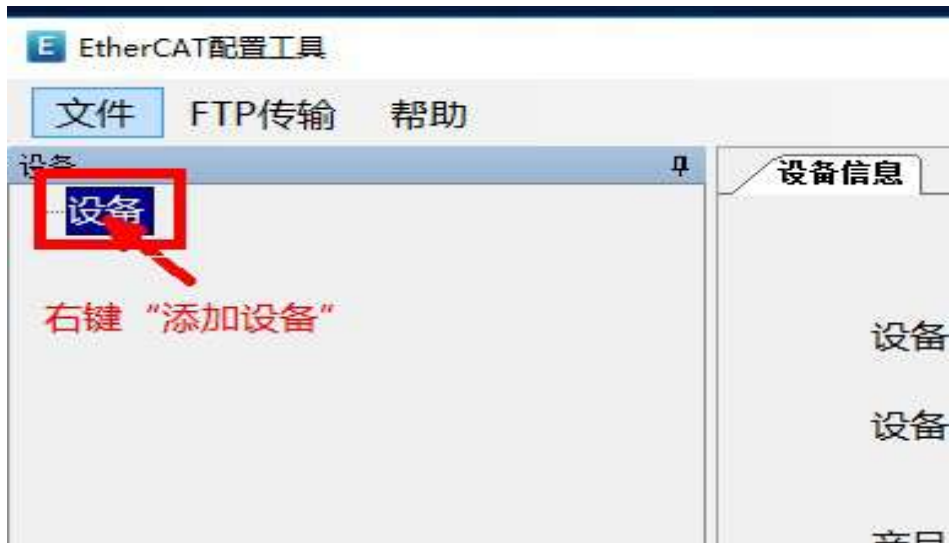
Select ".XML file" provided by the configured device, as shown in the figure
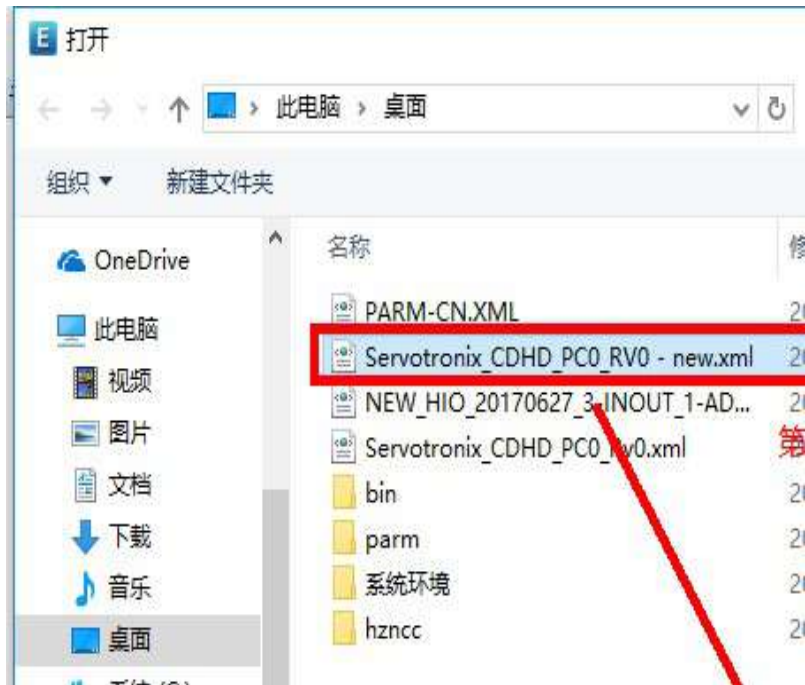
After xml file of drive is imported successfully, slave station device information of this product number is generated.
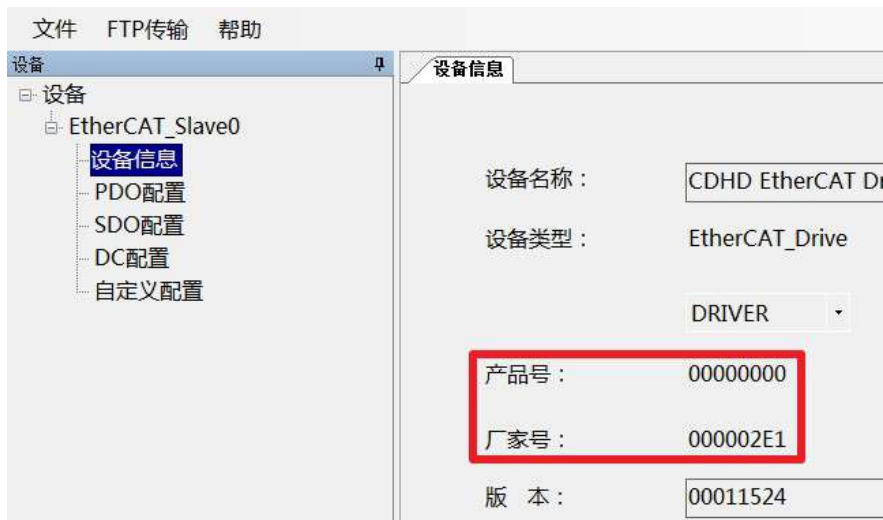
Check product number and manufacturer number.

Check whether product number and manufacturer number viewed through dmesg instruction backstage are consistent with product number and manufacturer number analyzed in XML.

Backstage:

Correspond to device manufacturer number

Correspond to device product number

XML：

If they are consistent, configuration file can be further made. Otherwise, contact and confirm with the drive manufacturer based on backstage.
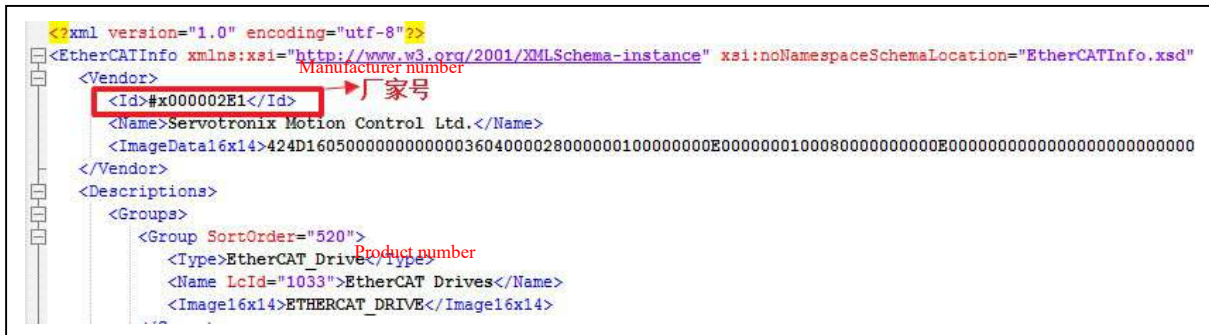
In some cases, corresponding product information in XML file can be modified manually after confirming with the manufacturer.

Modification method is as below:

Open the drive manufacturer's XML file, find out "ProductCode" and modify it based on backstage information. Details are as follows:

150E：

Inovance:

V&T:

Panasonic:

Note: Panasonic XML file contains configuration files of several models. The modified product numbers should correspond to actual drive models.

3.4.2 Device Type

4 device types are optional, NULL, DRIVER, IO and MCP.

Note: The selection should be based on the object, 150E drive should be selected as "DRIVER". If it is selected incorrectly, communication will fail.

3.4.3 PDO Configuration

In configuration tools, the following PDO objects must be configured for diagnosis of DRIVER device type:

60400010   //0X6040 Control word-output (all)

60600008   //0X6060 Control mode--output (all similar)

607a0020   //0X607A Target position--output (all)

60ff0020   //0X60ff Target speed--output (all)

60b80010   //0x60b8 touch probe Control word-output (specific to incremental motor and servo spindle)

60810020   //0x6081 Movement speed under orientation control mode-output (specific to servo spindle)

60410010   //0X6041 Status word-input (all)

60610008   //0X6061 Current control mode--input (all)

60640020   //0X6064 Current position value--input (all)

606c0020   //0X606c Current speed value-input (all)

60b90010   //0x60b9 touch probe status word--input (specific to incremental motor and servo spindle)

60ba0020   //0x60ba touch probe 1 Position latched on the rising edge--input (specific to incremental motor and servo spindle) load current   //Configured based on the manual provided by the manufacturer (all)

Modify directly in PDO configuration provided by the manufacturer

Compare configuration content and modify PDO file.

Comparison result: Except the deletable notes in the figure are deleted, 606c0020 and load current are needed.
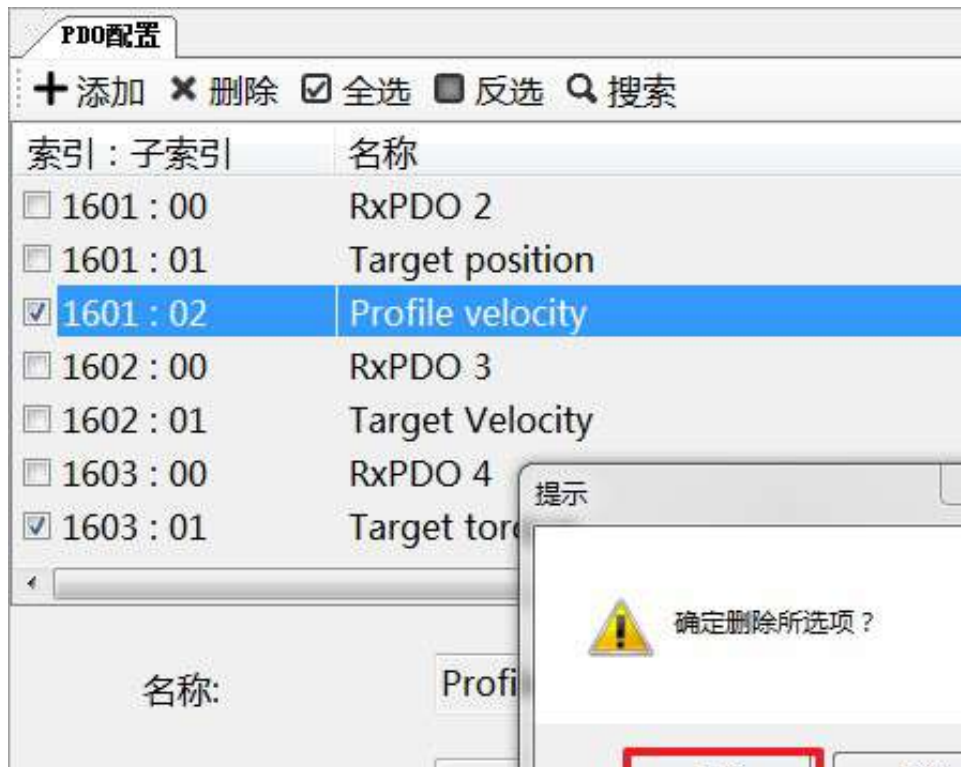
Delete Operation

Select items to be deleted in PDO configuration

Click on Delete

After a dialog box appears, click to complete delete operation.

Note: Only single mapping is supported currently. If the same object appears more than once in PDO, only an object should be retained and others should be deleted.

Add Operation

During the add operation, refer to the manual provided by the drive manufacturer.

Add 606C current speed value.

View Manual

606Ch – Velocity Actual Value

Object Description

Index	606C
Description	The actual velocity value derived e sensor or the position sensor.
Object Code	Variable
Data Type	Integer32
Category	Optional
VarCom	V

Entry Description

Data type: Integer32, 32-bit integer.
Range: -2147483648- 2147483647

Add PDO Object

Click on Add

A dialog box pops up

Add index:

Rxpdo (object output):1600-17FF.

Txpdo (object input):1A00-1BFF.

Generally, object output uses 1600 and object input uses 1A00.

606C is the object input, namely index is 1A00.

Sm attribute

The currently used Sm attributes are 2 and 3. 2 corresponds to Ropdo (object output, 1600-17FF) and 3 corresponds to Txpdo (object input, 1A00-1BFF). Please do not use others.

Name

Comments to the index can be made in Chinese or letters.

Value (hexadecimal)

Fill in corresponding PDO object.

Fill in: 606C0020.

Comment:

606C0020

Main index   Sub-index   Bit

20：32 bits
10：16 bits
8：8 bits

主索引   子索引   位

Data type	Range	Length
USINT(U8)	0-255	Single byte 8 bits
UINT(U16)	0-65535	Double byte 16 bits
UDINT(U32)	0-4294967295	4 bytes 32 bits
SINT(I8)	-127~128	Single byte 8 bits
INT(I16)	-32768~32767	Double byte 16 bits
DINT(I32)	-2147483648 ~ 2147483647	4 bytes 32 bits

If data type of 606C described in the drive manual is I32, value and type should be filled out as below:

Note: For data type, view the specification provided by the drive manufacturer. Data type must be set consistently.

The current is added in the same way

6078h – Current Actual Value

Object Description

Index	6078
Description	Indicates the actual value of the c the current in the motor.
Object Code	Variable
Data Type	Integer16
Category	Optional
VarCom	I (Motor Current)

Entry Description

添加PDO配置

索引(16进制)： 1A00   （RxPdo:1600-

Sm属性： 3

名称： Current Actual Value

值(16进制)： 60780010

Complete PDO Configuration

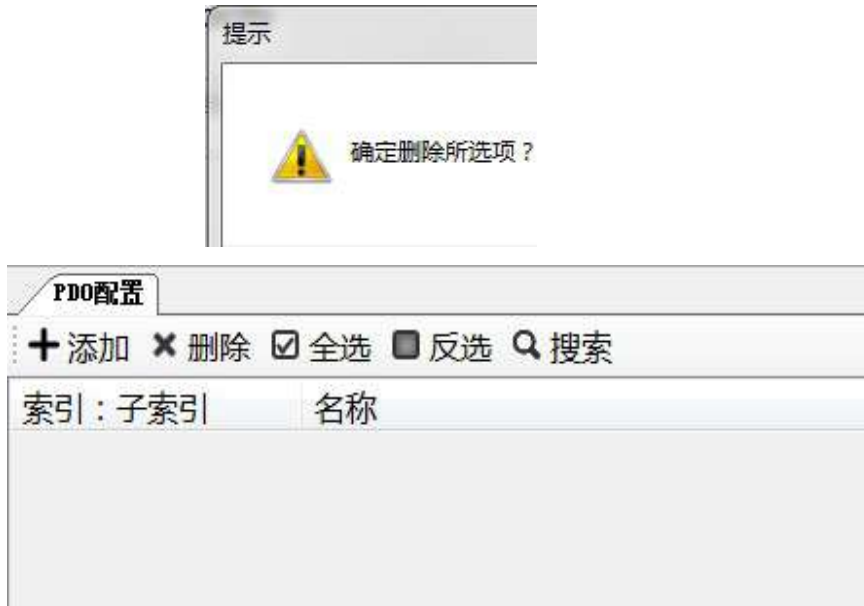| 1600 : 00 | RxPDO 1 | |
1600 : 01	ControlWord	U
1600 : 02	Modes of operation	S
1601 : 00	RxPDO 2	
1601 : 01	Target position	D
1602 : 00	RxPDO 3	
1602 : 01	Target Velocity	D
1A00 : 00	TxPDO 1	
1A00 : 01	StatusWord	U
1A00 : 02	Modes of operation display	S

Add PDO configuration manually.

Click on "Select all"

Click on "Delete"

A dialog box pops up and click on Confirm.

Perform the add operation. Before the add operation, the manual provided by the drive manufacturer must be viewed and the added object must be consistent with the manual.
Add indexes 1600 and 1A00

Add PDO object according to the manual provided by the driver manufacturer.

Test PDO configuration. To commission a new drive for the first time, drive parameters should be set when the system is not connected. Device database file is generated using EtherCat configuration tools.

Click on "File".

Click on "Save as device database".
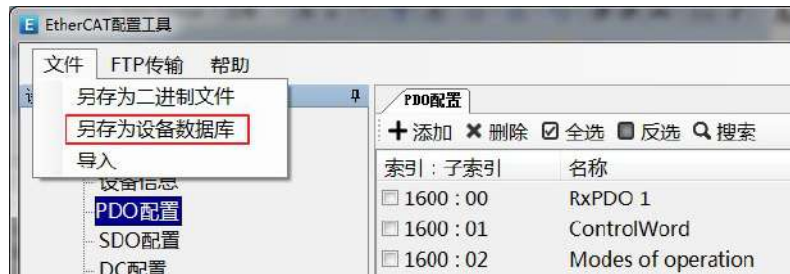
Select path, click on Confirm and device database file will be generated automatically.

The generated device database file should be named by product number and manufacturer number of device and suffixed with "edb".
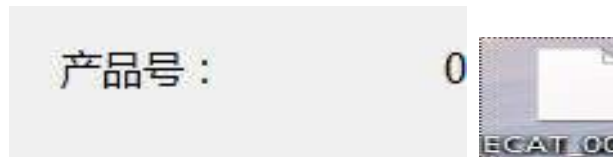
Copy edb file to USB flash disk.

Import edb file into the CNC system through data management.

Power off and restart the system.

Test PDO configuration. After PDO is configured, the system can control movement of the axis.

Power on again, check device configuration and view whether EtherCat device is identified. If so, perform commissioning as normal commissioning procedure. After commissioning, control movement of the axis with system and check whether the axis moves normally.
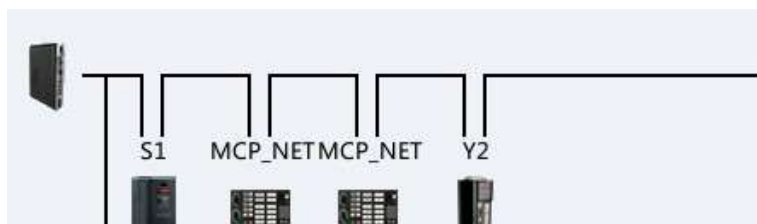
In case of exception, please check whether the above configuration is abnormal.

3.4.4 SDO Configuration

SDO configuration often includes parameter save, rated current of motor, alarm code and basic commissioning parameters of servo optimization.

3.4.4.1 Parameter Save

Add Data: Index, sub-index and type correspond to servo parameter manual. Name can be in Chinese for ease of search in the CNC system. The corresponding value and value range should be filled out according to the manual. If the setting is incorrect this time, users can modify it later.

3.4.4.2 Rated Current

Add data

3.4.4.3 Alarm

Add data

3.4.5 Common Servo Optimization Parameters

NL self-adaptive gain proportion factor

NL differential gain

NL proportional gain

Ml differential-integral gain

NL integral gain

NL Kff Spring gain

NL Kff Spring filter

NL Kff Spring filter

NL torque filter 2

NL torque filter 1

NL notch filter center

NL notch filter bandwidth

Acceleration

Deceleration

With "NL self-adaptive gain proportion factor" parameter as an example

Add Data

Input in other ways.

First, input the minimum value 0 and click on Confirm.

Select the added PDO data and click on "√" in front of the red box "Hexadecimal". If there is no "√", it means decimal input. Then, modify the minimum value to 0.001 and click on Confirm to complete modification.
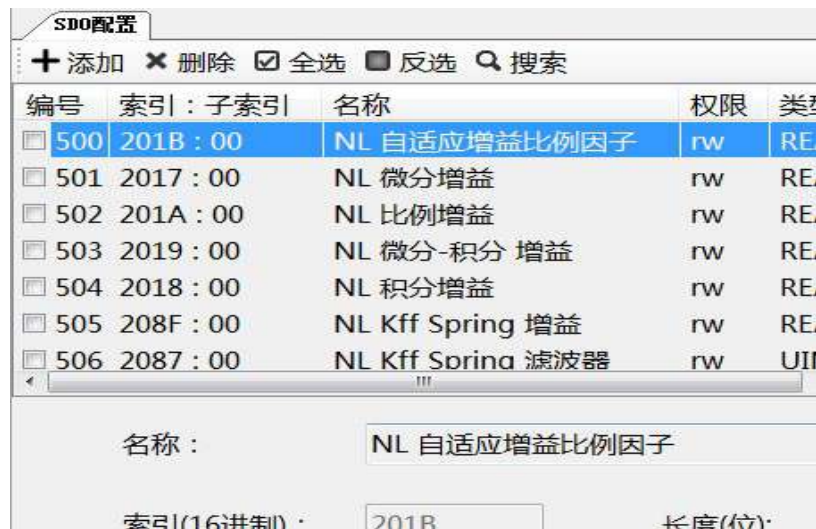
3.4.5.1 SOD Configuration Summary

3.4.6 DC Configuration

This option is EtherCat communication synchronized clock setup, just use the default value.

3.4.7 User-defined Configuration

1) Load current, rated current

The parameter setups have corresponding relations with system coordinate axis parameters 498 and 499.
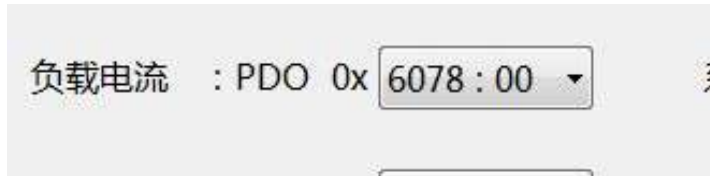
Load current corresponds to 6078:00 (actual current) in PDO configuration table and rated current corresponds to 6075:00 (rated current) in SDO configuration table.

The parameter can be set as 1 in parameter configuration tools and the specific value is set in coordinate axis parameters 498 and 499. e.g.: If rated current of motor is 2.8A, setups are as below:

System coordinate axis parameter 498, EtherCat rated current coefficient: 0.001; coordinate axis parameter is 499, EtherCat rated current: 2.8.

Load current coefficient of parameter configuration tools: 1; rated current coefficent: 1.

2) Save object word

Set according to parameter save requirements in servo parameter description.

Setups are as below:

3) Main code of alarm number, auxiliary code of alarm number

Uploading of servo alarm number through configuring main code and auxiliary code of alarm number. The system displays servo alarm contents in the CNC system interface through ETHCAT_ERR.XML alarm file and decoding.

Main code and auxiliary code of alarm number are stored in G[Axis number*80+57] and G[Axis number*80+56] registers of the system.

e.g.: If mask of alarm main code is set as 0xFFFF and mask of alarm auxiliary code is set as 0xFFFF, the corresponding relation after splicing is:

FFFFFFF

Main code mask, correspond to G [Axis number * 80+57]   **Auxiliary code mask, correspond to G [Axis number * 80+56]**

If main code of alarm is not set and mask of alarm auxiliary code is set as 0xFFFF, the corresponding relation after splicing is:

FFFF

Auxiliary code mask, correspond to G [Axis number* 80+56]

If main code of alarm is set as 0xFF00 and auxiliary code of alarm is set as 0xFF, the corresponding relation after splicing is:

FFFF

Main code mask   **Auxiliary code mask**
Correspond to G [Axis number * 80+56]

Format of ETHCAT_ERR.XML is:

"ID" corresponds to device manufacturer number and "ErrorCode" corresponds to main code and auxiliary code of alarm number.

150E alarm setup method

User-defined configuration:

View the servo manual and the drive will send error code to the system through 603F.
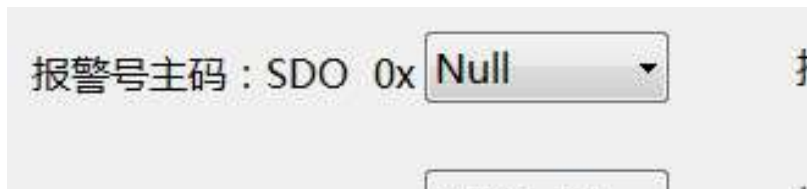
Write alarm text:

View the servo manual.

Table 12-5. Emergency Error Codes (Faults)

Fault Code	Fault Message/Description
2189h	Secondary Encoder 5V Over-Current
2214h	Over-Current

Write corresponding alarm text

Panasonic alarm setup method

User-defined configuration:

View the servo manual and the drive will send error code to the CNC system through 4DA0:02H.

Where, bit14-8: Main code of alarm.

bit7-0: Auxiliary code of alarm.

Index	Sub-Index	Name / Description	Units	Range

4DA0h		• Represent additional information of the designated alarm of 4308h (History number).
		  – When 4308h (History number)=0, it represents additional information of current alarm.
		  – When 4308h (History number)=1-3, it represents additional information of alarm before it occurs 1-3 times.
		
		    – 设定为 4308h (History number)=0 时，表示现在的报警的附带信
		• Represent Sub-Index number of 4DA0h (Alarm accessory information).
		    – 设定为 4308h (History number)=1~3 时，表示过去发生的报警
				—

	00h	• Represent ecobag of history number set using 4308h (History number). Number of entries – 表示 4DA0h (Alarm accessory information) 的 Sub-Index 的数		
	0	• Represent alarm code. bit31-15: Used by the manufacturer bit14-8: Main code of alarm bit7-0: Auxiliary code of alarm		—

报警号主码: SDO 0x 4DA0 : 02 ▼

报警号主码: SDO 0x Null ▼
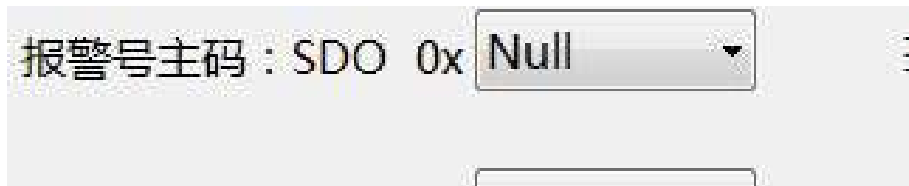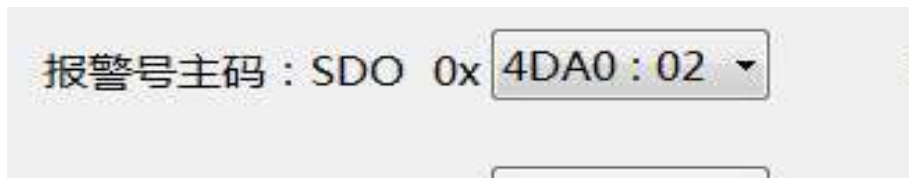
The above two methods can realize correct conversion of alarm code.

Write alarm text:

View the servo manual.

Alarm No. 号 Main 主 —Auxiliary 辅		Alarm name 报警名称	Reset	Immediate stop *1)	History *2)	Meaning of ERR Indicator 可	ESC register AL Status Code *1)	*2
		Voltage protection of control power shortage						
		Overvoltage protection						
11		Voltage protection of main power shortage (voltage shortage between PN) 控制电源不足电压保护				Yes	No	N
12		Voltage protection of main power shortage (AC interrupt detection)				Yes	No	Ye
		Overcurrent protection						
13		IPM error protection （PN 间电压不足）				Yes	Yes	N
		Overheat protection （AC 遮断检出）				Yes	Yes	N
		Encoder overheat error protection						
14		Overload protection				No	No	Ye
	1	Torque saturation error protection				No	No	Ye

Write corresponding alarm text. (Decimal system should be converted into hexadecimal system for alarm number)

```
<Vendor ID="0000066f"><!--松下Panasonic驱动器报警信息 -->
    <Info ErrorCode="0B00" Description="控制电源不足电压
    <Info ErrorCode="0C00" Description="过电压保护"/>
    <Info ErrorCode="0D00" Description="主电源不足电压保
    <Info ErrorCode="0D01" Description="主电源不足电压保
    <Info ErrorCode="0E00" Description="过电流保护"/>
    <Info ErrorCode="0E01" Description="IPM 异常保护"/>
    <Info ErrorCode="0F00" Description="过热保护"/>
    <Info ErrorCode="0F01" Description="编码器过热异常保
    <Info ErrorCode="1000" Description="过载保护"/>
    <Info ErrorCode="1001" Description="转矩饱和异常保护
    <Info ErrorCode="1200" Description="回生过负荷保护"/:
    <Info ErrorCode="1201" Description="回生 Tr 异常保护
    <Info ErrorCode="1500" Description="编码器通信断线异
```

Alarm setup method for Inovance

Display 显示	Fault name 故障名称	Fault type	Reset or not	Error code (603Fh)	能否复位	Auxiliary code (203Fh) 辅
Er.10	Parameter error 参数异常 / Programmable logic configuration fault		No / No	NO.1	否	0x63
Er.102	FPGA software version is too low 内部程序和其配置故障	低	No	NO.1	否	0x75
Er.10	Programmable logic interrupt fault	低	No	NO.1	否	0x75
Er.10	Internal program error / Parameter storage error 障 / 2000h/2001h parameter error / Product matching fault	障	No / No / No / No	NO.1	否	0x75

User-defined configuration: View the servo manual, main code of alarm is 603F and auxiliary code is 203F. Whereas main code and auxiliary code of alarm are converted into G register, G register is a 16-bit register and alarm auxiliary code is 32-bit register. Check the alarm auxiliary code. If there is only low 16-bit and there is no repeated bit, this method can be used for alarm.

报警号主码：SDO 0x 603F : 00 ▼   掩

Corresponding alarm text writing: (For alarm auxiliary code, only the low 16-bit is taken)

```
<Vendor ID="00100000"><!--汇川Inovance驱动器报警信息 --><
<!--故障类报警-->
<Info ErrorCode="63200101" Description="参数异常"/>
<Info ErrorCode="75000102" Description="可编程逻辑配置
<Info ErrorCode="75000103" Description="FPGA 软件版本过
<Info ErrorCode="75000104" Description="可编程逻辑中断
<Info ErrorCode="63200105" Description="内部程序异常"/>
<Info ErrorCode="55300108" Description="参数存储故障"/>
<Info ErrorCode="63200111" Description="2000h/2001h 组参
<Info ErrorCode="71220120" Description="产品匹配故障"/>
<Info ErrorCode="54410121" Description="伺服 ON 指令无效
<Info ErrorCode="71220122" Description="绝对位置模式产
<Info ErrorCode="63200130" Description="DI 功能重复分配
<Info ErrorCode="63200131" Description="DO 分配超限"/>
```

Other notes

Reset to clear servo alarm

Servo alarm reset and clear function (many alarms of EtherCAT servo can be cleared online without power-off and restart). Search output of R100.0 (servo alarm) in PLC and insert the following contents:
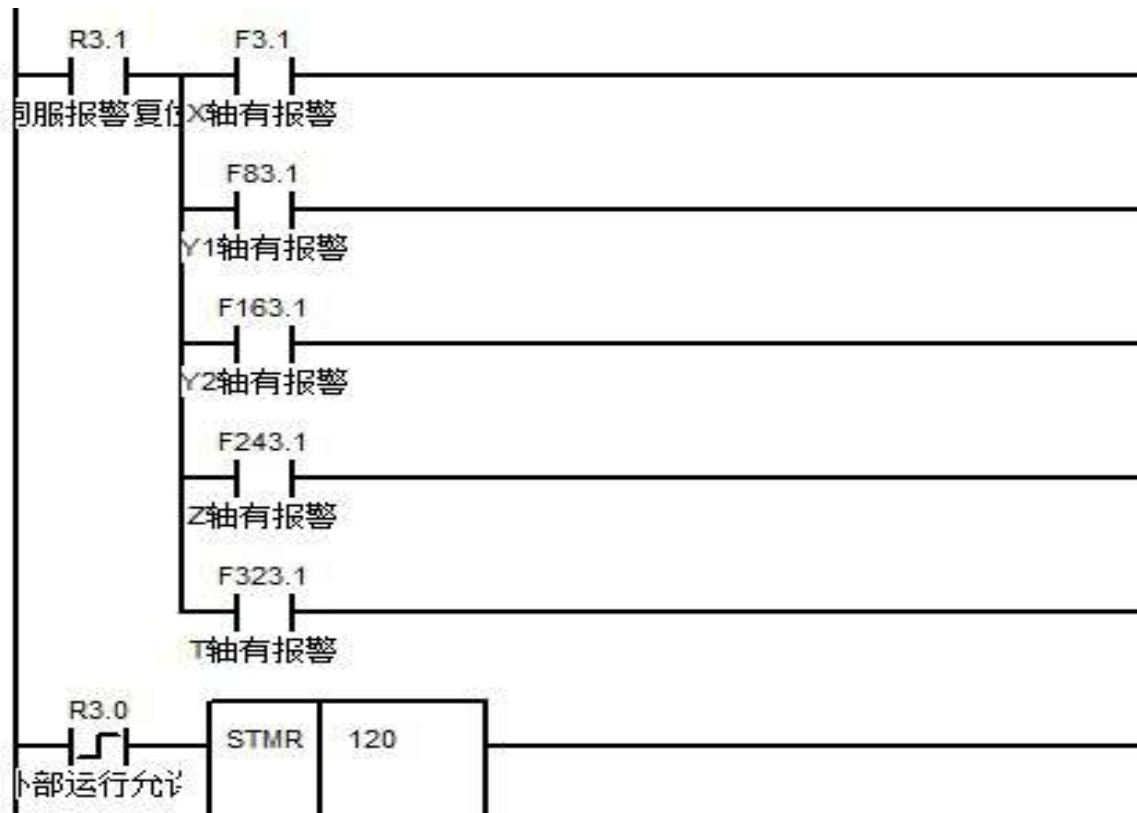
4) Unit of EtherCat spindle speed

The spindle speed of V&T spindle given is not consistent with actual speed probably because the rotation speed unit given by the system is not consistent with that of servo. We check corresponding device interface

parameters.

0: NCUC protocol rad/min;

1: EtherCat protocol pulse/s.

5) EtherCat Orientation Function

Parameter setting

For Orientation function, "Reserved【0】", "Reserved【1】" and "Reserved【2】" parameters in device interface parameters need to be used, which are defined as below:

Reserved 【0】: Orientation mode (1: Orientation along the positive direction, 2: Orientation along the negative direction, 3: Orientation along the spindle rotation direction, 4: Internal orientation mode of V&T spindle servo. If this mode is designated, orientation speed and orientation angle parameters will not work)

Reserved 【1】: Orientation speed

Reserved 【2】: Orientation angle (unit: Pulse)

PDO configuration of ETHCAT_CONFIG.DAT configuration file should include the following PDO objects:
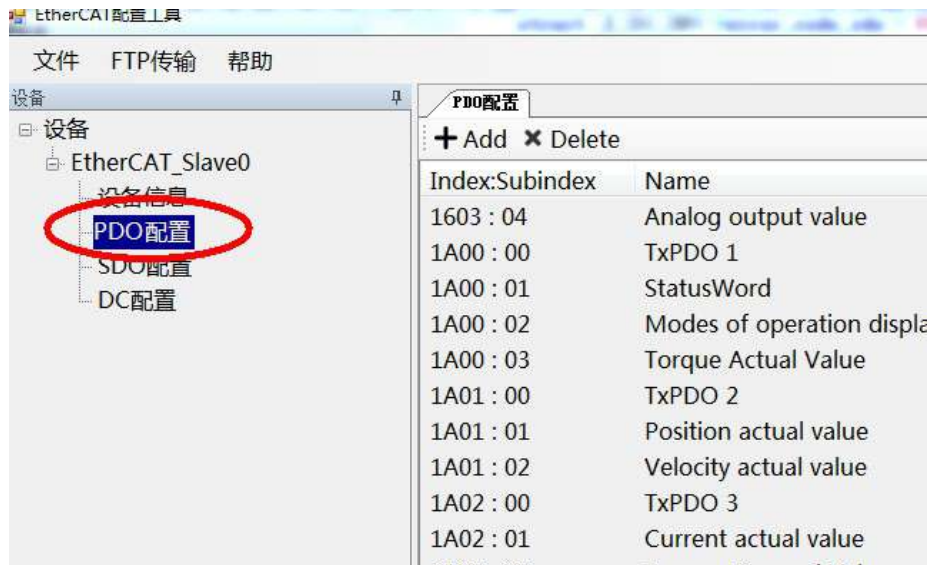
606c0020   // current speed value

60610008   // current control mode

60b90010   // touch probe status

60810020   // speed under orientation control mode

60400010   // control word

60600008   // control mode

60ff0020   // target speed

60640020   // current position

607a0020   // target position

60b80010   // touch probe function control word

60ba0020   //Touch Probe 1 Position Positive Edge

Troubleshooting

When orientation function cannot be used, view the following registers or signals for troubleshooting:

1.   [Axis number*80+2].12=1 of F register, the signal is Spindle Orientation Start.

2.   [Axis number*80+3].0=1 of F register, the signal is Servo Enable.

3.   [Axis number*80+2].8=1 of G register, the signal is Servo Ready.

4. Whether "Working mode" in "Device interface parameters" is 3.

5. [Axis number*80+3].8=1 of G register, the signal is orientation completion.

When conditions 1, 2, 3 and 4 are met, orientation starts. Condition 5 is met when orientation is completed

6) Reference Point Return of EtherCat Incremental Motor

Parameter setting

PDO configuration of ETHCAT_CONFIG.DAT configuration file should include the following PDO objects:

60b80010   // touch probe function control word

60b90010   // touch probe status

60ba0020   //Touch Probe 1 Position Positive Edge

Troubleshooting

When reference point return function cannot be used, view the following registers or signals for troubleshooting:

1.   [Axis number*80+2].0=1 of F register, the signal is Z Pulse Acquisition.

2.   [[Axis number*80+2].0=1 of G register, the signal is Z Pulse Capture.

When condition 1 is met, start to capture Z pulse. When Z pulse is captured, condition 2 is met.

7) Internal Reference Point Return Function of EtherCAT Drive

Parameter setting

"Reference point return mode" in "Coordinate axis parameters" should be set to 8

参数号	参数名	
100000	显示轴名	X
100001	轴类型	1
100004	电子齿轮比分子[位移](um)	1
100005	电子齿轮比分母[脉冲]	1
100006	正软极限坐标(mm)	20
100007	负软极限坐标(mm)	-2

F[Axis number*80+76].2 normally-open edited in PLC is suffixed with G[Axis number*80+3].8

PDO configuration of ETHCAT_CONFIG.DAT configuration file should include the following PDO objects:

    60600008   // control mode
    60610008   // current control mode
    60400010   // control word
    60640020   // current position
    60410010   // status word

Troubleshooting

When reference point return function is not available, view the following registers or signals for troubleshooting:

Condition 1: F[Axis number*80+3].0=1, servo enable signal.

Condition 2: F[Axis number*80+3].8=1, servo reference point return start signal.

Condition 3: F[Axis number*80+76].2 and G[Axis number*80+3].8, these two signals are switches to control internal reference point return function of drive.

Condition 4: G[Axis number*80+2].8=1, servo ready signal.

Condition 5: G[Axis number*80+3].9=1, servo reference point return completion signal.

When conditions 1, 2, 3 and 4 are met, internal reference point return starts. After reference point return is completed, condition 5 is met.

3.5 Gantry Synchronization Function

Gantry synchronization means that a mechanical axis is controlled by at least 2 servo motors, of which one is the master axis and others are slave axes. Generally gantry milling machine use this function.
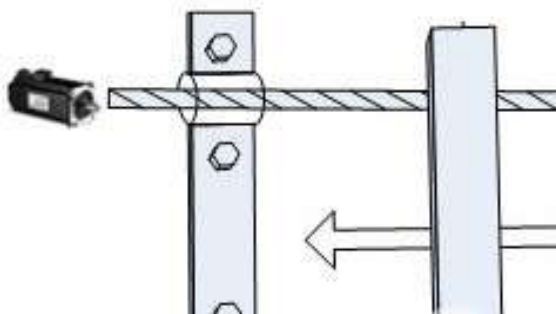
Due to different feedback modes of synchronous axis (including incremental encoder, absolute encoder, distance-coded grating ruler and absolute grating ruler), configuration of HNC-8 system is different.

Configuration of synchronous axis is described as below. With configuration in the following figure as an example, Y axis is a synchronous axis consisting of Y1 and Y2 axes, in which Y1 axis is a master axis and Y2 is a slave axis.
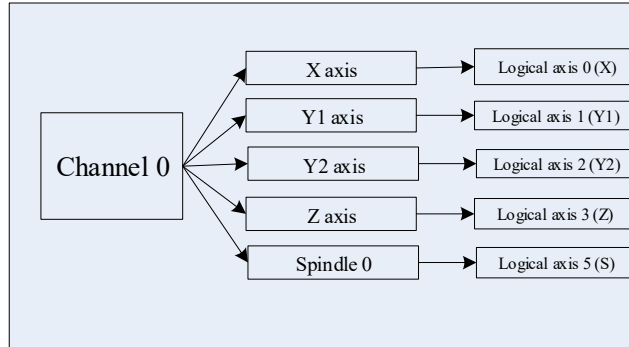
3.5.1 Commissioning of Synchronous Axis With Incremental Encoder

Machine Tool User Parameter Setting

Parameter 010050 total number of PMC and coupling slave stations is set as 1. Only Y2 axis is the slave axis, so the parameter should be set as 1.

Parameter 010051 PMC and coupling slave axis number [0] are is as 2. Logical axis 2 in coordinate axis parameters is the slave axis, so the parameter should be set as 2.

	参数号	参数名	
NC参数	010045	半径补偿=半径减/加磨损	0
机床用户参数	010046	半径补偿干涉控制	0
+ 通道参数	010047	半径补偿干涉检查段数	0
+ 坐标轴参数	010049	机床允许最大轴数	10
+ 误差补偿参数	010050	PMC及耦合从轴总数	1
+ 设备接口参数	010051	PMC及耦合从轴编号[0]	2
数据表参数			

Coordinate Axis Parameter Setting

Logical axis 1 (master axis), parameter 101000, display of axis name is set as Y1.

参数号	参数名

Logical axis 2 (slave axis), parameter 102000, display of axis name is set as Y2.

参数号	参数名

Logical axis 2 (slave axis), axis type, gear ratio, axis movement speed and axis acceleration/deceleration are set as per parameters of logical axis 1.

参数号	参数名	
102000	显示轴名	Y2
102001	轴类型	1

Note: When the movement direction of master axis is opposite to that of slave axis, positive and negative symbols of electronic gear ratio can be modified.

Logical axis 2 (slave axis), parameter 102100, axis motion control mode is set as 1.

102100	轴运动控制模式	1	复位

If it is set to 1, it represents synchronous axis.

Logical axis 2 (slave axis), parameter 102101, and guide axis 1 number is set to 1.

102101	导引|轴1编号	1
102102	导引|轴2编号	-1
102103	导引|轴3编号	-1

Master axis is Y1 axis and corresponding logical axis is 1, so guide axis 1 number is set as 1 corresponding to master axis number.

Logical axis 2 (slave axis), parameter 102062, automatic adjustment of flexible synchronization enable is set as 0.

102062	柔性同步自动调整使能	0

Automatic adjustment function of flexible synchronization should be disabled before initialization, so the value is set as 0.

Logical axis 2 (slave axis), relevant thresholds of synchronization setting.

102106	同步位置误差补偿阈值(mm)	0.0000
102107	同步位置误差报警阈值(mm)	0.0000
102108	同步速度误差报警阈值(mm/min)	0.0000

Upon initialization, the above thresholds for synchronization are set as 0 and detection is not turned on.

Save parameters, power off and restart the system.

PLC Setup

Add slave axis enable signal
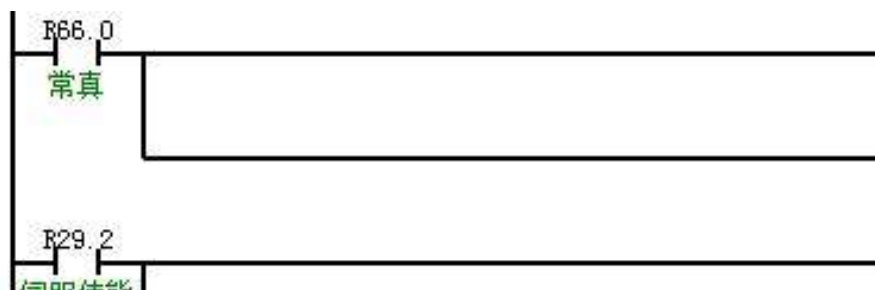
Add external reset sign G2960.3 at the time of reset.
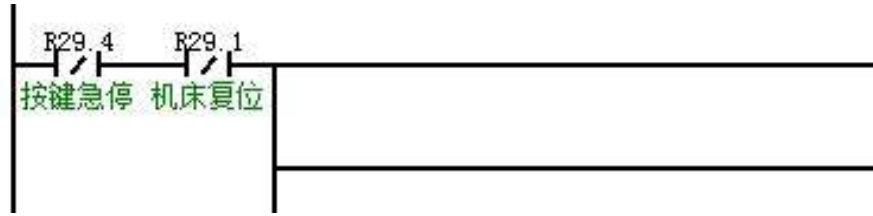
Note: When external reset sign G2960.3 is not added and the system interface displays "Alarm against large tracking error of slave axis", this message cannot be eliminated by reset but by adding this sign into PLC.

Add slave axis synchronization release to PLC.
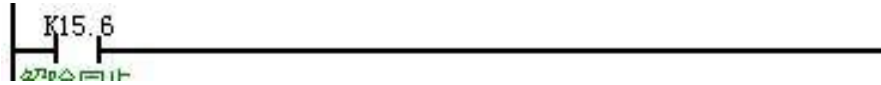
Adjustment with MPG

In some cases, the position of synchronous axis should be calibrated. Handwheel can be used for adjustment of synchronous axis after synchronization release.

The system releases emergency stop and switches to MPG mode. Meanwhile, PLC releases synchronization function of synchronous axis. Adjust the position of synchronous axis and then enable synchronization function in PLC.

The mode is switched to reference point return mode in channel, and then reference point return starts.

After reference point return succeeds, enable automatic adjustment of synchronous axis (set **Parm102062** "Automatic adjustment of flexible synchronization enable" as 1).

102062	柔性同步自动调整使能	1	复位

Set compensation threshold and alarm threshold of synchronous axis to complete configuration of synchronous axis.

102106	同步位置误差补偿阈值(mm)	0.0000
102107	同步位置误差报警阈值(mm)	0.0000
102108	同步速度误差报警阈值(mm/min)	0.0000

Alarm threshold of synchronous position error and alarm threshold of synchronous current error should be set based on actual situation.

Currently, alarm threshold of synchronous position error and alarm threshold of synchronous speed error are system standby parameters and need not be set.

Note:

● After automatic adjustment of flexible synchronization is enabled, if synchronous position error value is less than synchronous position error alarm threshold and emergency stop is released, the position of slave axis motor will be adjusted automatically in order that actual machine coordinates of master axis and slave axis are consistent. If synchronous position error value is greater than synchronous position error alarm threshold, the system will give an alarm "Synchronization error" and the position of slave axis motor will not be adjusted automatically either.

● When automatic adjustment of flexible synchronization is disabled, synchronous position error occurs and the system releases emergency stop, the position of synchronous axis will not be adjusted automatically.

After setting is completed, restart the system to complete configuration of synchronous axis.

3.5.2 Configuration of Synchronous Axis with Absolute Encoder (Absolute Grating Ruler)

Machine tool user parameter setting

Parameter 010050, total number of PMC and coupling slave stations is set as 1. Only Y2 axis is the slave axis, so the parameter should be set as 1.

Parameter 010051, PMC and coupling slave axis number [0] is set as 2. Logical axis 2 in coordinate axis parameters is the slave axis, so the parameter should be set as 2.

	参数号	参数名	
─ NC参数	010045	半径补偿=半径减/加磨损	0
─ 机床用户参数	010046	半径补偿干涉控制	0
⊞ 通道参数	010047	半径补偿干涉检查段数	0
⊞ 坐标轴参数	010049	机床允许最大轴数	10
⊞ 误差补偿参数	010050	PMC及耦合从轴总数	1
⊞ 设备接口参数	010051	PMC及耦合从轴编号[0]	2
─ 数据表参数			

Coordinate axis parameter setting

Logical axis 1 (master axis), parameter 101000, display of axis name is set as Y1.

参数号	参数名

Logical axis 2 (slave axis), parameter number 102000, display axis name is set as Y2.

参数号	参数名

Logical axis 2 (slave axis), axis type, gear ratio, axis movement speed and axis acceleration/deceleration are set as per parameters of logical axis 1.

参数号	参数名	
102000	显示轴名	Y2
102001	轴类型	1

Note: When the movement direction of master axis is opposite to that of slave axis, positive and negative symbols of electronic gear ratio can be modified.

Logical axis 2 (slave axis), parameter 102100, motion control mode of axis is set as 1.

102100	轴运动控制模式	1	复位

If it is set as 1, it represents synchronous axis.

Logical axis 2 (slave axis), parameter 102101, guide axis 1 number is set as 1.

102101	导引|轴1编号	1
102102	导引|轴2编号	-1
102103	导引|轴3编号	-1

Master axis is Y1 axis and corresponding logical axis is 1, so guide axis 1 number is set as 1 corresponding to master axis number.

Logical axis 2 (slave axis), parameter 102062, automatic adjustment of flexible synchronization enable is set as 0.

102062	柔性同步自动调整使能	0

Automatic adjustment of flexible synchronization should be disabled before initialization, so the value is set as 0.

Logical axis 2 (slave axis), relevant thresholds of synchronization setting.

102106	同步位置误差补偿阈值(mm)	0.0000
102107	同步位置误差报警阈值(mm)	0.0000
102108	同步速度误差报警阈值(mm/min)	0.0000

Upon initialization, the above synchronization thresholds are set as 0 and detection is disabled.

Save parameters, power off and restart the system.

**PLC Setup**

Add slave axis enable signal
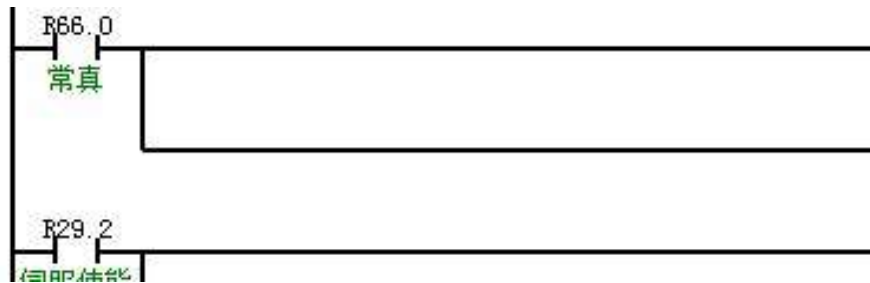
Add external reset marker G2960.3 upon at the time of reset.
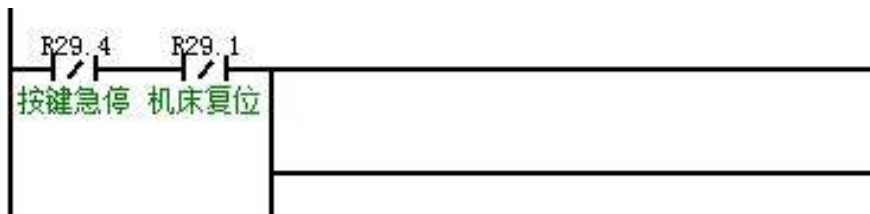
Note: When external reset marker G2960.3 is not added and the system interface displays "Alarm against large tracking error of slave axis", this message cannot be eliminated by reset but by adding this marker into PLC.

Add synchronization release of slave axis to PLC.
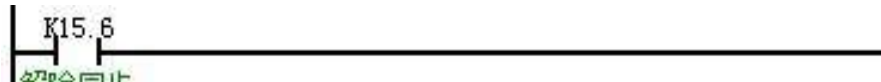
In some cases, the position of synchronous axis should be calibrated. Handwheel can be used for adjustment of synchronous axis after synchronization release.

Adjustment with MPG

The system releases emergency stop and switches to handwheel mode. Meanwhile, PLC releases synchronization function of synchronous axis. Adjust the position of synchronous axis and then set the coordinate zero.

Coordinate Zero Setting

Set the zero point of master axis and slave axis by "Auto offset" button.

Click on "Auto offset" button and the dialog box "Please input axis number:" will appear. Input 1 and press Enter. The system dialog box displays "Encoder feedback offset of axis 1 is set as XX". Continue to click on "Auto offset" and the dialog box "Please input axis number:" will appear. Input 2 and press Enter. The system dialog box displays "Encoder feedback offset of axis 2 is set as XX". Click on Save. After save succeeds, press and release emergency stop once.

Move the axis to the position to be set as the zero point and reset the coordinate zero

Steps for setting the coordinate zero are consistent with those in 3.5.

Enable Automatic Adjustment of Synchronous Axis

102062	柔性同步自动调整使能	1	复位

Set compensation threshold and alarm threshold of synchronous axis to complete configuration of synchronous axis.

102106	同步位置误差补偿阈值(mm)	0.0000
102107	同步位置误差报警阈值(mm)	0.0000
102108	同步速度误差报警阈值(mm/min)	0.0000

Alarm threshold of synchronous position error and alarm threshold of synchronous current error should be set based on actual situation.

Currently, alarm threshold of synchronous position error and alarm threshold of synchronous speed error are system standby parameters and need not be set.

Note:

● After automatic adjustment of flexible synchronization is enabled, if synchronous position error value is less than synchronous position alarm error threshold and emergency stop is released, the position of slave axis motor will be adjusted automatically in order that actual machine coordinates of drive axis and slave axis are consistent. If synchronous position error value is greater than synchronous position error alarm threshold, the system will give an alarm "Synchronization out of tolerance" and the position of slave axis motor will not be adjusted automatically either.

● When automatic adjustment of flexible synchronization is not enabled, synchronous position error occurs and the system releases emergency stop, the position of synchronous axis will not be adjusted automatically.

After setting is completed, restart the system to complete configuration of synchronous axis.

3.5.3 Configuration of Synchronous Axis with Distance-coded Grating Ruler

Machine Tool User Parameter Setting

Parameter 010050, total number of PMC and coupling slave stations is set as 1. Only Y2 axis is the slave axis, so the parameter should be set as 1.

Parameter 010051, PMC and coupling slave axis number [0] is set as 2. Logical axis 2 in coordinate axis parameters is the slave axis, so the parameter should be set as 2.

Coordinate Axis Parameter Setting

Logical axis 1 (master axis), parameter number 101000, display of axis name is set as Y1.

Logical axis 2 (slave axis), parameter number 102000, display of axis name is set as Y2.

Logical axis 2 (slave axis), axis type, gear ratio, axis movement speed and axis acceleration/deceleration are set as per parameters of logical axis 1.

参数号	参数名	
102000	显示轴名	Y2
102001	轴类型	1

Note: When the movement direction of master axis is opposite to that of slave axis, positive and negative symbols of electronic gear ratio can be modified.

Logical axis 2 (slave axis), parameter 102100, motion control mode of axis is set as 1.

102100	轴运动控制模式	1	复位

If it is set as 1, it represents synchronous axis.

Logical axis 2 (slave axis), parameter number 102101, guide axis 1 number is set as 1.

102101	导引轴1编号	1
102102	导引轴2编号	-1
102103	导引轴3编号	-1

Master axis is Y1 axis and corresponding logical axis is 1, so guide axis 1 number is set as 1 corresponding to master axis number.

Logical axis 2 (slave axis), parameter number 102062, automatic adjustment enable of flexible synchronization enable is set as 0.

102062	柔性同步自动调整使能	0

Automatic adjustment of flexible synchronization should be disabled before initialization, so the value is set as 0.

Logical axis 2 (slave axis), relevant thresholds of synchronization setting

102106	同步位置误差补偿阈值(mm)	0.0000
102107	同步位置误差报警阈值(mm)	0.0000
102108	同步速度误差报警阈值(mm/min)	0.0000

Upon initialization, the above synchronization thresholds are set as 0 and detection is not enabled.

Save parameters, power off and restart the system.

PLC Setup

Add slave axis enable signal
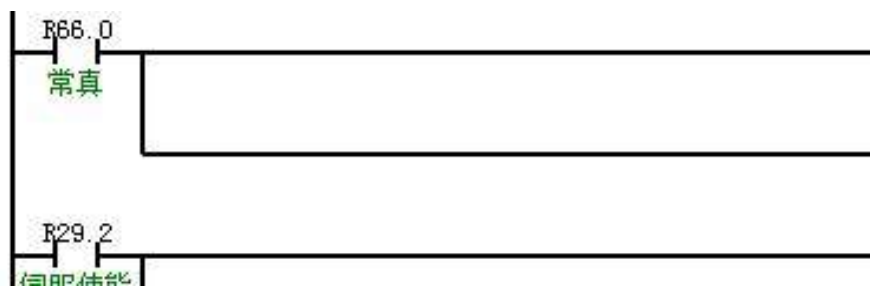
Add external reset marjer G2960.3 upon reset.
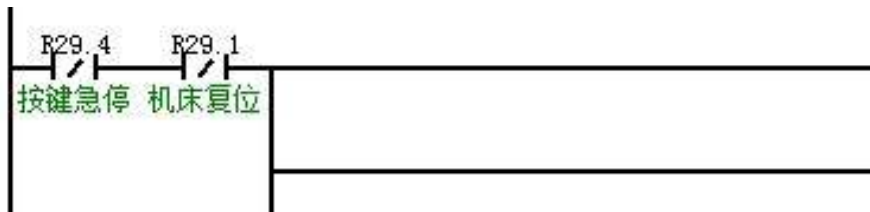
Note: When external reset sign G2960.3 is not added and the system interface displays "Alarm against large tracking error of slave axis", this message cannot be eliminated by reset but by adding this marker into PLC.

Add synchronization release of slave axis to PLC.
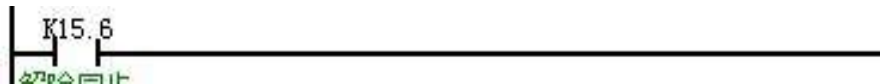
In some cases, the position of synchronous axis should be calibrated. Handwheel can be used for adjustment of synchronous axis after synchronization release.

Adjustment with MPG

The system releases emergency stop and switches to handwheel mode. Meanwhile, PLC releases synchronization function of synchronous axis. Adjust the position of synchronous axis and then start reference point return.

Set the coordinate zero

After reference point return succeeds, move the synchronous axis to the position to be set as the zero point. Set actual machine position into coordinate value of reference point.

Enable Automatic Adjustment of Synchronous Axis

✧ Set compensation threshold and alarm threshold of synchronous axis to complete configuration of synchronous axis.

Alarm threshold of synchronous position error and alarm threshold of synchronous current error should be set based on actual situation.

Currently, alarm threshold of synchronous position error and alarm threshold of synchronous speed error are system standby parameters and need not be set.

Note:

● After automatic adjustment of flexible synchronization is enabled, if synchronous position error value is less than synchronous position error alarm threshold and emergency stop is released, the position of slave axis motor will be adjusted automatically in order that actual machine coordinates of drive axis and slave axis are consistent. If synchronous position error value is greater than synchronous position error alarm threshold, the system will display "Synchronization out of tolerance" and the position of slave axis motor will not be adjusted automatically either.

● When automatic adjustment of flexible synchronization is not enabled, synchronous position error occurs and the system releases emergency stop, the position of synchronous axis will not be adjusted automatically.

After setup is completed, restart the system to complete configuration of synchronous axis.

3.6 4th Rotary Table Commissioning

This chapter contains the commissioning of the indexing axis function of the fourth axis, commissioning of disabling the fourth axis rotary table lock and commissioning of enabling the fourth axis rotary table lock.

In this chapter for the 4th axis, the A axis is assigned to logical axis 3.

3.6.1 Commissioning of Indexing Axis Function of the Fourth Axis

1) Relevant coordinate axis parameters

● 103077, indexing/orientation axis type:

0: Disable indexing/orientation axis.

1: When the movement command of the axis appears in the executing G code, the system unlocks it automatically by parameter "indexing/orientation axis unlock M code" until there is no movement command of the axis in the next line of program. The system automatically locks by parameter "Indexing/orientation axis

lock M code".

3: When the movement command of the axis appears in the executing G code, the system unlocks it automatically by parameter "Indexing/orientation axis unlock M code" and the program ends. The system locks automatically by parameter "Indexing/orientation axis lock M code".

- 103078, initial value of indexing/orientation axis:
  The parameter is used to set the initial degree of indexing for indexing/orientation axis.
- 103079, spacing between indexing/orientation axes:
  After indexing axis function is enabled, the command position of indexing movement must be an integral multiple of this value.
- 103080, indexing/orientation axis lock M code
  It corresponds to the fourth axis lock M code in PLC, generally it is 40.
- 103081, indexing/orientation axis unlock M code
  It corresponds to the fourth axis unlock M code in PLC, generally it is 41.

2) Commissioning

Coordinate axis parameters:

103077, indexing/orientation axis type: set to 1 or 3

103078, initial value of indexing/orientation axis: set based on actual situation

103079, spacing between indexing/orientation axes: set based on actual situation of indexing axis

103080, indexing/orientation axis lock M code: 40 by default, correspond to M40 in PLC

103081, indexing/orientation axis unlock M code: 41 by default, correspond to M41 in PLC

103060, positioning tolerance (mm): The value can be set as default value 0.1, but it cannot be set as 361 as per the original version. If 361 is set, A axis will not move. The default setup of the system is that the axis does not move if the movement command of the axis is smaller than the value of positioning tolerance.

Parameters relating to PLC:

K6.0, 4th axis is valid, 0: Invalid; 1: Valid

K6.1, whether indexing axis control is used for 4th axis, 0: Not use; 1: Use

K6.4, Whether there is clamping/releasing in the position signal for 4th axis, 0: Yes; 1: No

K6.5, Clamping/releasing signal for 4th axis is exchanged

K6.6, Whether shield alarm of clamping/releasing signal in the position exception, 0: No; 1: Yes

(K6.6 is mainly used for overhaul when the indexing axis in position signal is abnormal)

P170, initial value of indexing/orientation axis, the set coordinate value is consistent with coordinate axis parameter 103078, but unit is um.

P171, spacing between indexing/orientation axes, the set coordinate value is consistent with coordinate axis parameter 103079, but unit is um.

P172, indexing/orientation axis movement in-position range setting, unit is um. If it is set as 200, it means that the in-position detection range is -200um<rotary table position<200um.

(determination of axis position is added to PLC, the main purpose is to protect the indexing axis position before it is allowed to lock)

Relevant PLC

- When 4th axis clamping/releasing not in position signal is added to the initialization part, the clamping/release state before power failure is recovered.

- Add determination of call indexing axis position in PLC1;

Function: determine whether indexing axis moves to the right position.

Four axes are valid **Whether four axes**
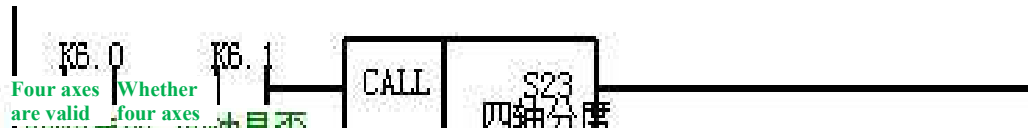
Correspond to subprogram:

1	SP	S23 四轴分度轴位置判断
2	ASSEM	F272 轴3机床
3		2
4		D7 轴3位置
5	DIV	D7 轴3位置
6		100
7		D7 轴3位置
8	SUB	D7 轴3位置
9		P170
10		D8 转台位置
11	DIV	D8 转台位置
12		P171
13		D9 转台位置
14	MUL	D9 转台位置
15		P171
16		D13 转台位置
17	SUB	D8 转台位置
18		D13 转台位置
19		D14 转台位置

- Calling indexing axis unlock and lock control is added to PLC2.

Corresponding subprogram:

四轴转台断使能，自动松开夹紧

23 R340.0 / A回零条 — R3.0 / 外部运行

24 R56.1 / A松开M41   R56.0 / A锁紧M40

25 R342.7 / 分度轴功   R220.2 / 手动灯   R202.3 / +A   R203.3 / -A   R340.7 / A手动标

26 R203.3 / -A   R202.3 / +A   R340.7

Delay if there is an in-position signal

27 F2564.5 / 手摇状态   G2621.0 / 手摇0轴   G2621.1 / 手摇0轴   R342.7 / 分度轴功

28 R10.0 / 记录A轴   R340.3 / 四轴恢复

29 R70.0 / A轴松开_

有到位信号，

30 T5.3 / A轴松开   T5.2 / A轴锁紧   K6.5 / 四轴松紧   K6.4 / 四轴无松   TMRB   36

Delay if there is no in-position signal

31 T5.3 / A轴松开   T5.2 / A轴锁紧   K6.5 / 四轴松紧   0

32 500

33 R342.0 / A轴松开   K6.4 / 四轴无松   TMRB   37

34 0

无到位信号，延时

35 1500

36 R70.2 / A轴松开

37 R70.3 / A轴松开

38 T5.2 / A轴锁紧   T5.3 / A轴松开   K6.5 / 四轴松紧   K6.4 / 四轴无松   TMRB   39

39 T5.2 / A轴锁紧   T5.3 / A轴松开   K6.5 / 四轴松紧   0

40 500

41 R342.1 / A轴锁紧   K6.4 / 四轴无松   TMRB   41

42 0

43 1500

44 R70.4 / A轴锁紧

45 R70.5 / A轴锁紧

46 F2564.5 / 手摇状态

It must be reserved. When indexing axis type is 3, M40 follows M41 closely in the next line, and enable signal is turned off suddenly and then on, indexing axis command does not execute.

● Add alarm output and axis lock control to PLC2

In non-auto mode, when the signal A axis release in position is lost, A axis is locked. In auto mode, only the lock code is executed for A axis, and there is no A axis release in position signal, A axis is locked.
When A axis is not in release state, but instable signal of A axis release in position will result in A axis running position error of A axis.

● Add reset and clear alarm to S3 alarm clear subprogram
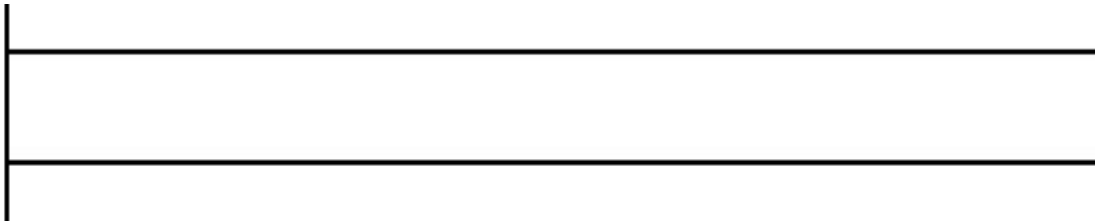
● Axis ready is not modified, A axis alarm is added to servo alarm .
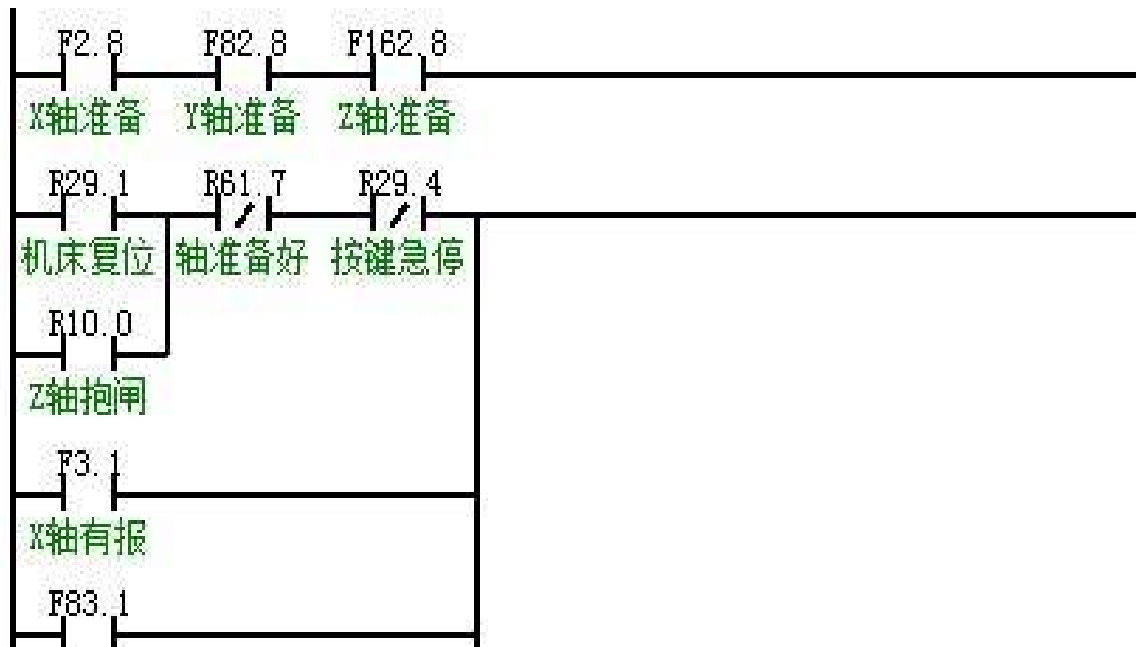
PLC alarm text

66 G3014.1:4th axis release overtime (not loosened in the position)

67 G3014.2:4th axis clamping overtime (not tightened in the position)

97 G3016.0: indexing axis position is abnormal, lock is not allowed

104 G3016.07: There is no clamping/release in position signal for 4th axis, please check

508 Alarm for abnormal shielding of 4th axis clamping/release in position signal, care should be taken

P parameter comments (USERP.STR)

170 Initial value of indexing/orientation axis [unit um] 1

171 Spacing between indexing/orientation axes [unit um] 1

172 Indexing/orientation axis in-position range setting [unit um] 1

✧ Note

● Use indexing axis control. Turn off the Enable control when indexing axis clamping is used in PLC. Manual function cannot be used in PLC and handwheel function can be used. After release is executed with M code, handwheel function can be used, but the clamping can be executed with M code only after the handwheel must move to the corresponding position; otherwise, an alarm will be issued against abnormal position of indexing axis and the indexing axis cannot be clamped if the clamping is executed with M code.

● Operating risk: After the indexing axis is released, the indexing axis will move to the programmed position before Enable is turned off and continues to run. After the indexing axis is clamped and emergency stop is pressed or the system is powered off and restarted, the actual machine position will be assigned to the command position automatically. At this time, G91 indexing axis command will directly be executed and movement position error of the indexing axis may occur. The existing solution is: Execute reference point return of indexing axis or the program runs G90 command.

● Operating risk: If press emergency stop when the indexing axis rotates, the indexing axis motor will be disabled, The clamping/release state of indexing axis will not change and the dividing axis may stop freely.

● When the initial value of indexing/positioning axis is not 0, except relevant parameters are set, 103017 coordinate value of reference point (mm) also should be set to the same value. Meanwhile, 103021 coordinate value of the second reference point (mm) also should be set to the same value; otherwise, reference point return completion marker F240.8 of A axis in PLC cannot be turned on after reference point return of the rotary table is completed.

3.6.2 Commissioning of Disabling 4th Axis Rotary Table Clamping

1) Relevant coordinate axis parameters

103077 indexing/positioning axis type: 0: disable indexing/positioning axis.

2) Commissioning

Parameter setting

● Coordinate axis parameters:

103077, indexing/orientation axis type: set to 0.

103060, positioning tolerance (mm): The value can be set as default value 0.1.

● Machine tool user parameters:

010182, G1019 corresponds to M code: 10

010183, G1020 corresponds to M code: 11

Clamping /release of the rotary table is completed through calling subprogram with M code (M10 clamping, M11 release) , so that the position of A axis is updated when the rotary table releases.

Parameter relating to PLC

K6.0, 4th axis is, 0: Invalid; 1: Valid

K6.1, whether indexing axis control is used for 4th axis, 0: Not use; 1: Use

K6.2, when the indexing axis function is not used, whether 4th axis clamping is disabled 0: Yes; 1: No (current-limiting)

K6.4, Whether there is clamping/releasing in the position signal for 4th axis, 0: Yes; 1: No

K6.5, exchange 4th axis clamping/release signals

K6.6, Whether shield alarm of clamping/releasing signal in the position exception, 0: No; 1: Yes

(K6.6 is mainly used for overhaul when indexing axis in position signal is abnormal)

Relevant PLC

For the PLC part, the PLC with the same function as indexing axis used by the fourth axis is applied for control.

M code calls subprogram

Add USERDEF.CYC in bin directory to corresponding subprograms called by M10 and M11.

```
%1019 ; rotary table clamps
M40
G80
M99
%1020; rotary table releases
M41
#1 = #1151      ; save G0/G1/G2/G3 modal GRP1
#2 = #1158      ; save G20/G21/G22 modal GRP8
#3 = #1163      ; save G90/G91 modal GRP13
#4 = #1164      ; save G94/G95 modal GRP14
#5 = #1125      ; save F value before tool changing
#6 = #1013      ; save programmed position of the fourth axis before breakpoint
G00             ; recover initial value of modal group
G21
G90
G94
G31L-2K0  ; stop read-ahead
G31L-2K8  ; update position
G53G0A#6
G[#1]           ; recover modal value before entering the cycle
G[#2]
G[#3]
G[#4]
F[#5]              ; recover F value
G80
M99
```

Note

Operating risk:

After the rotary table is released in the position, the rotary table will move to the programmed position before Enable is turned off. After the rotary table is clamped and emergency stop is pressed or the system is powered off and restarted, the actual machine position will be assigned to command position automatically. At this time G91 rotary axis command will directly be operated and error of rotary table movement position may occur. The existing solution: Execute reference point return of rotary table or the program executes G90 command.

During programming, clamping and release correspond to M10 and M11. If users use M40 or M41, after M41 is

executed, G91 movement command of rotary table will be operated and an alarm that A axis is not at the breakpoint position may occur or error of programmedg coordinates and actual coordinates may occur.

3.6.3 Commissioning of Enable when 4th Axis Rotary Table is Clamped

1) Relevant coordinate axis parameters

103077 indexing/positioning axis type: 0: Disable indexing/positioning axis.

2) Commissioning

Parameter setting

103077 indexing/positioning axis type: 0.

103060 positioning tolerance (mm): the default value 0.1 is set.

Parameter relating to PLC

K6.0, 4th axis is, 0: Invalid; 1: Valid

K6.1, whether indexing axis control is used for 4th axis, 0: No; 1:Yes

K6.2, when indexing axis function is not used, whether 4th axis clamping is disabled 0: Yes; 1: No (current-limiting)

K6.3, external 4th axis clamping/release button is valid

K6.4, Whether there is clamping/releasing in the position signal for 4th axis, 0: Yes; 1: No

K6.5, exchange 4th axis clamping/release signal

K6.6, Whether shield alarm of clamping/releasing signal in the position exception, 0: No; 1: Yes

(K6.6 is mainly used for overhaul when indexing axis in position signal is abnormal)

Setting relating to servo current-limiting

Note: Feed axis drive is upgraded to version 2.811 or above

G242.15 axis 3 current-limiting marker in PLC needs to be turned on.

PB61, 0: Enable Current-limiting function; 1: Disable current-limiting function

PB62, current-limiting percentage: to limit the percentage of rated current that the current can reach when motor is stuck by external force, so as not to overload or even burn motor. It needs to cooperate with the PLC function.

Relevant PLC

● When the machine tool is powered on, the rotary table is in a loose state by default

● Calling clamping/release control of rotary table is added to PLC2
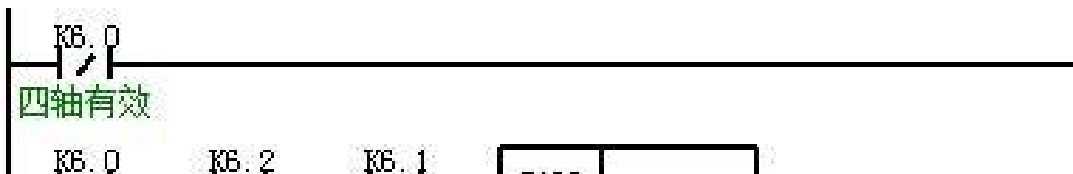
● Correspond to called subprogram:

1 | SP | S9 | 四轴有效不断使能

2 R29.2
   伺服使能

Current limiting function is enabled after locked.

3 R70.1
   A锁紧_I

4 R231.0
   循环启动 | MGET | 0 |
5   40

6 R231.0
   循环启动 | MGET | 0 |
7   41

Control of external loosening/tightening button

8 I6.1
   外接四轴

9 R370.1
   松紧

10 R370.0   R220.2   K6.3
   松紧按键   手动灯   外接四轴

11   R220.3
              增量灯

外接松紧按键控制

12 R370.2   R370.1   R56.1
   按键   松紧   A松开M41

13 R370.1   R370.2
   松紧   按键

```
21 ┤├─[ COIN │  F246  ]────────────────────────────────────
            │  A轴指令 │
22          │    0    │

23 ┤/├──┤/├──────────────────────────────────────────────
    R6.7   R70.0
   移动标记 A轴松开_

24 ┤├───┤├──[ TMRB │   8   ]────────────────────────────
    R55.6  R29.0
   未松到位 运行允许
25                    │   0   │

26                    │  100  │

27 ┤├──┤/├──┤/├──┤/├──[ TMRB │  27  ]──────────────────
    T5.3  T5.2  K6.5  K6.4
   A轴松开 A轴锁紧 四轴松紧 四轴无松
28 ┤├──┤/├──┤/├─────────│  0   │
    T5.3  T5.2  K6.5
   A轴松开 A轴锁紧 四轴松紧
29                      │ 500  │

30 ┤├───┤├──[ TMRB │  34  ]────────────────────────────
    R342.0 K6.4
   A轴松开 四轴无松
31                │   0   │

32                │ 1500  │

33 ┤├─┬──────────────────────────────────────────────
    R70.2
   A轴松开
    R70.3
```

41 R70.4
A轴锁紧

42 R70.5
A轴锁紧

43 R342.1
A轴锁紧

44

45 R342.0
A轴松开

46

47 R58.3   R202.3   R29.0
手动轴   +A   运行允许

48   R203.3   R29.0
            -A   运行允许

49 R202.3   R220.4   F240.8
+A   回零灯   A1参考点

50 R340.0
A回零条

51 R220.4   F240.8 | TMRB   150 |
回零灯   A1参考点 | |

52 | 0 |

53 | 800 |

R342.0   R70.0   K5.6

- Add alarm output and axis lock control to PLC2

In non-auto mode, when the signal A axis release in position is lost, A axis is locked. In auto mode, only the lock code is executed for A axis, and there is no A axis release in position signal, A axis is locked.
When A axis is not in release state, but instable signal of A axis release in position will result in A axis running position error of A axis.

- Add the alarm which is cleared at the time of reset to S3 subprogram
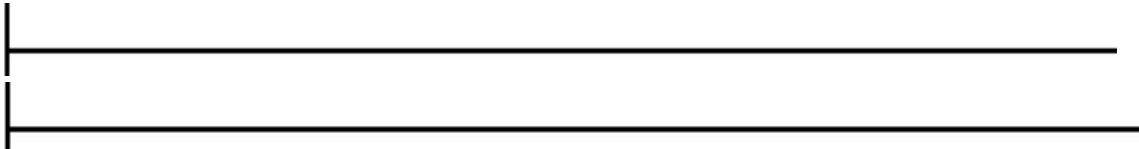
- Axis ready is not modified, A axis alarm is added to servo alarm.

PLC alarm text

66 G3014.1:4th axis release overtime (not release in the position)

67 G3014.2:4th axis clamping overtime (not clamping in position)

104 G3016.07: there is no clamping/release signal in-position signal for 4th axis, please check

508 "Alarm for abnormal signal of shielding of 4th axis clamping/release in position, care should be taken"

Note

Feed axis drive needs to upgrade to version 2.811 or above for using of the current-limiting function.

3.6.4 Notes About Use Of Rotary Table

IO point locations used by the PLC are as below:

I6.1, external rotary table clamping/release button (valid when the rotary table uses current-limiting function)

Q3.6, external rotary table clamping/release button light (valid when the rotary table uses current-limiting function)

I5.3, rotary table release in the position signal

I5.2, rotary table clamping in the position signal

Q3.4, rotary table clamps

Q3.5, rotary table releases

● When rotary axis function is used, NC parameter 000013 G00 interpolation is recommended to be turned off, and 0 is set. When it is turned on, the rotary table does not move to the right position during simultaneous motion of axes.

● For rotary table using 360° reset mode, feedback cycle mode of corresponding axis in device interface parameters should be set as 1 (feedback position adopts cycle count mode) and encoder working mode in corresponding logical axis parameters should be set as 0X1100 (long travel is enabled).

● After rotary table or indexing axis clamping is disabled, emergency stop is pressed or the machine tool is powered off and restarted, if G91 rotary table or indexing axis movement command is executed, movement position error of the rotary table may occur. e.g.: When the actual machine coordinates of the rotary table runs to 5°, conduct the clamping operation. After the clamping is in the position, the rotary table motor is disabled and the actual coordinates of the rotary table may change due to mechanical force, for example coordinates change to 5.02°. At this time, the actual machine coordinates of the rotary table are 5.02° and the command coordinates of machine tool are 5°. If emergency stop is not pressed, G91 continues to be operated, and the axis moves 5° in incremental mode, then after the rotary table is released, the rotary table will return to #1013 programmed position first (namely the position of command machine coordinates 5°) and the rotary table stops at the actual machine coordinates 10° position after G91 is executed. However, if emergency stop is pressed or the system is powered off and restarted, the system will assign the actual machine coordinates to its command coordinates and actual and command machine coordinates change to 5.02°. After the rotary table is released, #1013 corresponds to 5.02°. G91 code continues to be executed, then rotary axis stops at the actual machine coordinate 10.02° and consequently positional deviation occurs. It is recommended to adopt G90 programming mode when the rotary table or indexing axis adopts clamping for disabling control.

3.7 Function of Oblique Axis

When the inclined angle between horizontal axis and vertical axis is not 90°, the axis is called oblique axis. Control function of oblique axis is used to control the movement distance of all axes based on oblique angle. In control function of oblique axis, X is often defined as the oblique axis and Z axis is the vertical axis.
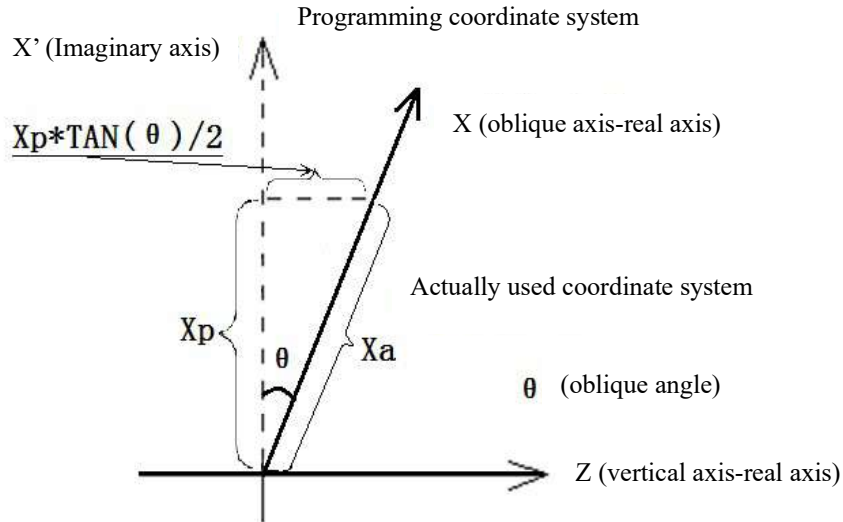
When the oblique axis is X axis and the vertical axis is Z axis, the movement distance on all axes is calculated as below:

The movement distance along X axis:

$$Xa= Xp/COS(-\theta)$$

The movement distance along Z axis is corrected according to dip angle of X axis:

$$Za= Zp-Xp*TAN(-\theta)/2$$

Where:
Xa and Za are actual distance;
Xp and Zp are programmed distance.

3.7.1 Parameter Setting

Channel Parameters
040310-Oblique axis control enable (1 is set when oblique axis is installed on machine tool; otherwise, it is set as 0).
040311-Channel axis number of orthogonal axis (X-0; Z-2).
040312-Channel axis number of oblique axis (X-0; Z-2).
040313-Negative value of oblique angle (unit: degree); negative value for clockwise inclination and positive value for anticlockwise inclination. It is often a negative value.

NC Parameter
000013-G00 interpolation enable is set as 1.

3.7.2 Imaginary Axis Coordinate System Programming

G135-Enable imaginary axis coordinate system programming.
G136-Disable imaginary axis coordinate system programming (switch to oblique axis programming).

3.7.3 JOG/MPG Switching

There are two JOG/handwheel control modes:
When G2578.1=1, imaginary axis coordinate system control mode is enabled
When G2578.1=0, oblique axis (real axis) coordinate system control mode is enabled

3.7.4 PLC Programming

After the system is powered on and emergency stop is activated, the functional lamp of oblique axis on the panel lights up (imaginary axis coordinate system control mode is enabled).
PLC is modified as below,

● During initialization, R199.0 is set to 1,

● R199.1 is turned on after emergency stop is enabled,
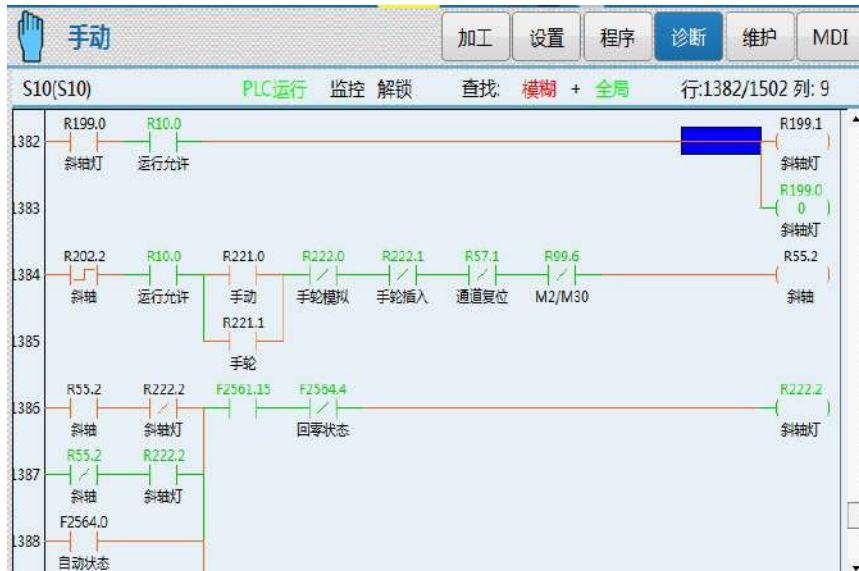
● R222.2 is turned on after R199.1 is turned on, that means the functional lamp of oblique axis on the panel lights up.

Under JOG and handwheel modes, user can manually turn on and off the oblique axis lamp on the control panel to control whether the X and Z axes run at the same time when the X axis is running in JOG or handwheel mode, or the X and Z axes run separately.

PLC is modified as below:

Through controlling R55.2, R202.2 in the subprogram control R222.2 (turning on and off of functional lamp of oblique axis on the panel).
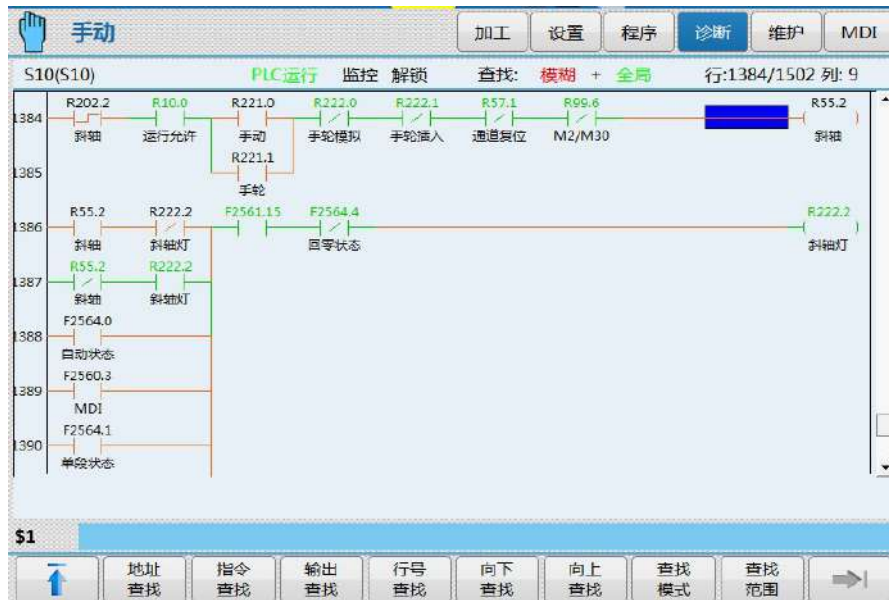
Oblique axis function is enabled (that is, in the G135 state) under auto, single block and MDI modes by default. Functional lamp of oblique axis lights up through F2561.15. When G136 is executed in the program, function lamp of oblique axis lights off automatically and oblique axis function will be enabled again through emergency stop, reset and G135.

PLC is modified as below:

F2561.15 in the subprogram controls R222.2 (turning on and off of functional lamp of oblique axis on the

panel).

The functional lamp of oblique axis on the panel can be turned off under reference point return mode (that is, in the G136 state), the feed axis returns to reference point alone, and only the X axis can return to reference point, the Z axis can return to reference point.

PLC is modified as below:

F2564.4 in the subprogram controls R222.2 (turning on and off of functional lamp of oblique axis on the panel).

3.7.5 Reference Point Return of Absolute Motor

In the subprogram and in the zero mode F52564.4, the F0.0 register the logical axis moving to determine R67.0 the logical axis returning zero. The F0.8 register the first reference point position of the logical axis is valid at

the zero position, and R188.0 is set as the zero marker of the X axis

In the subroutine, whether the Z axis can return to zero is controlled by R188.0 whether the X axis is at the zero marker.

3.7.6 Macro Programming

Description of values of macro-variables which may be used for user programming.

Macro-variable number	Macro-variable name	Value type
#1000-#1008	Machine tool position in current channel axis (9-axis)	Real axis value

#1030-#1038	Workpiece origin in current channel axis (9-axis)	Imaginary axis value (Cartesian coordinate value)
#70006	X offset value of tool 1	Real axis value
#70008	Z offset value of tool 1	Real axis value
#70206	X offset value of tool 2	Real axis value
#70208	Z offset value of tool 2	Real axis value
#70406	X offset value of tool 3	Real axis value
#70408	Z offset value of tool 3	Real axis value
#70029	Z wear value of tool 1	Real axis value
#70034	X wear value of tool 1	Real axis value
#70229	Z wear value of tool 2	Real axis value
#70234	X wear value of tool 2	Real axis value
#70429	Z wear value of tool 3	Real axis value
#70434	X wear value of tool 3	Real axis value

Remarks:

● Real axis value is the value in the oblique axis coordinate system and virtual axis value is the value in the Cartesian coordinate system.

● Macro-variable corresponding to offset value of tool number=#【70006 (70008)+(tool number -1)*200】.

● Macro-variable corresponding to wear value of tool number=#【70029 (70034)+ (tool number -1)*200】.

3.7.7 Note

● When 040310 parameter oblique axis control enable in channel parameters is set as 1, the oblique axis is enabled by default and oblique axis function needs not be enabled with G135, that is, in the programming coordinate system environment.

● Please use T command for programming after oblique axis function is enabled.

● When oblique axis function is used for tool setting in the tool compensation interface:

Please ensure the functional lamp of oblique axis on the panel lights up before tool setting.

The input value of precutting diameter is the programming value. After it is input, the system will calculate it in X and Z offset automatically.

The input value of wear is the programming value. After it is input, the system will calculate it in X and Z offset automatically.

● For the oblique axis retraction, system invalidates oblique axis function forcibly. Only the oblique axis runs to the retract position, the vertical axis does not.

● X and Z values of G10L14P tool number in oblique axis function are programming value and the system will calculate them in X and Z offset after operation.

● If the angle of oblique axis control approaches 0 or 90°, error will occur during software computing. A reasonable angle of oblique axis is ±20° to ±60°.

3.8 Switching Gear Ratio Online

Each feed axis provides two sets of gear ratio parameter settings, and different gear ratios can be freely switched in the case of uninterrupted power supply, and it will take effect immediately. This function can be used to meet the machine tool requirements of some special mechanical mechanisms.

3.8.1 Parameter Description

Name of reference point	Parameter address	Parameter value	Corresponding G register in PLC
Number of feed axis gear stages	10X189	2 [Two gears stages]	
Numerator of transmission ratio of feed axis gear stage 1	10X190	Fill out according to actual situation	G[X*80+76] = 1
Denominator of transmission ratio of feed axis gear stage 1	10X191	Fill out according to actual situation	
Numerator of transmission ratio of feed axis gear stage 2	10X192	Fill out according to actual situation	G[X*80+76] = 2
Denominator of transmission ratio of feed axis gear stage 2	10X193	Fill out according to actual situation	

3.8.2 PLC Modification

Auto save after power failure and initialization of gear ratio status

Execute during PLC initialization, restore gear ratio state after power-off and restart

When gear ratio is changed through F1/F2 switching, trigger 103 event and save the value of B register
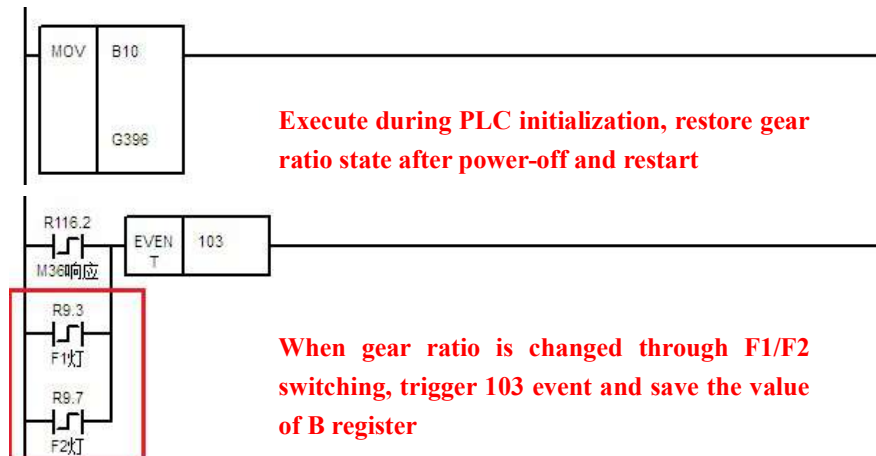
Note:

● G396=4x80+76, G396 represents gear ratio G register of logical axis 4.

● 【EVENT】【103】 event----PLC notifies HMI, PLC modifies B register, and HMI will save B register at the time of power failure.

3.8.3 Application Example

Transmission structure of motor is: Low gear speed ratio 1/24, high gear speed ratio 4/1; gear transmission ratio 19/49.

Name of reference point	Parameter address	Parameter value	Corresponding G register in PLC
Number of feed axis gear stages	10X089	2	
Numerator of transmission ratio of feed axis gear stage 1	10X190	19 =1x19	G[X*80+76] = 1
Denominator of transmission ratio of feed axis gear stage 1	10X191	1176=49x24	
Numerator of transmission ratio of feed axis gear stage 2	10X192	76 =19x4	G[X*80+76] = 2
Denominator of transmission ratio of feed axis gear stage 2	10X193	49 =1x49	

3.9 Five Software Limits

The system can set no more than 5 pairs of software limits, and validate a pair of soft limits through G register of axis in PLC. Details are as follows:

software limit name	Software limit parameter	Parameter address	Limit validation G register
The first pair of limits	Positive software limit coordinate (mm)	10X006	**When soft limits 2, 3, 4 and 5 are validated, limit 1 is not validated**
	Negative software limit coordinate (mm)	10X007	
The second pair of limits	2nd positive software limit coordinate (mm)	10X008	When G(X*80+1).2=1, limit 2 is validated
	2nd negative software limit coordinate (mm)	10X009	
The third pair of limits	3rd positive soft limit coordinate (mm)	10X202	When G(X*80+1).3=1, Limit 3 is validated
	3rd negative soft limit coordinate (mm)	10X203	
The fourth pair of limits	4th positive soft limit coordinate (mm)	10X204	When G(X*80+62).10=1, Limit 4 is validated
	4th negative soft limit coordinate (mm)	10X205	
The fifth pair of limits	5th positive soft limit coordinate (mm)	10X206	When G(X*80+62).11=1, Limit 5 is validated
	5th negative soft limit coordinate (mm)	10X207	

3.10　Functions of Reference Points 2, 3 and 4

The system can designate no more than 5 reference points under the machine tool coordinate system. When the actual position of machine tool is at corresponding reference point, corresponding F register will be triggered. e.g.: During tool changing, F register can be used to judge whether the axis is at the tool changing point in PLC.

Parameter Setting

Name of reference point	Parameter address	Reference point F register	G code corresponding to machining programming
Coordinate value of reference point (mm)	10X017		G28
Coordinate value of reference point 2 (mm)	10X021	F(X*80).8=1	G30P2
Coordinate value of reference	10X022	F(X*80).9=1	G30P3

point 3 (mm)			
Coordinate value of reference point 4 (mm)	10X023	F(X*80).10=1	G30P4
Coordinate value of reference point 5 (mm)	10X024	F(X*80).11=1	G30P5

4 Other Functions

4.1 Manual Intervention and Return Function

During auto operation, after feed hold, stop movement of axis by switching to jog or handwheel modes. After confirming the cutting face via manual intervention, restart the program.

4.1.1 How to Enable Function

1) Add Breakpoint Return Program Block to Canned Cycle

Add the following program blocks to user-defined canned cycle file USERDEF.CYC:

```
%1007
G53    X#1110    Y#1111
G53    Z#1112
G31    L-2 K0
G115    L11
M99
```

2) Parameter Setting

● Channel parameter----040059 automatic breakpoint return program number. 1007 is set (consistent with program number of subprogram corresponding to USERDEF.CYC).

参数号	参数名
040055	G05.1Q2圆弧降速半径
040056	G05.1Q2圆弧降速速度
040057	G05.1Q3圆弧降速半径
040058	G05.1Q3圆弧降速速度
040059	循环启动自动回断点程序号
040060	工具跟随的摆动半径

- NC parameter----000013 G0 interpolation enable, set to 1.

3) PLC Modification

Add register G2636.9 status response (G2636.9 doesn't need to be connected in parallel in V2.4)


```
X480.0
 | |
自动
```

4) Function Usage Diagram

- Cutting workpiece in N1 program block.

Tool 刀具
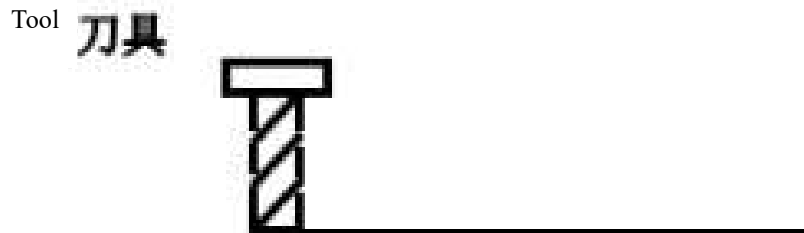
- Stop at A point in N1 program block by feed hold mode.
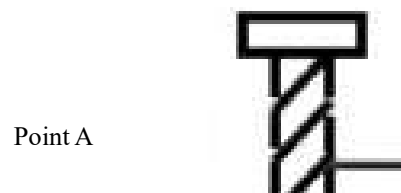
Point A

- Tool retracts to B point in JOG, and then press cyclestart

Point B

Manual intervention

手动干预
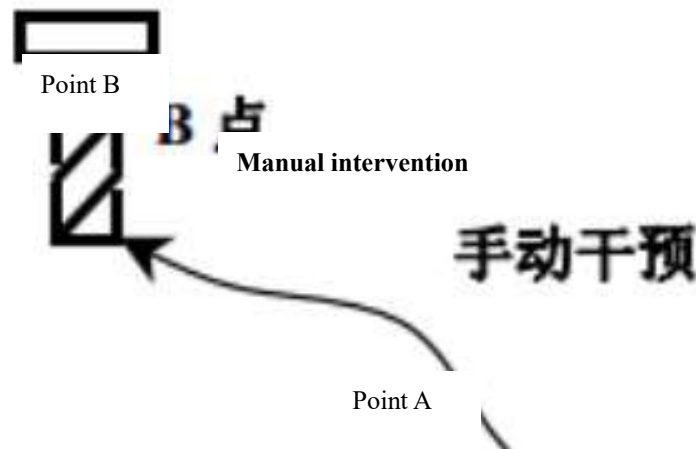
Point A

● Return all axes to the breakpoint position successively in the order of axes which is programmed in the breakpoint return subprogram, and then execute remaining movement commands of N1 block.

Point B Return 返回
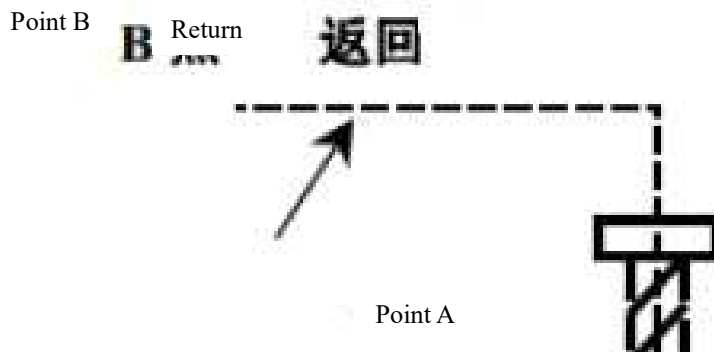
Point A

5) Note

● Change coordinate system and tool compensation during manual intervention, which cannot be validated immediately after breakpoint return.

● It should be noted that 117 rerun event in PLC cannot be conflict with use of this function.

4.2 Manual Subprogram Call Function

Under JOG mode, users can define keys on MCP panel. Set G register as 1 using this key and call relevant subprograms in order to realize some complex functions, such as one-click tool returning/tool clamping, one-click zero return of magazine and one-click zero return of three axes.

The corresponding relation between point location of G register and subprogram is shown below

Point location of G register	Canned cycle subprogram
G2637.1	Call canned cycle subprogram O1007
G2637.2	Call canned cycle subprogram O1008
G2637.3	Call canned cycle subprogram O1009
G2637.4	Call canned cycle subprogram O1010
G2637.5	Call canned cycle subprogram O1011
G2637.6	Call canned cycle subprogram O1012

G2637.7	Call canned cycle subprogram O1013
G2637.8	Call canned cycle subprogram O1014
G2637.9	Call canned cycle subprogram O1015
G2637.10	Call canned cycle subprogram O1016
G2637.11	Call canned cycle subprogram O1017
G2637.12	Call canned cycle subprogram O1018
G2637.13	Call canned cycle subprogram O1019
G2637.14	Call canned cycle subprogram O1020
G2637.15	Call canned cycle subprogram O1021
F2637.0	Status bit: It means]subprogram is running in JOG

4.2.1 Function Usage

✧   Conduct programming in PLC as shown below (users can define keys based on actual situation), output G command signal and call corresponding subprograms.

Example: Call reference point return subprogram of three axes with one click.

4.2.2 Add Subprogram Content

Through searching point location of G register and subprogram comparison table, subprogram name corresponding to G2637.4 is O1010.

Add corresponding subprogram contents to system canned cycle USERDEF.CYC.

```
%1010        This cycle command is applicable to three-axis reference point return
G40
                 Save G0/G1/G2/G3 modal GRP1
                 Save G20/G21/G22 modal GRP8
#1 = #115  Save G90/G91 modal GRP13
#2 = #115  Save G94/G95 modal GRP14
                 Save F value before tool changing
#3 = #1163    :  保存G90/G91模态 GRP1
#4 = #1164 Restore the initial value of the modal group

#5 = #1125    :   保存换刀前F值

                 :  Firtst, return to the zero point of Z axis
G00              :  Then return to the zero points of X axis and Y axis
G21
                 :  Restore the modal value before entering cycle
G90

G94

G49G53 G90 G: Retore the previous F value
G53G90G0X0Y0           : 再回X、Y轴零点
```

Save after programming.

● Switch to JOG mode and press corresponding three-axis reference point return button to call subprogram O1010 and realize three-axis reference point return.

4.2.3 Precautions for Function Use

● While program is being executed, F2637.0 is 1 and other buttons on the panel are shielded and invalid except reset and emergency stop buttons. When corresponding G command signal (such as G2637.1) is 0 and subprogram is executed, F2637.0 is 0.

● Subprograms O1007-O1021 must be placed in file USERDEF.CYC. The subprogram corresponding to O1007 program starts with %1007 and O1008 corresponds to %1008, and so on. In the previous line of each subprogram end M99, add G80 to clear canned cycle mode for milling system and G115L10 to clear canned cycle mode for lathe system.

4.3 Precutting Function of Handwheel

When the system is in auto or single block mode, press handwheel precutting button and the program stops running immediately. The operator can control operation state of the program through rotating the handwheel positively or negatively. This function is often used for first commissioning of the part machining.

This function has three modes, (set through PLC programming, generally the default is mode 3)

Mode 1: Handwheel rotation in both CW and CCW means moving forward

Mode 2: Handwheel rotation in both CW and CCW means moving backwards

Mode 3: Handwheel rotation in CW means moving forward, and handwheel rotation in CCW means moving backwards.

4.3.1 Realization Description

✧ Before use, enable handwheel precutting function through system setting and set handwheel precutting to function (F4 key) to be effective in the "Maintain"→"User setting"→"PLC switch" interface of the system. (As shown below)

✧ The operator should open handwheel precutting function key (F4 key on the panel) before or when the program runs.

✧ Rotate the handwheel CW to control running status of program (moving forward) and inspect running status of program.

4.3.2 Register Description

✧ Handwheel retraction function is controlled by G2562.8: when 1 is set, retraction with handwheel is effective; when 0 is set, retraction with handwheel is ineffective.

✧ Handwheel magnification function is controlled by G2562.15: when 1 is set, handwheel magnification is effective: when 0 is set, handwheel magnification is ineffective.

4.3.3 PLC Editing

PLC program for precutting with handwheel is edited as below，P19614 is the PLC switch set in the user setting of system.

Mode 3

When mode 1 or mode 2 is used, PLC with red mark in the figure (mode 3) is modified as below

Mode1

1.1 Note:

● G64 mode and G00 interpolation must be enabled.

- The number of read-ahead blocks must be greater than 500.
- Retraction of canned cycle and multiple repetitive cycle is not supported.
- Retraction is not performed if there is G31, M code and G09 instruction.
- For some long line segments of lathe, the tool is unable to move backwards.

4.4 Handwheel Interrupt Function

In auto mode, the handwheel feed can be superimposed on the movement based on automatic operation by rotating the MPG. The minimum unit of every scale of movement amount is a length resolution unit (namely (1/length resolution) mm)

The interruption amount caused by the manual handwheel is set in the external workpiece zero offset (EXOFS) to offset the workpiece coordinate system and the local coordinate system. Therefore, although the machine tool moves, the coordinate values in the workpiece coordinate system and the local coordinate system remain unchanged.

Thus, the value of axes in the workpiece coordinate system is the value of axes in the machine coordinate system-External workpiece zero offset value-Workpiece coordinate system origin.

e.g.: The coordinate value of axes in the machine coordinate system is 100mm, and the external workpiece zero offset value is 0mm, the origin of the workpiece coordinate system is 50mm, then the displayed position of the workpiece coordinate system is 50mm.

When handwheel interruption is enabled, rotate the handwheel and 1mm handwheel interruption amount will be produced (external workpiece zero offset value arising from handwheel interruption amount). Then, the axis will move for 1mm, the coordinate value in the machine coordinate system is 101mm, the external workpiece zero offset is 1mm, the origin of the workpiece coordinate system is 50mm, and the displayed position of the workpiece coordinate system is still 50mm.

Even though manual handwheel interruption is executed, the machine coordinate system will not change. The absolute command (G53) in the machine coordinate system is not affected by manual handwheel interruption.

Before manual handwheel interruption function is used, control mode of axis should be switched to handwheel interruption mode. Under handwheel interruption mode, the system will not only receive movement commands issued in JOG and auto modes but also receive movement commands arising from change of handwheel interruption amount.

When axis mode control register is set to 102, the axis control mode is requested to switch to the handwheel interruption mode. When 0 is set, exit the handwheel interruption mode.
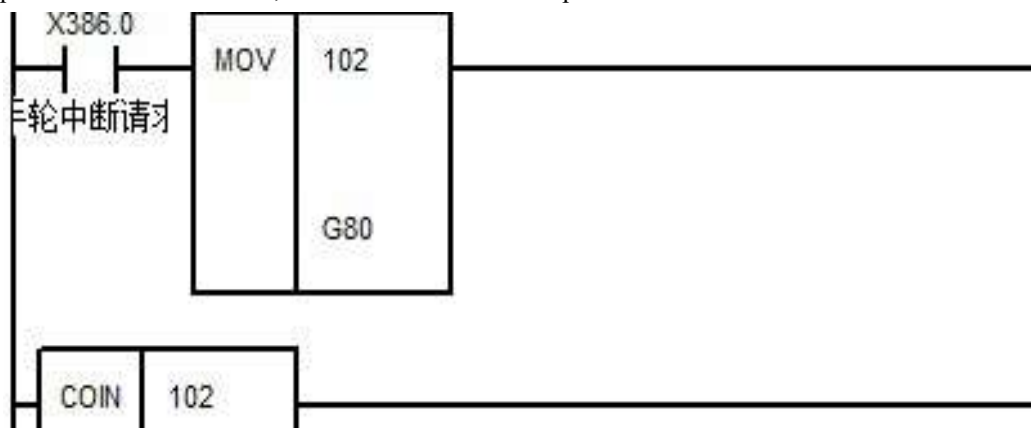
When X386.0 (handwheel interruption request) is valid, set G60 as 102 to request for switching axis 0 to handwheel interruption mode. Then, compare whether F70 is equal to 102. If it is equal to 102, axis 0 has been switched to handwheel interruption mode and Y386.0 lights up (handwheel interruption light).

4.4.1 Handwheel Interruption Mode Switching

After switching to handwheel interruption mode, set handwheel interruption enable (G2561.12) as 1 for handwheel interruption control.
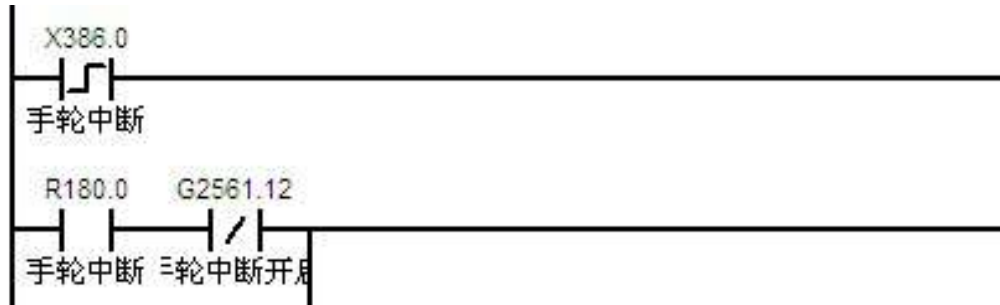
4.4.2 Manual ON and OFF

After switching to handwheel interruption mode, set handwheel interruption enable (G2561.12) as 1 for handwheel interruption control.
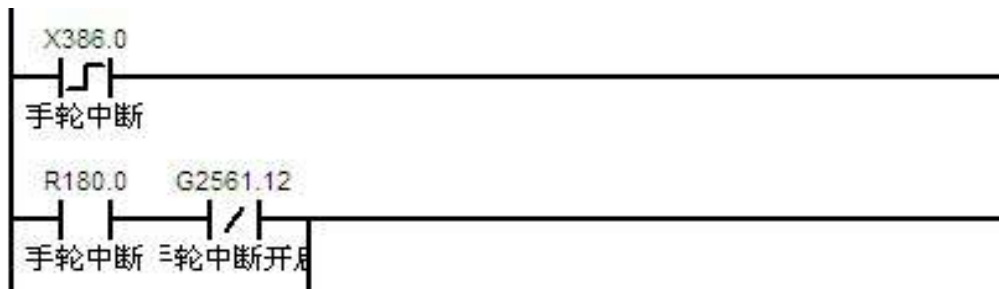
4.4.3 Auto ON and OFF

During auto operation, M24 and M25 can be used for ON and OFF of handwheel interruption.
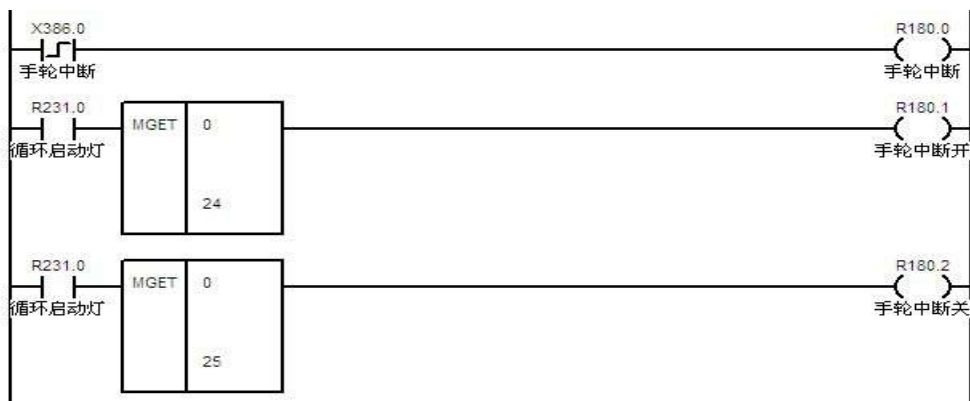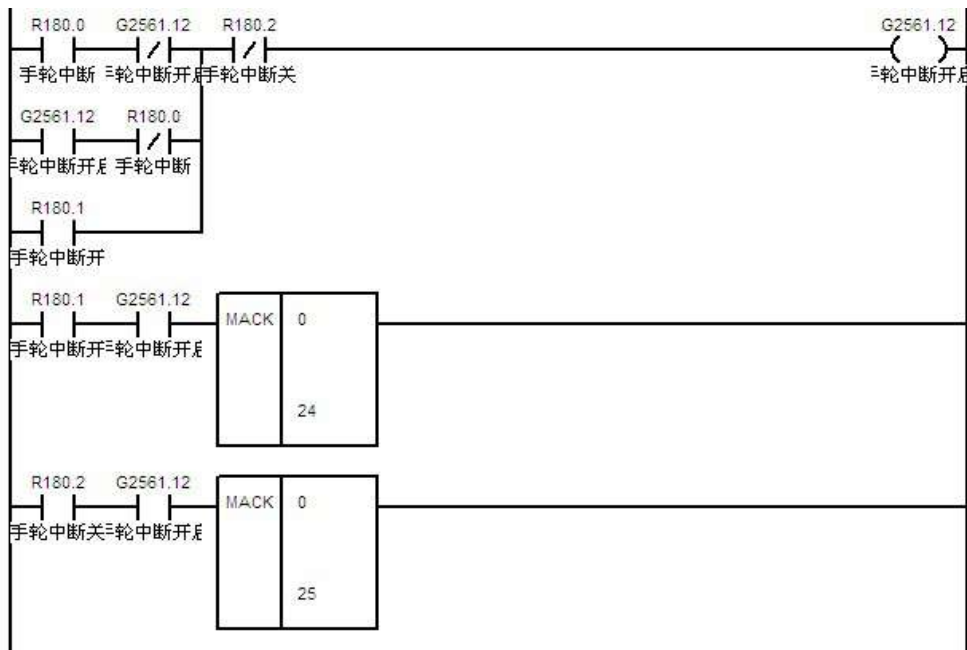
M24 and M25 set and clear G2561.12 for ON and OFF of handwheel interrupt function.

4.4.4 Valid Range of Handwheel Interruption

When there is a value in handwheel interruption amount, even though the handwheel interruption function for current axis is disabled and the handwheel interruption mode is exited, handwheel interrupt amount still remains valid until it is reset.

4.4.5 Handwheel Interruption Amount Reset

While canceling interruption amount, the workpiece coordinate system only offsets the manual handwheel interruption amount. The manual handwheel interruption amount is reflected in absolute coordinate value.
Cancel interruption amount under the following situations:

- When reset is executed
- When emergency stop is released
- When the reference point return is manually executed
- When reference point is set if there is no baffle block (set floating zero)
- When presetting workpiece coordinate system is executed
- Reset interface setups
- Trigger G register

While setting G[Axis number*80+62].1, the system will reset total interruption amount and interruption amount of the last cycle simultaneously.

4.4.6 Parameter

- Maximum cycle overlap of external command (PARM.100057/101057/102057): Set the maximum overlap value of every cycle for each axes, unit: mm. The parameter is used to restrict the overlap amount of each cycle.

4.4.7 Register Description

- Handwheel interruption enable (G2561.12): Handwheel interruption switch.

- Axis mode control (G[Axis number*80+60]): When axis control mode is set as 102, axis control mode is requested to switch to handwheel interruption mode. When 0 is set, exit handwheel interruption mode.
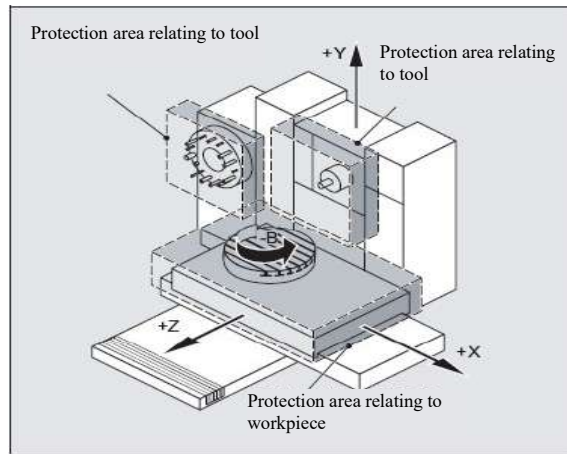- Axis mode status (F[Axis number*80+70]): When axis mode status is 102, handwheel interruption mode is validated.

4.5 Function of Space Protection Area

With the machine protection area, the protection area for key parts of machine tool can be set, such as tailstock and magazine tool, thus avoiding damage to machine caused by misoperation.

4.5.1 Relevant Parameters

Machine user parameters:
- PARM010110, "Internal prohibition mask of machine protection area"
- PARM010111, "External prohibition mask of machine protection area"
- Parm010112 "Negative boundary of X axis of machine tool protection area【0】"
- Parm010113 "Positive boundary of X axis of machine protection area【0】"
- Parm010114 "Negative boundary of Y axis of machine protection area【0】"
- Parm010115 "Positive boundary of Y axis of machine protection area【0】"
- Parm010116 "Negative boundary of Z axis of machine protection area【0】"
- Parm010117 "Positive boundary of Z axis of machine protection area【0】"
- Parm010118 "Negative boundary of X axis of machine protection area【1】"
- Parm010119 "Positive boundary of X axis of machine protection area【1】"
- Parm010120 "Negative boundary of Y axis of machine protection area【1】"
- Parm010121 "Positive boundary of Y axis of machine protection area【1】"
- Parm010122 "Negative boundary of Z axis of machine protection area【1】"
- Parm010123 "Positive boundary of Z axis of machine protection area【1】"

Parameter Setting
- PARM010110, "Internal prohibition mask of machine protection area"

To set quantity of internal protection areas.

Internal prohibition mask of corresponding protection area [G2580]

D7	D6	D5	D4	D3	D2	D1	D0
						Mask in space protection area 2	Mask in space protection area 1

When mask bit is 1, internal protection area is valid; when it is 0, internal protection area is invalid.

When G2580.0 is 1, machine protection area 【0】 is valid;

When G2580.1 is 1, machine protection area 【1】 is valid;

When G2580.0 and G2580.1 are 1, machine protection area 【0】 and machine protection area 【1】 are valid;

After internal protection area is set, axes are not allowed to move to the protection area. When axes are about to move to the protection area, the system gives an alarm "Enter the restricted area" and prohibits the axes from continuing moving to the protection area.

- PARM010111, "External prohibition mask of machine protection area"
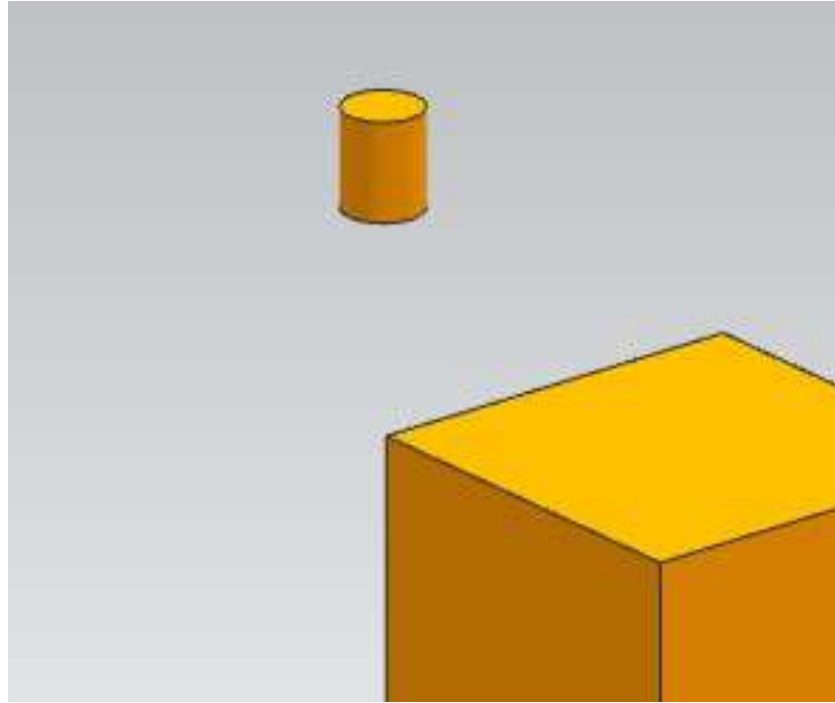
Set quantity of external protection areas.

External prohibition mask of corresponding protection area [G2581]

D7	D6	D5	D4	D3	D2	D1	D0
						External mask of spatial protection area 2	External mask of spatial protection area 1

When mask bit is 1, external protection area is valid; when it is 0, external protection area is invalid.

When G2581.0 is 1, machine protection area 【0】 is valid;

When G2581.1 is 1, machine protection area 【1】 is valid;

When G2581.0 and G2581.1 are 1, machine protection area 【0】 and machine protection area 【1】 are valid;

After external protection area is set, axes are not allowed to move to outside the protection area. When axes are about to move to outside the protection area, the system gives an alarm "Enter the restricted area" and prohibits the axes from continuing moving to outside the protection area.
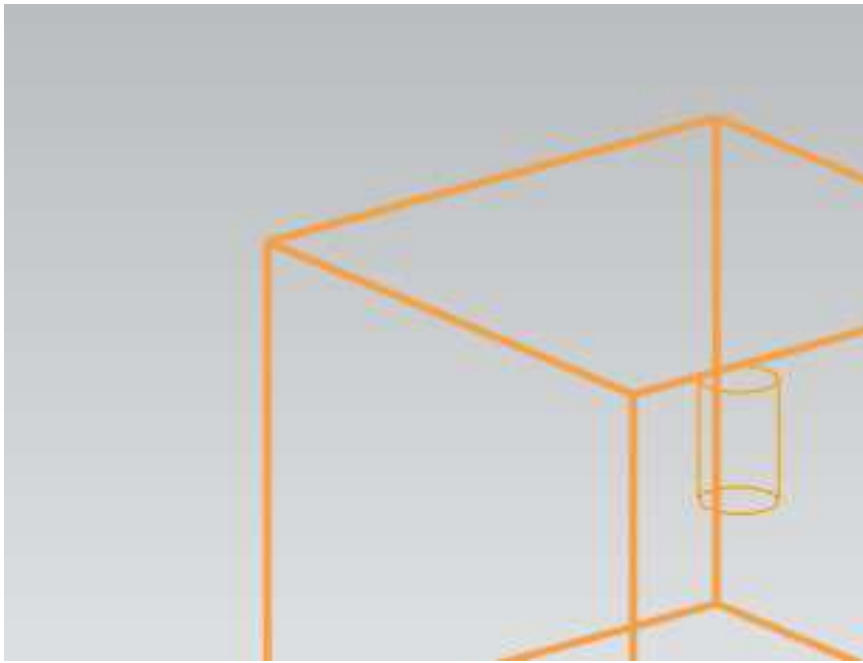
4.5.2　Application Example

4.5.2.1 Spatial protection area of single axis

Set the spatial protection area of X axis as the prohibition area (10cm-20cm) as below,
- Set Parm010110 "Internal prohibition mask of machine protection area" as 1 (machine protection area 【0】 is valid);
- Set Parm010111 "External prohibition mask of machine protection area" as 0;
- Set Parm010112 "Negative boundary of X axis of machine protection area 【0】" as 10;
- Set Parm010113 "Positive boundary of X axis of machine protection area 【0】" as 20;
- Set Parm010114 "Negative boundary of Y axis of machine protection area 【0】" as 0;
- Set Parm010115 "Positive boundary of Y axis of machine protection area 【0】" as 0;
- Set Parm010116 "Negative boundary of Z axis of machine protection area 【0】" as 0;
- Set Parm010117 "Positive boundary of Z axis of machine protection area 【0】" as 0.

If Parm010110 "Internal prohibition mask of machine tool protection area" is set as 0, this function also can be enabled by PLC.

4.5.2.2 Space protection area of multi-axis

Set the spatial protection area of X, Y and Z axes as the area that X, Y, Z axes can only moves within 10cm and 20cm.
- Set Parm010110 "Internal prohibition mask of machine protection area" as 0;
- Set Parm010111 "External prohibition mask of machine protection area" as 1 (machine protection area 【0】 is valid);
- Set Parm010112 "Negative boundary of X axis of machine protection area 【0】" as 10;

- Set Parm010113 "Positive boundary of X axis of machine protection area 【0】" as 20;
- Set Parm010114 "Negative boundary of Y axis of machine protection area 【0】" as 10;
- Set Parm010115 "Positive boundary of Y axis of machine protection area 【0】" as 20;
- Set Parm010116 "Negative boundary of Z axis of machine protection area 【0】" as 10;
- Set Parm010117 "Positive boundary of Z axis of machine protection area 【0】" as 20.

If Parm010111 "External prohibtion mask of machine tool protection area" is set as 1, this function also can be enabled by PLC.

4.6 PMC Axis Function Application

PMC axis is used to prevent the axes from participating in interpolation but enable them to accept the commands issued by PMC to move.

PMC axis and interpolation axis can be configured in the same channel and axes can be switched between PMC axis and interpolation axis.

4.6.1 Register

- Axis mode control (G[Logical axis number*80+60]):

  When register of axis control mode is set as 103, axis control mode is requested to switch into PMC axis mode.

  When 0 is set, exit PMC axis mode.
- Axis mode status (F[Logical axis number*80+70]):

  When register of axis mode status is set as 103, PMC axis mode is valid. The axis will no longer receive G code command but control of AXISMOVE (relative movement) and AXISMVTO (absolute movement) in the ladder diagram.
- PMC axis override (G[Logical axis number*80+61]):

  Assign a value to register to control movement speed of PMC axis.
- PMC axis stop (G[Logical axis number*80+62].0):

  When PMC axis moves, this point is set effectively and PMC axis stops moving.
- PMC axis idle (F[Logical axis number*80+1].0):

  When PMC axis moves, this point is invalid;

  When PMC stops, this point is valid. When PMC axis is idle, new commands for PMC axis movement can be received.

4.6.2 PMC Axis Mode Switching

Before PMC axis function is used, axis control mode should be switched to PMC axis mode. Under PMC axis mode, the system will not receive movement commands issued under JOG mode and auto mode but movement commands issued by PLC module.
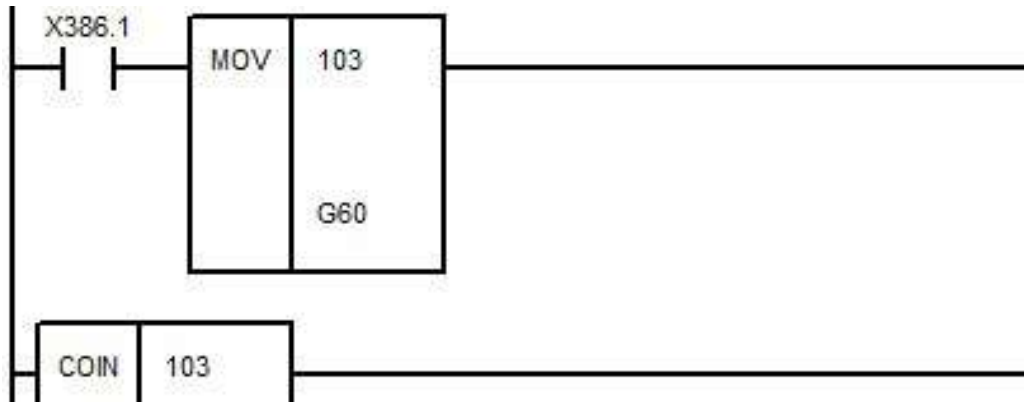
When X386.1 (PMC axis request) is valid, set G60 as 103 to request for switching axis 0 to PMC axis mode. Then, compare whether F70 is equal to 103. If it is equal to 103, axis 0 has been switched to PMC axis mode and Y386.1 lights up.

4.6.3 PMC Axis Speed

The speed of PMC axis is the maximum speed in used axis parameters.

4.6.4 PMC Axis Override

When PMC axis moves, PMC axis speed can be controlled through PMC axis override. In the following example, PMC axis override is set as 100:

4.6.5 PMC Axis Stop

✧ When PMC axis moves, G[Axis number*80+62].0 is set effectively to stop movement of PMC axis. In the following example, press key X386.3 to stop movement of PMC axis.
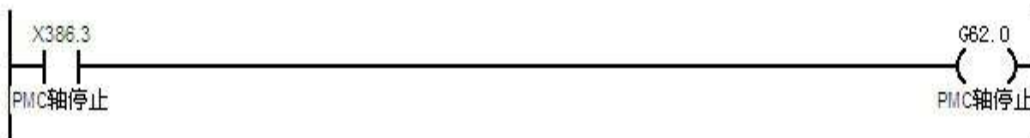
● After axis control mode is switched to PMC axis mode, PLC module can control movement of PMC axis.
● PLC module AXISMOVE is the relative movement module of PMC axis.
● This module has two parameters:

Parameter 1: Logical axis number.

Parameter 2: Movement amount of axis (unit: 1/1000mm or 1/1000°).
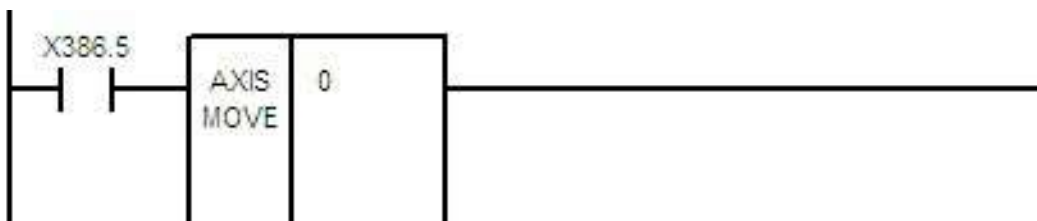
If P50 is set as 10000, this PLC function is that PMC axis moves for 10mm in the positive direction when X386.5 is valid.

Note:

● As long as X386.5 is valid for 1 cycle, PMC axis will move 10mm, and X386.5 is not required to be valid during the movement.

● Before the previous movement command is completed, PMC axis will not accept other movement commands.

● PMC axis idle (F[Axis number*80+1].0) can be used to detect whether movement of PMC axis is completed.

4.6.6 Absolute Movement of PMC Axis

● After axis control mode is switched to PMC axis mode, PLC module can control movement of PMC axis.
● PLC module AXISMVTO is the absolute movement module of PMC axis.
● This module has two parameters:

Parameter 1: Axis number.

Parameter 2: Axis moving position (unit: 1/1000mm or 1/1000°).
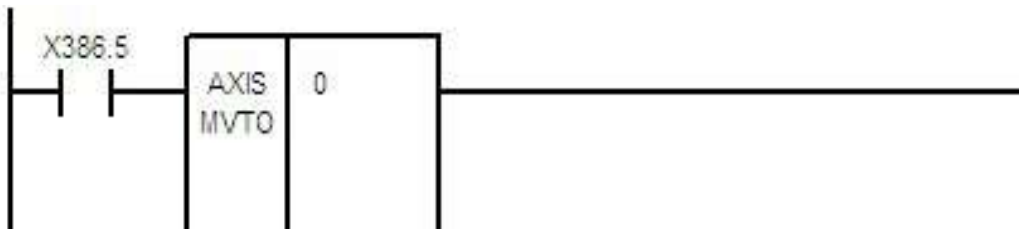
If P51 is set as 20000, this PLC function is that PMC axis moves to the position of machine coordinate 20mm when X386.5 is valid.

Note:

● As long as X386.5 is valid for 1 cycle, PMC axis will move 10mm, and X386.5 is not required to be valid during the movement;

● Before the previous movement command is completed, PMC axis will not accept other movement commands.

● PMC axis idle (F[Axis number*80+1].0) can be used to detect whether movement of PMC axis is completed.

4.6.7 Oscillation of PMC Axis

When PMC axis is used for oscillation, it should be noted that the starting point must be the end point of the oscillation.

With logical axis 7 as an example, PLC is modified as below:

Add the subprogram S20

```
 ┌─────┬─────┐
 │ SP  │ S20 │
 └─────┴─────┘

    R29.2
  ──┤ ├──
  伺服使能

    X0.6
  ──┤ ├──
  轴7正限位

    X0.7
  ──┤ ├──
  轴7负限位

    X2.7
  ──┤ ├──
  轴7回零

    R0.7
  ──┤ ├──
  轴7正限位

    R1.7
```

```
┌─────┬──────┐
│ MOV │ P103 │
│     │      │
│     │ G621 │
└─────┴──────┘

R231.0   ┌──────┬─────┐                                              R80.0
──┤├──────┤ MGET │  0  │──────────────────────────────────────────────( )──
循环启动灯 │      │     │                                            切换PMC轴
          │      │ 80  │
          └──────┴─────┘

R80.0    ┌──────┬─────┐
──┤├──────┤ MOV  │ 103 │──────────────────────────────────────────────────
切换PMC轴 │      │     │
          │      │ G620│
          └──────┴─────┘

R80.0    ┌──────┬─────┐                                              R80.1
──┤├──────┤ COIN │ 103 │──────────────────────────────────────────────( )──
切换PMC轴 │      │     │                                            PMC判断
          │      │ F630│
          └──────┴─────┘

R80.0    R80.1   ┌──────┬─────┐
──┤├──────┤├──────┤ MACK │  0  │──────────────────────────────────────────
切换PMC轴 PMC判断 │      │     │
                  │      │ 80  │
                  └──────┴─────┘

R80.1    R80.7                                                       R80.2
──┤├──────┤/├──────────────────────────────────────────────────────────( )──
PMC判断                                                             PMC轴

R80.2
──┤├──
PMC轴
```

```
┌─────┬──────┐
│ MUL │ P102 │─────────────────────────────────────
│     │      │
│     │      │
│     │      │
│     │  -1  │
│     │      │
│     │      │
│     │      │
│     │ D50  │
└─────┴──────┘


  R80.2      F561.0       F560.0      R80.3      ┌──────┬──────┐
──┤ ├────────┤ ├──────────┤/├─────┬───┤ ├───────│ AXIS │  7   │────────
                                   │            │ MOVE │      │
  PMC轴    'MC移动状态 轴7移动中  PMC轴方向       │      │      │
                                   │            │      │ P102 │
                                   │            └──────┴──────┘
                                   │
                                   │   R80.3      ┌──────┬──────┐
                                   └───┤/├────────│ AXIS │  7   │────────
                                       PMC轴方向  │ MOVE │      │
                                                  │      │      │
                                                  │      │ D50  │
                                                  └──────┴──────┘

  R80.2      F560.0
──┤ ├────────┤↑├──────────────────────────────────────────────────────
  PMC轴     轴7移动中
```
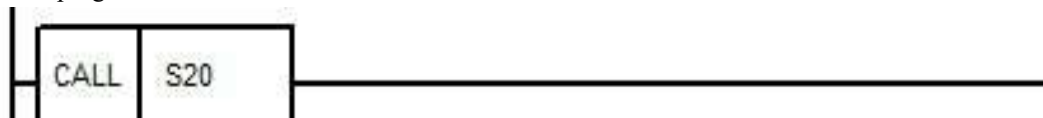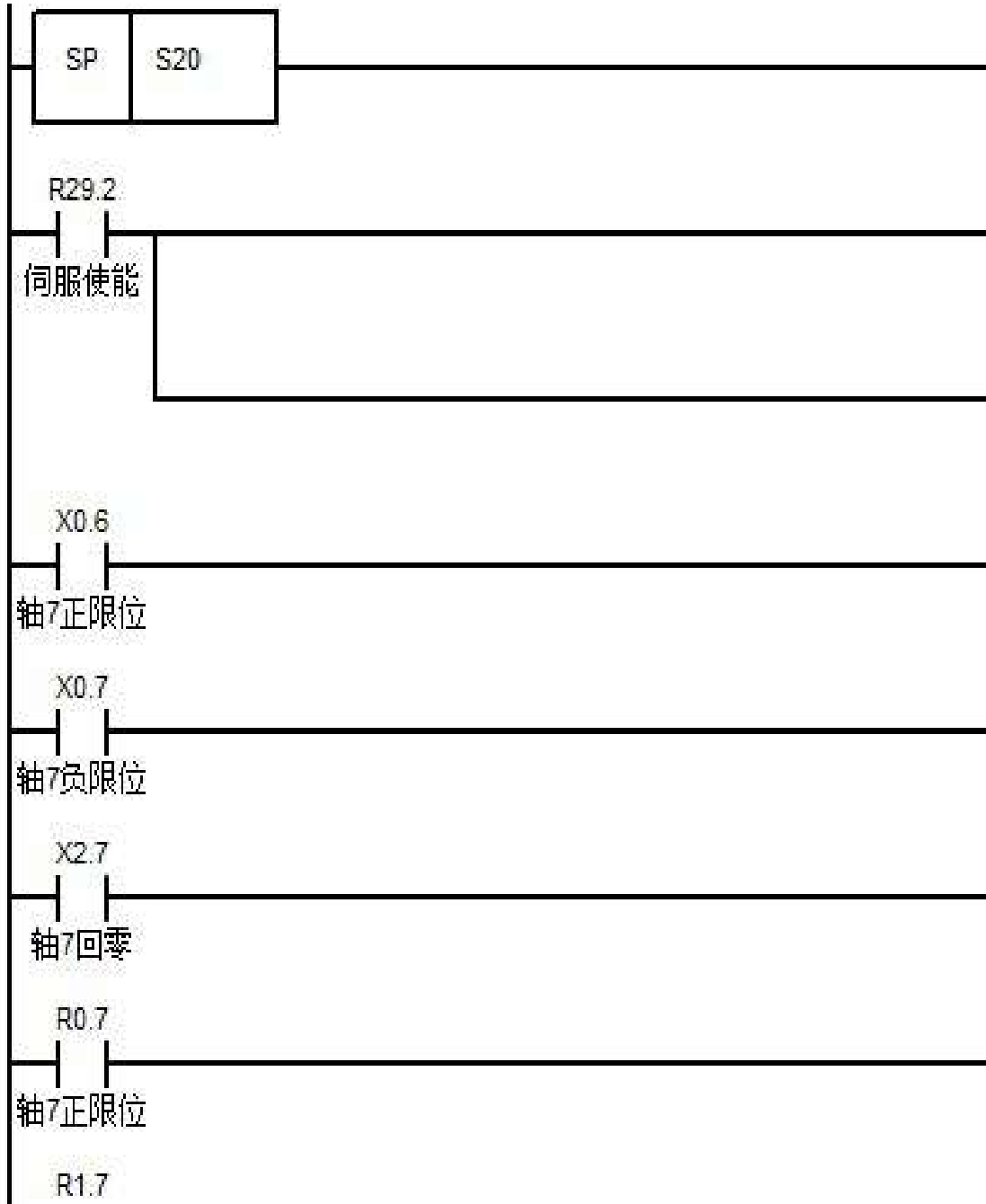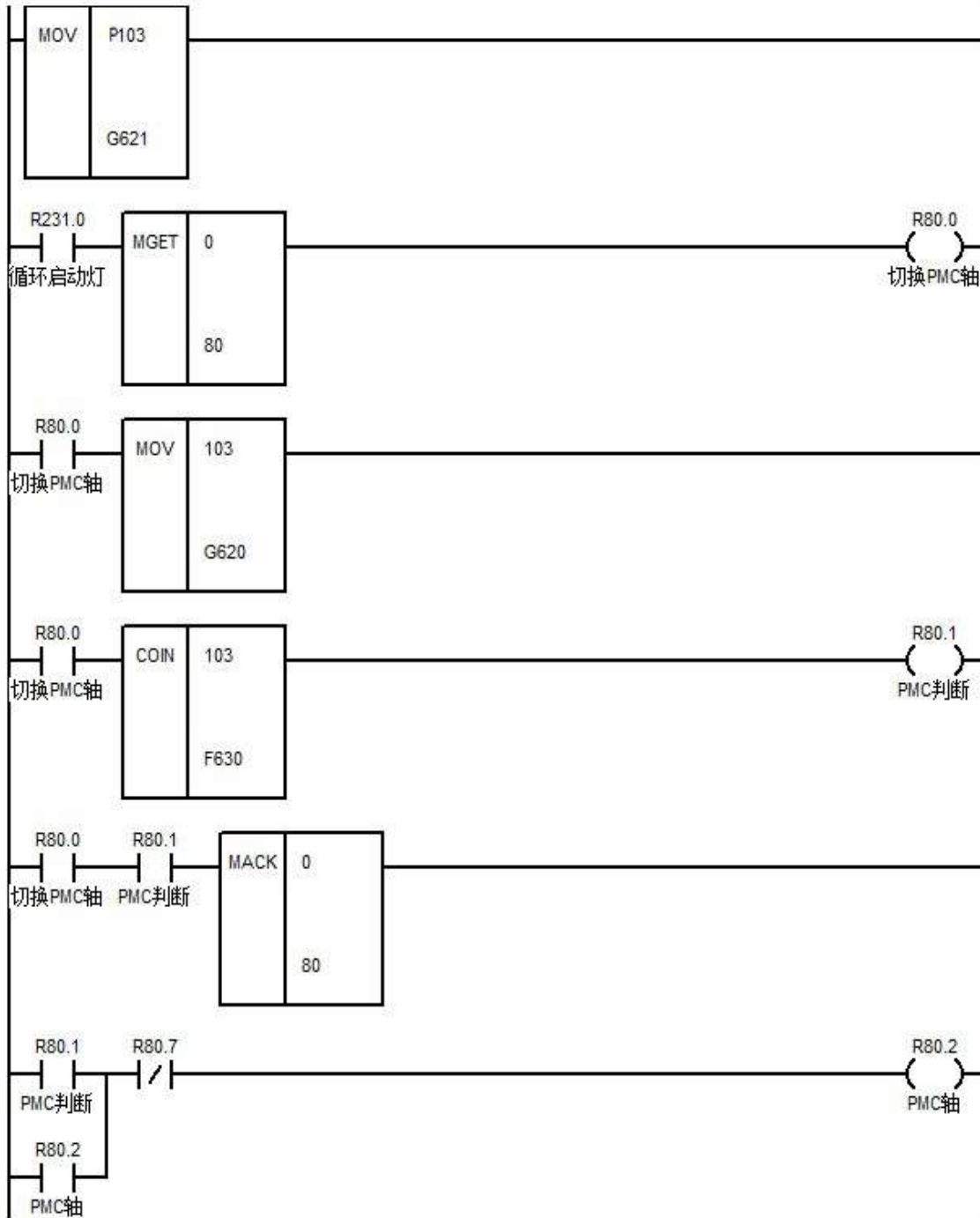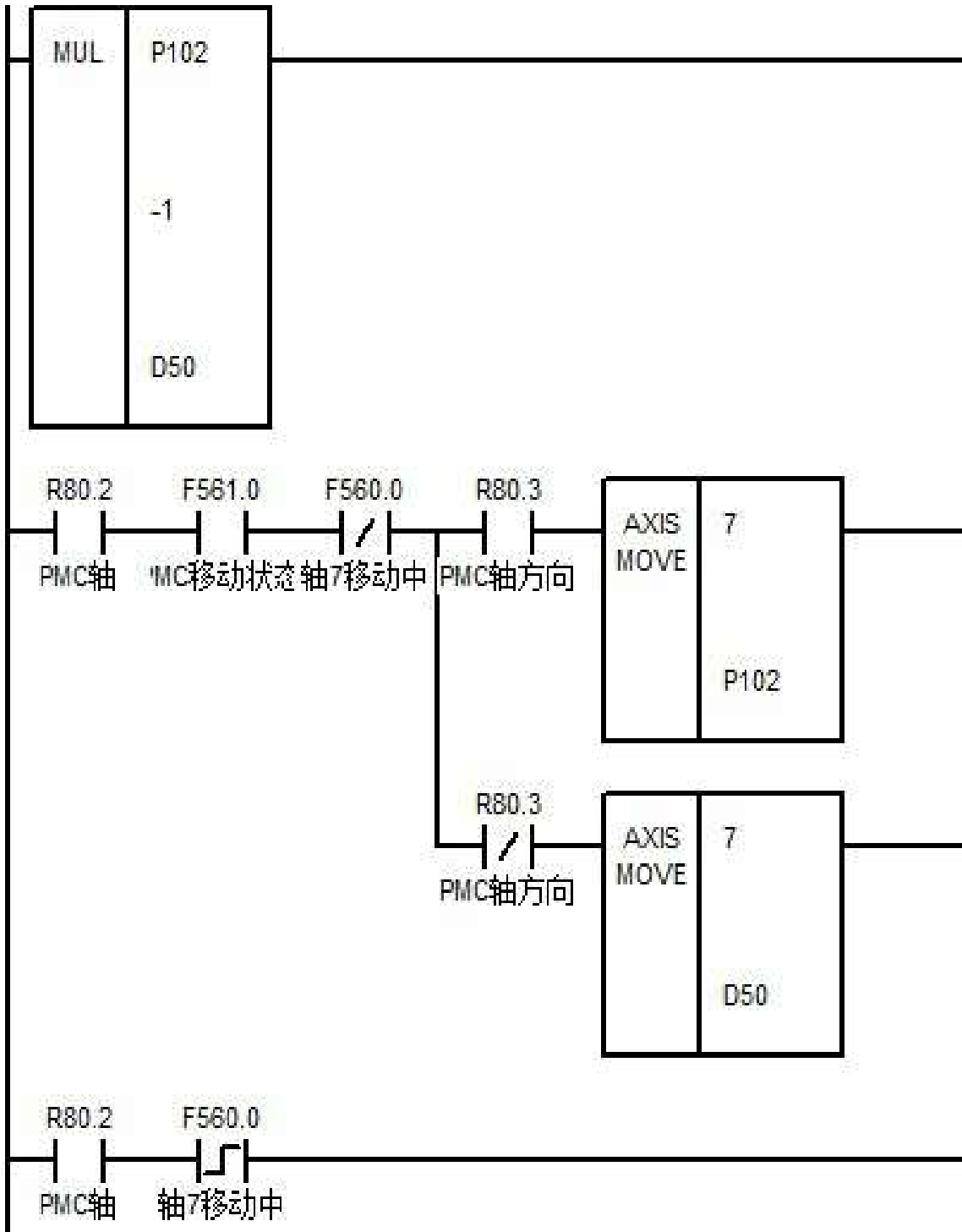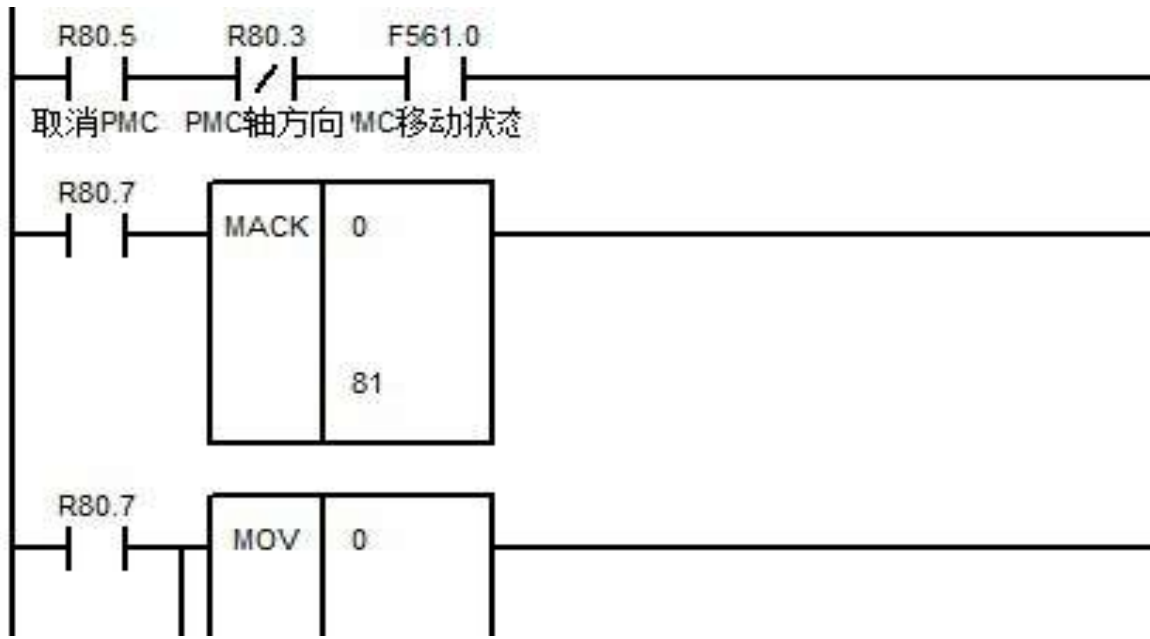
Add the following contents to reset subprogram S3:

Add corresponding user-defined canned cycle G command, e.g.:

%0182

;G82 E_R_

G01

#6 = #1163; save G90G91 modal

IF [AR[#4] EQ 0] ; if E is not defined, perform the return

G110 P-8000

ENDIF

G10 L52 P010402 R[#4 * 1000] ; assign the value after E in G82 to P102

G10 L52 P010403 R[#17] ; assign the value after R in G82 to P103

G11

G[#6] ; recover G90G91 modal

G80

M99

Programming:

G82 E_ R_

; E-Oscillation distance

; R-Oscillation speed magnification

M80: PMC axis starts oscillation

M81: PMC axis finishes oscillation

4.6.8 Axis Oscillation G Command

Format: G153 Z (logical axis number and name) distance   P oscillation speed;

Description: G153 axis oscillation command, followed by logical axis number and name, oscillation distance (incremental value) and P oscillation speed.

Remarks:

● Unit of P oscillation speed:

mm/min when logical axis is linear axis;

r/min when logical axis is rotary axis;

● Coordinate axis parameter 154 of corresponding logical axis can be used to select whether feedrate override modifies oscillation speed of G153P

● Actual oscillation speed is related to oscillation distance and acceleration/deceleration time of axis.

Format: G154 Z (logical axis number and name)   0;

Description: G154 stops axis oscillation command, followed by logical axis number and name, 0; 0 represents stop.

Example:

```
%1
G54 G0 X50
Z2                    ; locate starting point of oscillation
G153 Z-22 P500    ; oscillate back and forth within 2 to -20 at speed of 500mm/min
G1 U-1 F10          ; feed in X direction
G4 X1                ; delay oscillation
G154 Z0              ;Z stops oscillation at Z2
G0 X100 Z30
M30
```

4.7 Collision Protection Function

If a collision occurs (load current of any feed axis continuously exceeds the set collision current for a certain time) when the machine tool works, it can automatically enter the machine tool protection state: The system gives an alarm and performs emergency stop, the interface remains unchanged upon collision and cannot be switched, clicking on NCP and MCP is invalid, and the interface still remains unchanged when power off and restart the system. To exit the protection state, it requires to enter the permission password of CNC manufacturer or above.

4.7.1 Modification of Ladder Diagram

Call S73 collision protection PLC subprogram in PLC2.

Call S73 subprogram
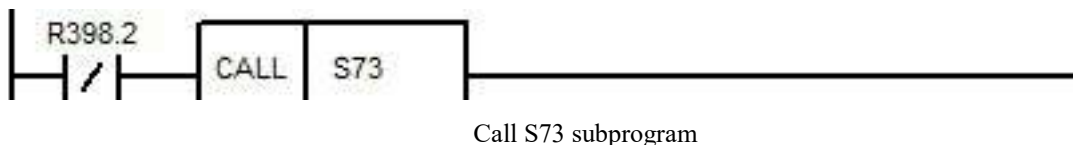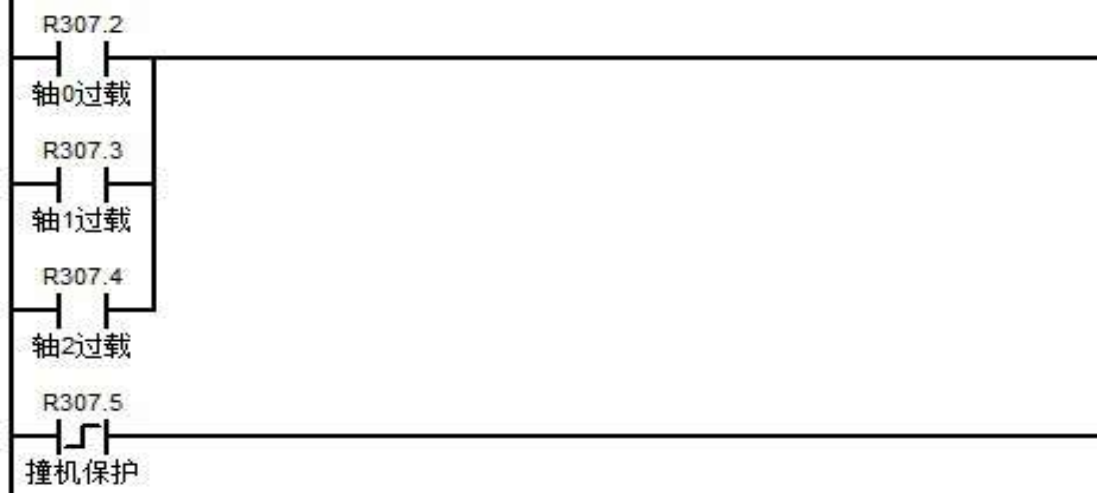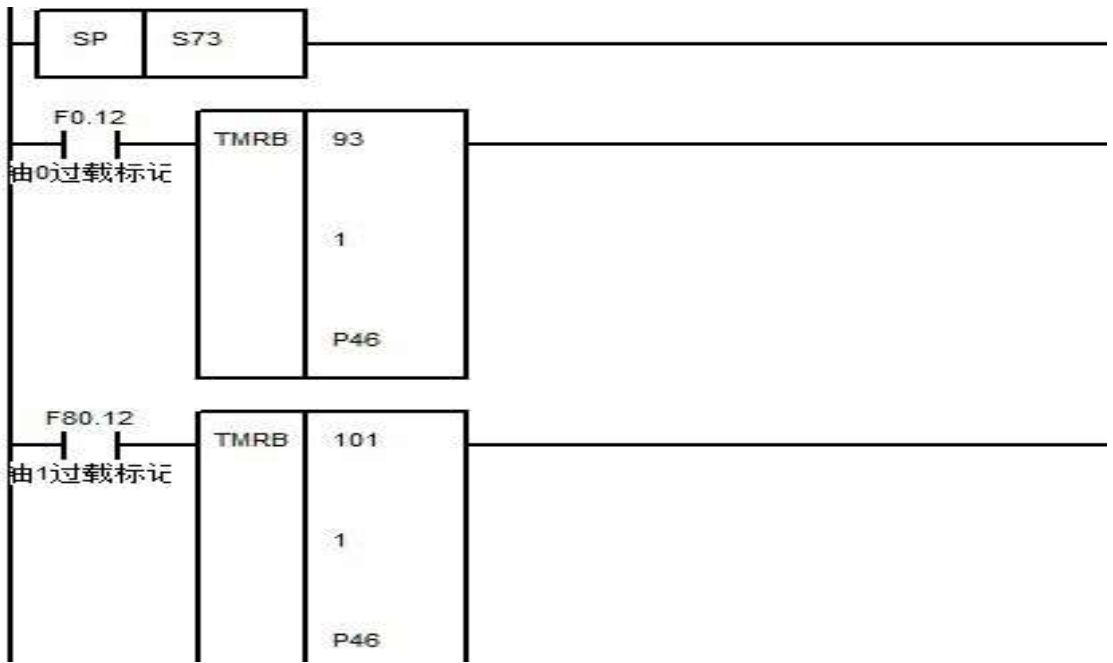
S73 subprogram

Emergency stop of system in case of collision

4.7.2 Parameter Modification

The coordinate axis parameter 10X087 Axis overload threshold (percentage of current load current of axis and motor rated current): When the ratio between load current of axis and rated motor current exceeds the set value, axis register F[ax*80].12 is 1; otherwise, it is 0.

| 100087 | 轴过载判定阈值 | 0 |

4.7.3 Enter Collision Protection State

When movement current is detected abnormal and PLC issues a collision protection signal, the system enters collision protection state:

- Any menu operation cannot be conducted;
- MCP panel is locked;
- The interface stops refreshing (including time);
- After power-off and restart, the system still maintain collision protection state;
- The interface displays a pop-up box;

4.8 Electronic Gearbox Function

"Electronic gearbox" function can be used to control transmission ratio of synchronous axis through programming and control high-precision motion coupling of spindle. 3 groups of motion (a total of 6 spindles) (master axis and slave axis) can be controlled through programming command and channel parameter.

4.8.1 Programming Command Format

Enable synchronization: G146 I_ J_ R_ P_   Disable synchronization: G147 P_

- Command parameter description:
  I: Set transmission ratio of master axis
  J: Set transmission ratio of slave axis
  R: Set phase angle deviation of master and slave axes
  P: Synchronous group number (the system has designed a total of 3 groups of axis coupling control, whose serial number is 1, 2 and 3, and 1 by default)
- System parameters corresponding to commands (channel parameters, * represents channel number):

Table 1

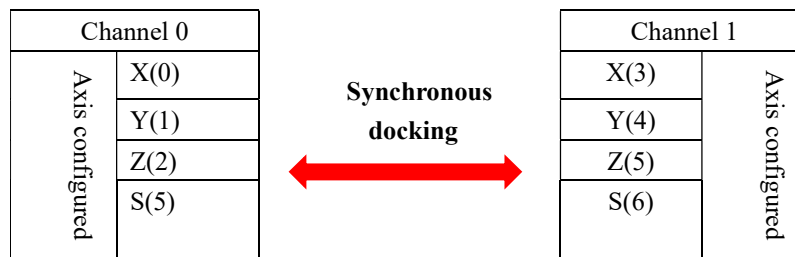| Parameter number	Parameter name	Description
04*340	Master axis number of the first group of electronic gearbox	Set logical axis number of master axis
04*341	Slave axis number of the first group of electronic gearbox	Set logical axis number of slave axis
04*342	Proportion of master axis of the first group of electronic gearbox	【I】 Set transmission ratio of master axis
04*343	Proportion of slave axis of the first group of electronic gearbox	【J】 Set transmission ratio of slave axis
04*344	Synchronization type of the first group of electronic gearbox	Set synchronization type of master and slave axes (0: Synchronization of actual position 1: Synchronization of command position)

04*345	Enable phase of the first group of electronic gearbox	Set whether to synchronize phase position when master and slave axes rotate (0: No 1: Yes)
04*346	Phase angle of the first group of electronic gearbox	【R】 Set angle of synchronous phase angle (0-360°)
04*347 -04*353	The second electronic gearbox parameters	Parameter description is consistent with the first group
04*354-04*360	The third electronic gearbox parameters	Parameter description is consistent with the first group

Note:

● If I, J and R are designated in G146 command, corresponding functions set in parameters take effect. At this time, the parameter settings in program machining command should prevail. If I, J and R are not designated in G146, the two spindle coupling control parameters should be based on the channel parameter settings (Table 1).

● When there are no P parameters in G146 instruction, the system uses parameters of the first group of electronic gearbox by default.

● If master and slave axes are set in two channels respectively, when electronic gearbox function is used, G146 command should be executed in the channel of slave axis and parameters also should be set in the channel of slave axis. Otherwise, when program runs in the channel of master axis, the system will give an alarm: Program syntax error.

● If G147 is not written in program, the system will cancel G146 mode during panel reset or emergency stop reset. Please cancel G146 synchronization using G147 during programming. Otherwise, when program runs again, the system will give an alarm: If the spindle is not ready, an alarm will be issued.

4.8.2 Application Example 1

The system offers two channels and spindles of the two channels should be synchronous to exchange workpiece (spindle 5 and spindle 6)

Parameter Setting

Parameter name	Channel 0		Channel 1		
	Parameter number	Set value	Parameter number	Set value	Description
Master axis number of the first group of electronic gearbox	040340	5	041340	0	Set axis 5 as master axis

Slave axis number of the first group of electronic gearbox	040341	0	041341	6	Set axis 6 as slave axis
Proportion of master axis of the first group of electronic gearbox	040342	0	041342	1	Set transmission ratio of master and slave axes
Proportion of slave axis of the first group of electronic gearbox	040343	0	041343	-1	
Synchronization type of the first group of electronic gearbox	040344	0	041344	0	Set synchronization based on actual situation
Enable phase of the first group of electronic gearbox	040345	0	041345	1	Enable synchronization of phase angle
Phase angle of the first group of electronic gearbox	040346	0	041346	0	

Program Example

Channel 0	Channel 1
T0101 G99	G104P1
M3 S1000 ; start master axis	M4 S200; slave axis rotates first (servo should be enabled first)
G4X2	G146 ; start synchronization (synchronization parameters are based on Table 2)
G104P1	
G104P2 ; wait for completion of synchronization	T2222
	G98
G0 Y0.0	G28 Z0.0 X0.0 F5000
G99G0 X30.0 Z15.2	G104P2
G4X0.5	G104P3
G104P3	M21; loosen the chuck automatically
G104P4	G98
G4 X0.3	G0 Z-182.0
G99G1X-2.0F0.06	G1 Z-204 F5000
M5 ; master and drive axes stop	G4 X1.0
G104P5	M20 ; tighten the chuck automatically
G104P6	G4 X0.3
M30	G104P4
	G104P5
	G28 Z0.0
	M5
	G104P6
	G147 ; finish synchronization
	M30

4.8.3 Application Example 2

The system offers a single channel, a spindle, and a power head

The power head and the spindle synchronously complete machining of 4, 6 and 8 polygons using disk (the disk has 2 tools).

Channel 0

Feed axis	X(0)
	Z(2)
Spindle	S(5)
Power head	S1(3)

Parameter Setting

	Channel 0		
Parameter name	**Parameter number**	**Set value**	**Description**
Master axis number of the first group of electronic gearbox	040340	5	Set axis 5 as master axis
Slave axis number of the first group of electronic gearbox	040341	3	Set axis 3 as slave axis
Proportion of master axis of the first group of electronic gearbox	040342	0	Set transmission ratio of master and slave axes
Proportion of slave axis of the first group of electronic gearbox	040343	0	Parameters are not set
Synchronization type of the first group of electronic gearbox	040344	0	Set synchronization based on actual situation
Enable phase of the first group of electronic gearbox	040345	1	Enable synchronization of phase angle
Phase angle of the first group of electronic gearbox	040346	0	Not set

Example Program

%1234

M103S1=0 ; enable power head (slave axis)

M3S200; start master axis

G0Z30

G146 I1 J-2 R0; transmission ratio of master and slave axes is 1: -2 (power head rotates reversely),

When R value of phase angle is 0, quadrangle is processed

T1

G0Z2

X-23

G01X-12.44F2

Z0

Z-3F1

G0X-23

M3S200

G146I1J-3R0; transmission ratio of master and slave axes is 1: -3 (power head rotates reversely),

When R value of phase angle is 0, hexagon is processed

G1X-17.6F1

Z-6

G0X-23

M3S200

G146I1J-4R0; transmission ratio of master and slave axes is 1: -4 (power head rotates reversely),

When R value of phase angle is 0, octagon is processed

G1X-20.32F1

Z-9

G0X-23

Z50

X-50

G147   ; Synchronization end

M30

4.9 Workpiece Measurement Function of Mill

After this measurement cycle is installed in the HNC-8 system, size and angle of workpiece can be measured using touch probe on machine tool. The executable measurement includes X/Y/Z single plane position measurement, intersection position measurement of two planes/three planes, boss/pocket midpoint/width measurement, inner hole/outer circle center/diameter measurement and X/Y/Z plane angle measurement. After measurement is completed, the workpiece origin can be set or the tool compensation value can be corrected automatically and the measurement results are output to macro-variables.

4.9.1 Program Content

● Program file description

Subprogram: O9726   Basic secondary measurement movement

O9801   Calibration of probe length

O9802   Calibration of eccentricity values on X and Y with probe

O9803   Calibration of radius on X and Y with probe

O9810   Protected positioning movement

O9811   Measurement of X, Y and Z planes

O9812   Measurement of boss and pocket

O9814   Inner hole/outer circle measurement

O9817   Measurement of angle of the fourth axis in X/Y direction

O9830   Protected tool length validation movement

O9843   Measurement of angle of X/Y plane

Alarm file: USR_SYTAX.TXT

Macro-variable configuration file: USERMACROVAR.CFG   USERMACROVAR.DAT

4.9.2 Output Macro-variable List

Data of probe used for measurement program (power-off save):

#600	The distance from the actual center to trigger point in X positive direction
#601	The distance from the actual center to trigger point in X negative direction
#602	The distance from the actual center to trigger point in Y positive direction
#603	The distance from the actual center to trigger point in Y negative direction
#604	Length of probe
#605	Eccentricity of probe in X direction
#606	Eccentricity of probe in Y direction
#607	Trigger radius of probe in X direction

| #608 | Trigger radius of probe in Y direction |
| #609 | Secondary measurement speed of probe (initial value is 100mm/min) |

Measured data output by measurement program:

#630	Center position of X plane or X direction (MCS)
#631	Center position of Y plane or Y direction (MCS)
#632	Position of Z plane (MCS)
#633	Positional deviation of X direction
#634	Positional deviation of Y direction
#635	Positional deviation of Z direction
#636	Size: Width/diameter
#637	Size deviation
#638	Angle (unit: °)

4.9.3 Optional Input Parameters

F	Positioning movement speed. The default is 1000mm/min by default, and an alarm will be given if it exceeds 2000
R	Safe distance. The default is 5mm
H	Tool offset number to be set. It cannot be input together with S. While calibrating length of probe, H must be input to save length of probe in the tool offset table for use by other measurement programs.
S	Workpiece coordinate system number to be set. 1-6 correspond to G54-G59 (G54.1 fine coordinate system cannot be set automatically and users can take the measured value to set it after the end of measurement program)

4.9.4 Alarm List

8050	Movement speed F is not defined
8051	Target position value is not defined
8052	While colliding with an unexpected obstacles, please manually move the axis oppositely away from obstacles
8053	Trigger signal is not detected during measurement
8057	Measurement speed Q is too large
8058	Movement speed F is too large
8059	While measuring boss or cylinder, Z value must be less than 0
8050	Nominal angle A is not within the allowable range
8051	Movement distance D is not defined
8052	X or Y is not defined
8053	X and Y are defined simultaneously
8054	S and H cannot be defined simultaneously
8055	Insufficient retreat of the probe and failure to reset

4.9.5 Setups Before Program Installation and Use of Probe:

Note before Program Installation

It must be noted before program installation that the program must be modified if macro-variables #600-#609, #630-#638 and alarms 8050-8055 conflict with macro-variables and alarms used by the system.

Copy Files to System

Copy programs and alarm files to the system through upgrading with BTF upgrade package.

Import macro-variable configuration files USERMACROVAR.CFG and USERMACROVAR.DAT to the system.

Modify PLC

Two M codes are edited for enabling and disabling the probe before use. While enabling the probe, detect whether trigger signal of the probe changes in order to detect whether the probe is enabled correctly. Add 2 PLC alarms: G3012.6 low power of probe, G3012.7 probe communication failure. Write this program in PLC2

The skip code G31 L4 is used in the measurement program. To read and write the 6th bit of #1190 and #1191, corresponding programs must be added and the program must be written in PLC1.

4.9.6 Basic Movement Program:

The probe has 2 basic movement programs, protection positioning movement O9810 and measurement movement O9726.

4.9.6.1 Protection Positioning Movement O9810

While using the probe, it is important to protect the probe tip and prevent it from colliding with workpiece or clamp. This section describes how to use protection positioning macro-program O9810 of probe. If collision occurs when the macro-program is used correctly, the probe will stop moving.
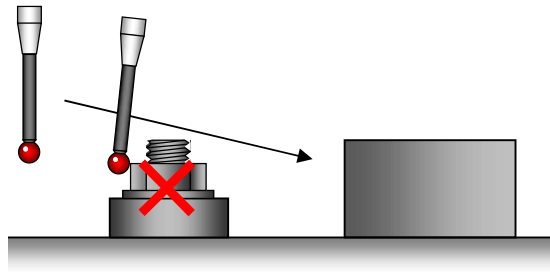
Fig. 4.1 Probe protection positioning

When the probe moves around the workpiece, it is very important to avoid collision of the probe tip. If the probe tip touches unexpected obstacles when O9810 cycle is used, the machine tool stop moving immediately, the program stops and the axis should be moved away from obstacles manually.

Application

Select a probe and move it to a safe position. The probe should be valid in this position. Call the macro-program and the probe can move to a measurement position.

In case of collision, the machine tool will stop. And alarm is issued: -8052 collides with obstacles, please move the axis oppositely away from obstacles"

(Alarm is called by the command G110 P-8052 in cycle and alarm content is defined in USR_SYTAX.TXT)

● Format:

G90/G91 G65 P9810 X_Y_Z_(F_)

X/Y/Z: Target position of probe. When multiple axes are input simultaneously, interpolation movement is conducted.

F: Movement speed of probe. (f ≤ 5000, otherwise, an alarm is given: -8058 positioning speed F is too large)

● Example:

G54

G90 G0 X20. Y30.

G43 H20 Z100.   Move to a safe position

M26   Start probe

G65 P9810 Z10. F3000   Protect positioning movement

G65 P9726 Z-5.   Measure a single plane

… …

● Action:

The probe moves to the target position at speed F. If it touches unexpected obstacles, it will move back 4mm

Z axis returns to zero and an alarm is issued. For multi-axis interpolation, each axis moves back 4mm.

● Note:

When probe is used, machine tool must be moved using O9810 except it is moved manually or by measurement program.

4.9.6.2 Measurement movement O9726

This movement is the basic secondary measurement cycle used in all measurement processes and is not required to be called separately. Relevant parameters of measurement movement can be modified as needed.
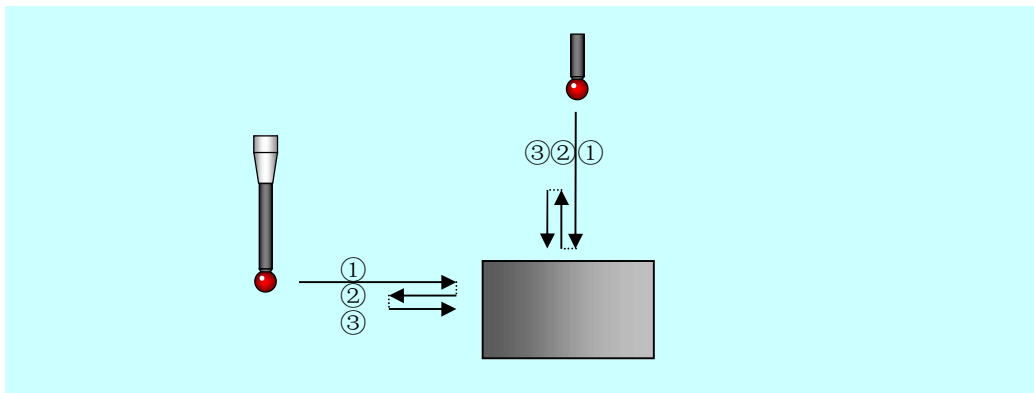
Format

G90/G91 G65 P9726 X_Y_Z_ (F_)

X/Y/Z: Target position of measurement movement. Only a single axis can be input; otherwise any movement is not allowed.

F: The speed at which the first movement measurement is triggered. (The default is f $=$ 1000. f $\leq$ 2000; otherwise, an alarm will be issued)

The speed at which the second movement measurement is triggered is set by the variable #609 and the initial value is 100mm/min.

Action

● The probe moves to the target position at the specified rapid traverse speed F, and the actual target position is the input target position + overtravel distance. The overtravel distance is 10mm by default and can be modified in the macroprogram;

● After touching the target position, the probe retracts 2mm. The retract distance can be modified in the macroprogram in order that the probe exits the touch contact;

● After the probe retracts, it moves forward again at #609 slow speed for 2 times the retreat distance, namely

4mm;

● After touching the target position again, the probe identifies the accurate position, stops moving and waits for the subsequent programs to process the value.

4.9.7 Probe Calibration Program:

After probe is installed and before it is used for measurement, related data must be calibrated in order to ensure measurement accuracy. There are 3 calibration cycles, length calibration O9801, eccentricity calibration O9802 and radius calibration O9803. There are no requirements for order of use of calibration cycles.

4.9.7.1 Length Calibration O9801

When length of probe is calibrated on a known plane, the length of probe based on electronic trigger point will be stored. It is different from the physical length of the probe component.
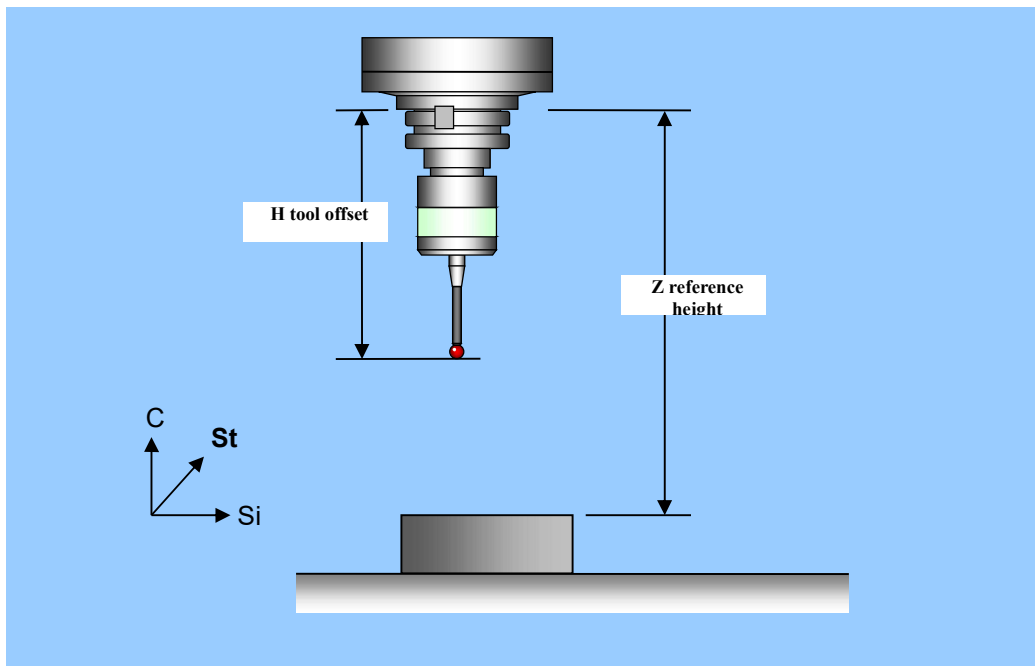
When length calibration is used, the system calculates length based on the machine coordinate system, so G43 the tool length offset cannot be used.

Format

G90/G91 G65 P9801 Z_ H_ (F_)

Z: Nominal position of calibration surface, can be set using G90 or G91, but the target position of Z axis must be in the negative direction.

H: Target address of probe length. (Current tool number)

F: Measurement positioning speed. (The default is f $=$ 600. f $\leq$ 2000; otherwise, an alarm will be issued)

Action

● Z axis moves from the current point to the target point at the given feedrate.

● After the standard plane is touched; (secondary measurement)

● Return to the initial measurement point and the measurement finishes.

Result

Calculate the difference between the measured position and the nominal position, and save it in #54104 and the tool offset represented by H.

4.9.7.2 Eccentricity Calibration O9802

Due to manufacture and assembly errors of shank, probe and probe tip, the ruby sphere center of the probe does not coincide with the rotation center line of the spindle, so probe must be calibrated before it is used for automatic measurement.
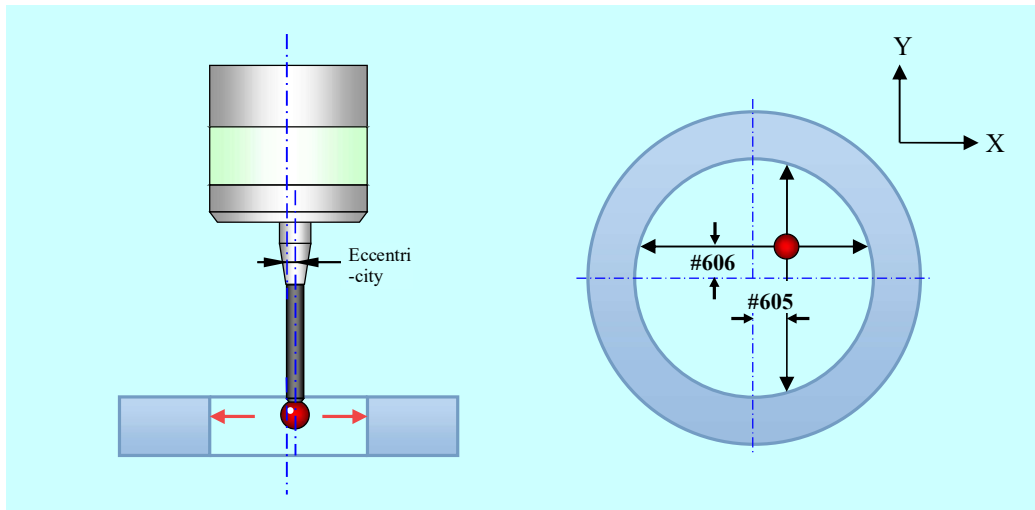
Position the probe in the bored hole and execute eccentricity calibration cycle, the system will store eccentricity of the measuring ball relative to the center line of the spindle automatically. The stored data will be used for measurement cycle automatically.

Application

It is used to compensate measurement results in order to acquire the position of the spindle center. First, bore a hole using a boring tool in order to identify the accurate center position of the hole. Then, locate the calibrated probe in the hole deep enough for calibration and locate the spindle in the known center position when the spindle orientation is effective. Ensure the spindle center is in the circle center before measurement.

- **Format:**

  G90/G91 G65 P9802 D_ (Z_ R_ F_)

  D: Diameter of bore hole, which need not be very accurate.

  Z: It is allowed to calibrate with the outer surface of the cylinder, and Z value is the position of measurement point in Z direction.

  R: Safety distance when measuring with outer surface of cylinder.

  F: Measurement positioning speed. (The default is f = 600. f ≤ 2000; otherwise, an alarm will be issued)

- **Action:**

  ①. Conduct measurement movement twice in X negative direction and Y positive direction successively

  ②. Return to the starting point

  ③. Conduct measurement movement twice in Y negative direction and X positive direction successively

  ④. Return to the starting point

- **Result:**

Calculate eccentricity value in X and Y directions and save them in #605 and #606.

4.9.7.3 Radius Calibration O9803 of Probe in X And Y Directions

When electronic trigger probe is used for measurement and the sphere just touches the measured surface, trigger signal will not be produced. There must be a small amount of squeeze to make the electronic sensor of the probe capture the trigger action and send out a signal. This displacement is reflected on the radius of sphere, referred to as trigger radius.
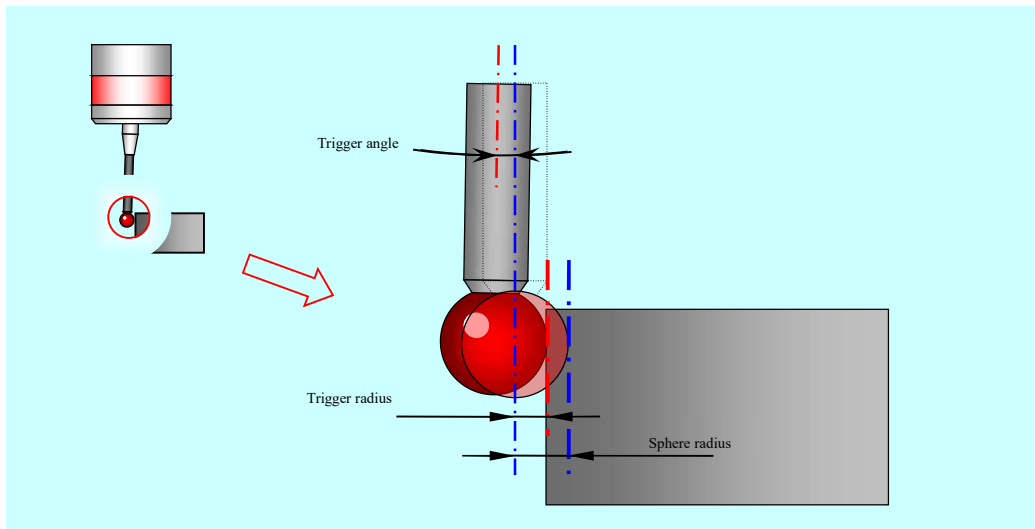
Description

Calibrating the probe with a ring gauge with a known diameter will automatically store the radius value of the probe. The stored data will be used for measurement cycle automatically in order to obtain actual size of profile. These values are also used to obtain the real position of a single plane. The stored radius value is based on the real electronic trigger point and is different from physical size.

Application

First, fix the ring gauge in a similar known position on the machine tool worktable. When the spindle orientation is effective, locate the probe to be calibrated close to the center of the ring gage before measurement.

- **Format:**

G90/G91 G65 P9803 D_ (Z_ R_ F_)

D: Accurate size of ring gage.

Z: Outer surface of cylinder can be used for calibration and Z value is the height of the measurement plane in Z direction.

R: Safety distance when measuring with outer surface of cylinder.

F: Measurement positioning speed. (The default is f $=$ 600. f $\leq$ 2000; otherwise, an alarm will be issued)

- **Action:**

①. Conduct measurement movement twice in X negative direction and Y positive direction successively

②. Return to the center position of two touch points and ensure the sphere is at the center point of X direction

③. Conduct measurement movement twice in Y negative direction and X positive direction successively

④. Return to the center position of two touch points, ensure the sphere is at the center point of Y direction and calculate trigger radius in Y direction

⑤. Conduct measurement movement twice again in X negative direction and X positive direction successively

⑥. Return to the center position of two touch points and calculate trigger radius in X direction
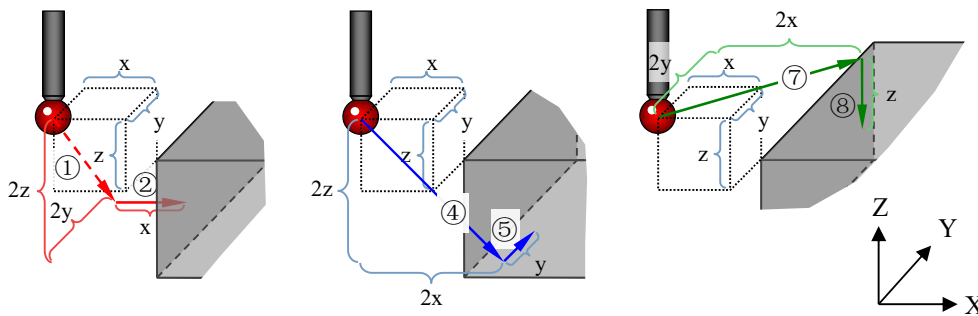
● **Result:**

Calculate trigger radius values of sphere in X and Y directions and save them in #607 and #608.

4.9.8 Measurement Program

4.9.8.1 XYZ Planes Measurement O9811

This program measures the position of a plane or the intersection position of multiple planes.

Application

When spindle orientation and probe & tool length offset are effective, move the probe to beside the plane or the intersection point to be measured through positioning movement or manual movement (ensure there is a certain distance from each plane) before measurement.

Format

G90/G91 G65 P9811 X_Y_Z_(S_ H_ F_)

X/Y/Z: Distance form starting measurement point to nominal distance (G91), or measurement position (G90).

S: Workpiece coordinate system number to be set: 1-6 correspond to G54-G59.

H: Tool offset number to be set, cannot be input together with S.

F: Measurement positioning speed. (The default is f $=$ 1000. f $\leq$ 2000; otherwise, an alarm will be given)

Action

● Move twice the set distance on both Y and Z simultaneously, and this is the starting point of measurement in X direction

● Start measurement in X direction from the starting measurement point in X direction and return to the starting measurement point in X direction after measurement

● Return to the starting point

● Move twice the set distance on both X and Z simultaneously, and this is the starting point of measurement in Y direction

● Start measurement in Y direction from the starting measurement point in Y direction and return to the starting measurement point in Y direction after measurement

● Return to the starting point

● Set a double of XY distance while moving in XY direction, it is the starting measurement point in Z direction

- Start measurement in Z direction from the starting measurement point in Z direction and return to the starting measurement point in Z direction after measurement
- Return to the starting point

Note:

If XYZ distance is not input while calling program, the measurement process in the direction will be ignored during movement. e.g.: If only Y, Z values are input but X value is not input, processes ①-③ will not be executed and there is no movement in X direction in processes ④ and ⑦.
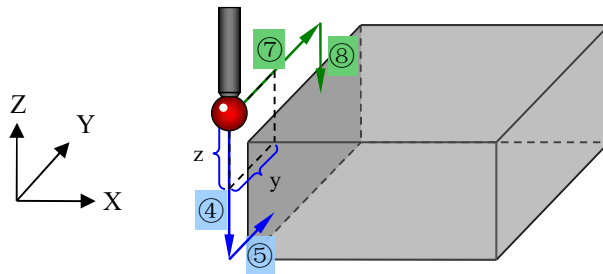
Result

Write the measured position in the set coordinate system or write the difference between the measured position and the nominal position in the set tool compensation data. And output related data to macro-variables.

4.9.8.2 Boss/Pocket Measurement O9812
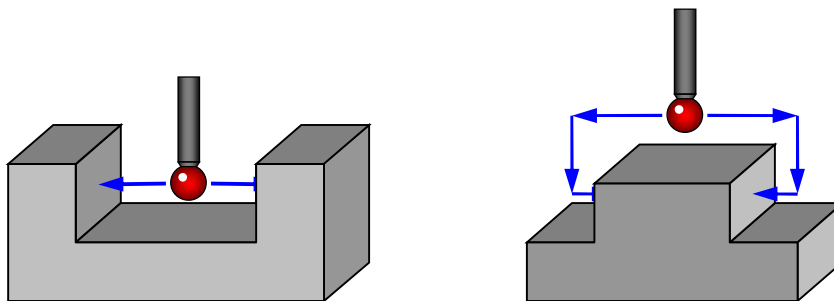
Application

The program measures width and center position of boss or pocket. When spindle orientation and probe & tool length offset are effective, move the probe to the position near the center of boss, or into the pocket center through positioning movement or manual movement before measurement.

- Format:

    G90/G91 G65 P9812 X_ / Y_ (Z_ F_ S_ H_)

    X/Y: Nominal width of measured boss or pocket, X and Y represent measurement directions and cannot be set simultaneously.

    Z: Position of measurement point in Z direction while measuring the boss

- Action:

Pocket

①. Move in the negative direction to the first starting measurement point (A safe distance R from the pocket boundary)

②. Conduct measurement movement in the negative direction from the first starting measurement point and return to the first starting measurement point after measurement

③. Move in the positive direction to the second starting measurement point A safe distance R from the pocket boundary)

④. Conduct measurement movement in the positive direction from the second starting measurement point and return to the second starting measurement point after measurement

⑤. Return to the center point

Boss:

①. Move to above the first starting measurement point in the negative direction (a safe distance R beyond the boundary of the boss)

②. Z axis moves down to the first starting measurement point

③. Conduct measurement movement in the positive direction from the first starting measurement point and return to the first starting measurement point after measurement

④. Return to above the first starting measurement point

⑤. Move to above the second measurement starting point in the positive direction (a safe distance R beyond the boundary of the boss)

⑥. Z axis moves down to the second starting measurement point

⑦. Conduct measurement movement in the negative direction from the second starting measurement point and return to the second starting measurement point after measurement

⑧. Return to above the second starting measurement point

⑨. Return to the center point

● Result:

Write the measured center point position in the set coordinate system or divide the difference between the measured width and the nominal position by 2 and write it in the set tool compensation data. And output related data to macro-variable.

4.9.8.3 Inner Hole/Outer Circle Measurement O9814

The program measures diameter of inner hole or outer circle and position of circle center.
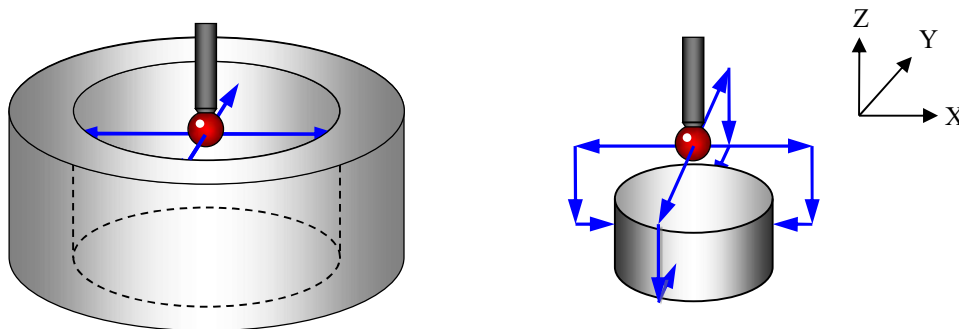
Application

When spindle orientation and probe & tool length offset are effective, move the probe to near the circle center into the groove or above the boss through orientation or manually before measurement.

● **Format:**

G90/G91 G65 P9814 D_(Z_ F_ S_ H_)

D: Nominal diameter of measured inner hole and outer circle

Z: Position of measurement point in Z direction while measuring outer circle

● **Action:**

The action process is basically the same as the procedure for measuring the boss/pocket. The center measurement is executed twice in X and Y directions to measure position of circle center and diameter of circle. The specific process is not repeated.

● **Result:**

Write the measured circle center position in the set coordinate system or divide the difference between the measured diameter and the nominal diameter by 2 and write it in the set tool compensation data. Output related data to macro-variables.

4.9.8.4 X/Y Plane Angle Measurement O9843:

The measurement in X or Y direction is performed in two positions to determine the inclined angle between the plane and X+ direction.
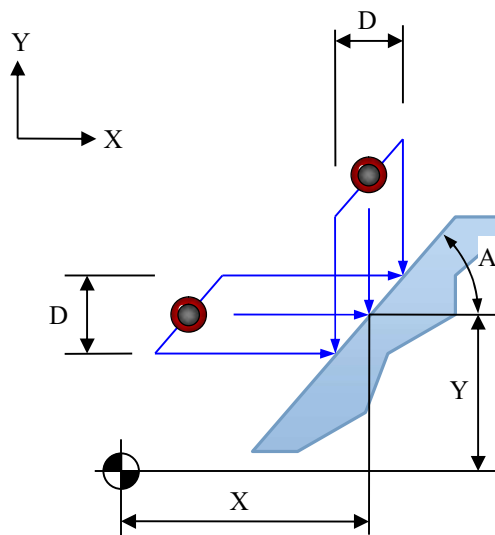
Application

When spindle orientation and probe & tool length offset are effective, move the probe to beside the measured plane through positioning movement or manual movement before measurement.

Format

G90/G91 G65 P9843 A_ X_ / Y_ D_

A: Nominal angle of the measured plane (inclined angle with X+ direction ±90°)

X/Y: Target position and direction of measurement movement. X and Y cannot be set simultaneously

D: The distance from the second starting measurement point to the first starting measurement point

Action

①. Conduct measurement movement in the set X or Y direction. After measurement, return to the starting point, namely the first measurement starting point

②. Move the distance set as per D value along the set angle to reach the second starting measurement point

③. Conduct measurement movement in the set X or Y direction. After measurement, return to the second starting measurement point

④. Return to the starting point

169

Result

Calculate the inclined angle between the measured plane and X+ direction according to the measured position value and output the angle to macro-variable.

4.9.8.5 Angle Measurement of the Fourth Axis In X/Y Direction O9817

The program measures the inclined angle between the plane and the horizontal plane along X direction or Y direction and compensates error through rotation angle of the fourth axis.
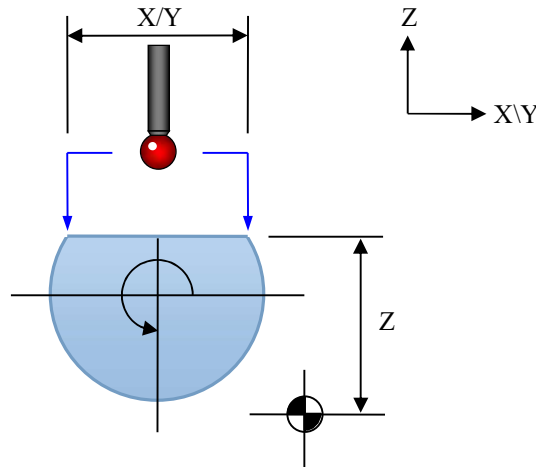
Application

When spindle orientation and probe & tool length offset are effective, move the probe to above the measured plane through positioning movement or manual movement before measurement.

Format

G90/G91 G65 P9817 X_ /Y_ Z_

X/Y: It represents the movement distance and direction of the second measurement point

Z: Nominal position of the measured plane

Action

①. Conduct measurement movement in Z direction and after measurement return to the starting point, namely the first measurement point

②. The distance and direction to move to the second measurement point

③. Conduct measurement movement in Z direction and after measurement return to the second starting measurement point

④. Return to the starting point

Result

Calculate the inclined angle between the measured plane along the set direction and the horizontal plane according to the measured position value and output the angle to macro-variables

4.9.8.6 Protected Tool Length Validation Movement O9830

The program measures the inclined angle between the plane and the horizontal plane along X direction or Y

direction. When spindle orientation and probe & tool length offset are effective, move the probe to above the measured plane through positioning movement or manual movement before measurement.

Format

G90/G91 G65 P9830 H_ Z_ (F_)

H: Tool length compensation number to be validated, the same as H of G43

Z: Target position of tool length compensation validation movement, the same as Z of G43

Action

The machine will move to the position of Z with G31 and starts tool length compensation using G43 (actual movement will not be produced since it is in the current position) in order to protect movement

4.10 Lathe Tool Measurement User Manual

Lathe tool measurement function is used to measure tools and set tool offset with tool setter on the lathe in order to realize continuous and automatic machining, thereby improving machining quality and efficiency.

4.10.1 Brief Procedure of Lathe Tool Measurement

Tool measurement process of HNC CNC lathe system: 01. Lathe tool calibration; 02. Tool measurement; 03. Offset setting. The main interface of tool measurement menu is shown below:

Precondition and brief operation procedure of tool measurement

Steps	Operation contents
1	Enter the setup interface, type the password, 【Parameter】->【System parameter】->【Enter password】. And modify PLC, add G31 skip statement of 【ESCBLK】 in PLC.
2	Enter the sub-interface of 【Tool measurement】 interface: 【Tool measurement】->【Measurement parameter】->Set parameter: Fill in length of measuring instrument, width of measuring instrument, standard tool nose direction, measurement times, measurement speed and trigger speed.
3	Lathe tool calibration, note: Calibration is the precondition for measurement: After parameters in the 【Parameter】 attribute page are set, press 【Lathe tool calibration】 to enter the lathe tool calibration interface, complete the operation process according to interface prompts and press

	【Start measurement】 and 【Cycle Start】 to start automatic tool calibration.
4	Lathe tool measurement: Press 【Lathe tool measurement】 to enter the lathe tool measurement interface, set tool nose direction of each tool, select 【Start】 in the list box after the tool number to be measured and press 【Cycle Start】, the system will complete the measurement process of each lathe tool automatically.
5	Offset setup: Offset setup is used to set lathe tool offset. Press 【Offset setup】 to enter the offset setup interface and complete setup operation according to prompt message in the interface.

Note: Press 【Start measurement】 before starting lathe tool calibration and lathe tool measurement. If an emergency occurs in the measurement process, press 【Feed hold】 to stop the program and 【Stop measurement】 to end the measurement process. Whereas the measurement process cannot be interrupted, press 【Stop measurement】 to finish measurement.

4.10.2 Preparatory Work

PLC Modification for Lathe Tool Measurement

● For the parts to be added to PLC, find four input points of tool measuring instrument and add 【ESCBLK】 skip statement G31L1 to PLC1. The internal regulations of the system must be 【ESCBLK】【0】【1】, as shown below,

Note: X3.0, X3.1, X3.2 and X3.3 are four input trigger signals of tool setter of lathe for testing

Lathe Tool Calibration Parameter Diagram
Lathe tool calibration is the precondition for lathe tool measurement. Calibrate the standard tool first, then measure other tools, and finally set tool offset value.
Fig. 1 is lathe tool measurement parameter diagram and there are 10 parameters, as shown below:

Fig. 1 【Lathe tool calibration】 parameter diagram

- Lathe tool calibration parameter diagram

Parameter name	Function and value range
Length of measuring instrument	Length of measuring instrument (along X axis) (parameter D)
Width of measuring instrument	Width of measuring instrument (along Z axis) (parameter E)
Calibrate tool nose direction	Calibrate tool nose direction, (parameter A, X direction; parameter B, Z direction), The value is within 0 to 9 0, 3, 7, 8 and 9 mean that the tool nose direction is the X positive direction and the Z positive direction 1 means that the tool nose direction is the X negative direction and the Z negative direction 2 and 6 mean that the tool nose direction is the X negative direction and the Z positive direction 4 and 5 mean that the tool nose direction is the X positive direction and the Z negative direction
Measurement times	It represents the times that the tool to be measured touches the same point on the measuring instrument, (parameter I) (the lathe tool touches P1 and P2 successively. This parameter means that the times of touching P1 is equal to the times of touching P2). The larger times is, the higher measurement accuracy is and the longer consumed time is. The value is greater than or equal to 2 and less than or equal to 5.
Measurement speed	The speed when the tool touches P1 point on the surface of the measuring instrument for the first time and the speed that the tool retracts from P1 and P2 points on the surface of the measuring instrument (parameter F)
Trigger speed	Speed when the tool touches P1 and P2 points on the surface of the measuring instrument (except the speed when the tool touches P1 on the surface of the measuring instrument for the first time) (parameter Q) P1 absolute position (Z direction): Z axis position value of P1 point on the surface of the measuring instrument (cannot be directly input by the user)

	P2 absolute position (X direction): X axis position value of P2 point on the surface of the measuring instrument (cannot be directly input by the user)
	P3 absolute position (Z direction): Z axis position value of P3 point on the surface of the measuring instrument (cannot be directly input by the user)
	P4 absolute position (X direction): X axis position value of P4 point on the surface of the measuring instrument (cannot be directly input by the user)

- Lathe tool measurement parameter diagram

Fig. 2 is lathe tool measurement parameter diagram and there are 4 parameters, as shown below

Fig. 2 【Lathe tool measurement】 parameter

【Lathe tool measurement】 parameter description:

Parameter name	Function and value range
Tool number	Tool number
Tool nose direction	Mounting direction of the nose of the tool to be measured, tool nose direction, the value is within 0-9 0, 3, 7, 8 and 9 mean that the tool nose direction is X positive direction and Z positive direction 1 means that the tool nose direction is X negative direction and Z negative direction 2 and 6 mean that the tool nose direction is X negative direction and Z positive direction 4，5 means that the tool nose direction is X positive direction and Z negative direction
Length 1	Length of tool on X relative to measuring instrument (radius display)
Length 2	Length of tool on X relative to Z measuring instrument

- Offset setting parameter

Fig. 3 is offset setting parameter diagram and there are 6 parameters, as shown below:

Fig. 3【Offset setting】parameter

Lathe offset setting parameter description:

Parameter name	Function and value range
Standard tool number	Standard tool number
Initial offset value of standard tool	1 means to use the original tool offset of the standard tool; 0 means to set the standard tool offset value by manual precutting
Precutting diameter	Precutting diameter of lathe tool (X direction)
Precutting length	Precutting length of lathe tool (Z direction)
Offset on X relative to measuring instrument	The distance from the workpiece center to the measuring instrument center in X direction (it equals to current machine coordinates - precutting diameter/2 - measured length value 1 of current tool number)
Offset on Z relative to measuring instrument	The distance from the workpiece center to the measuring instrument center in Z direction (current machine coordinates - precutting length - measured length value 2 of current tool number)
	Remarks: Z offset of corresponding tool number in tool offset is the offset on Z relative to measuring instrument+ measured length 2 of corresponding tool number X offset of corresponding tool number in tool offset is the offset on X relative to measuring instrument + measured length 1 of corresponding tool number

4.10.3 Detailed Process of Lathe Tool Measurement

Enter the setup interface, type the password, 【Parameter】-> 【System parameter】->【Enter password】. The operation process is omitted. It should be noted that password must be entered to use this function; otherwise, the system will give a prompt message of permission denied.

Enter the sub-interface of 【Tool measurement】 interface: 【Tool measurement】->【Measurement parameter】 ->Set parameters of tool setter: Fill in length of measuring instrument, width of measuring instrument, standard tool nose direction, measurement times, measurement speed and trigger speed. The interface is shown below:

Operation process: Fill in the following parameters necessary for measurement. Please fill in the following values in the measurement process according to actual situation:

Parameter name	Length of measuring instrument	Width of measuring instrument	Tool nose direction	Measurement times	Measurement speed	Trigger speed
Test parameter value	40	40	3	3	300	50
Description	Actual length of measuring instrument	Actual width of measuring instrument	The lathe has a total of 9 tool nose directions	No more than 5 times	Speed of touching G01 for the first time	Actual measurement speed of G01

Note: The absolute position of P1P2P3P4 in the interface cannot be set in the 【Measurement parameter】 interface and should be set in the 【Lathe tool calibration】 interface.

Lathe Tool Calibration

Note: Calibration is the precondition for measurement. After parameters in the 【Parameters】 attribute page are set, press 【Lathe tool calibration】 to enter the lathe tool calibration interface and complete the operation process according to prompt messages in the interface. The interface is shown below:

Operation process:

1)   In JOG mode, move the cursor to the position of P1. Then, move XZ axis manually to P1 point of Z axis which is very close to tool measuring instrument and do not touch P1 point. Then, Press Enter and the interface will give a prompt message: Press Y[Yes] to confirm.

2)   In JOG mode, move the cursor to the position of P2. Then, move XZ axis manually to P2 point of Z axis which is very close to tool measuring instrument and do not touch P2 point. Then, Press Enter and the interface will give a prompt message: Press Y[Yes] to confirm.

3) Press 【Start measurement】 and a prompt message 【Program load completed, please press Cycle Start】 will be given. Then, switch the operation mode to 【Auto】 and press Cycle Start to start automatic tool measurement program.

Note: When automatic tool measurement function is used for the first time, please pay attention to the action in the measurement process and control the measurement speed using magnification button. Besides, in case of an accident, please press 【Stop measurement】 and emergency stop button to avoid damaging to tool setter.

Lathe Tool Measurement

Press 【Lathe tool measurement】 to enter the lathe tool measurement interface, as shown below:

Operation process:

Steps	Operation contents
01	Set each tool to be measured and pay attention to mounting direction of the tool nose, which must be filled out correctly;
02	Select 【Start】 in the list box after the tool number to be measured and press 【Start measurement】;
03	Then, press 【Cycle Start】, and the system will complete the measurement process of each in-service lathe tool automatically.
04	Note: Press 【Cycle Start】 and a prompt message *Execute G code and wait for user intervention* may occur when the measurement program runs. After the operator confirms that there is no measurement error, press 【Cycle Start】 and the measurement program will continue running.

Offset Setting

Offset setting is used to set the lathe tool offset. Press 【Offset setup】 to enter the offset setting interface, as shown below:

Operation process:

Steps	Operation contents
1	Set standard tool number: Select a tool from the measured tools as the standard tool.
2	Whether to use the original tool offset value: If the standard tool has undergone precutting, fill in 1 to call the original tool offset value of the standard tool. If the standard tool has not undergone precutting or precutting should be conducted again, fill in 0.
3	Precutting diameter and length: If precutting should be conducted again, please move the tool to the workpiece surface, record diameter and length of workpiece and fill in them respectively.
4	After tool offset is set, the offset value has been updated automatically. Please switch to the tool offset interface to check whether offset value has been updated.

Note:

Before starting lathe tool calibration and measurement, press 【Start measurement】. If an emergency occurs in the measurement process, press 【Feed hold】 to stop the program and 【Stop measurement】 to end the measurement. Whereas the measurement process cannot be interrupted, must press 【Stop measurement】 to finish measurement.

4.10.4 Appendix: Lathe Tool Measurement Principle

● Tool measurement process: Calibrate and then measure. Calibration is the precondition for measurement. Finally, set the tool offset value.

Lathe tool calibration diagram
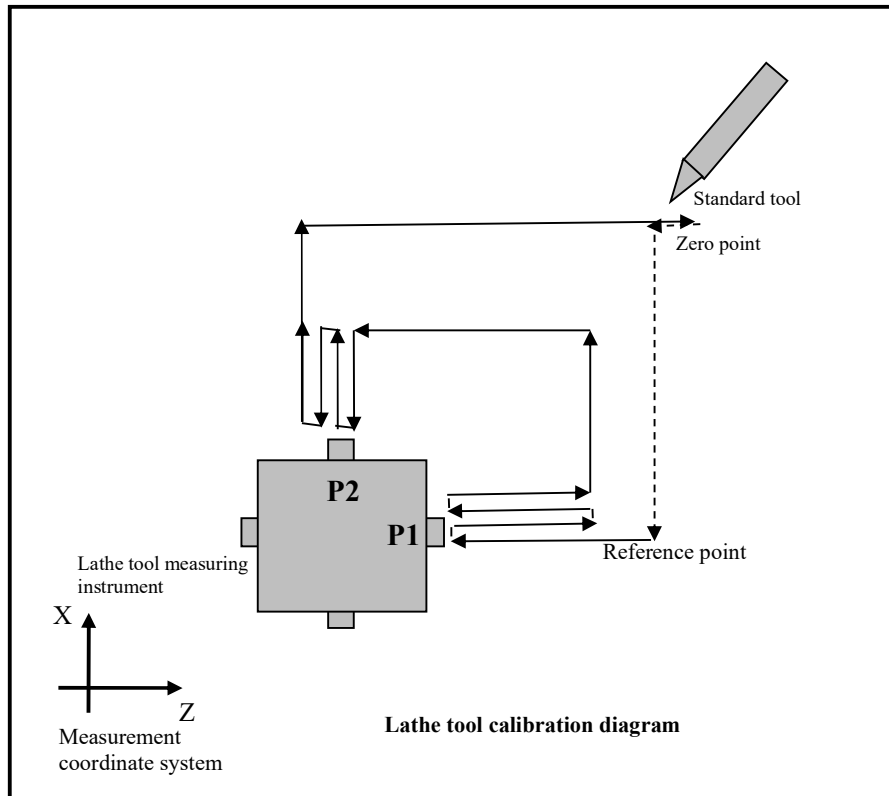
● Lathe tool calibration process:

Calibration steps	Lathe tool calibration and measurement
01	Return to the machine zero and locate to the reference point (Z axis: Coordinates of P1 point-half of measuring instrument width; X axis: Coordinates of P2 point-half of measuring instrument length).
02	Move in Z direction and touch P1 point of the probe for the first time, and the speed is Q.
03	After touching the surface of the measuring instrument, the tool retracts 20mm, and the speed is Q
04	The tool moves in Z direction and touches P1 point of the probe, and the speed is K
05	After touching the surface of the measuring instrument, the tool retracts upwards for 20mm, speed is Q
06	Repeat actions 4-5 (i-2) according to the measurement times I filled out by users
07	The tool moves in X direction to above P2 point
08	The tool moves in Z direction to right above P2 point

09	The tool moves in X direction and touches P2 point of the probe for the first time, and the speed is Q
10	After touching the surface of the measuring instrument, the tool retracts 20mm, and the speed is Q
11	The tool moves in X direction and touches P2 point of the probe, and the speed is K
12	After touching the surface of the measuring instrument, the tool retracts 20mm, and the speed is Q
13	Repeat actions 11-12(i-2) according to measurement times I filled out by users
14	After the reference point return and the lathe tool measurement are completed, take the mean value of the measured values and save it to the absolute position values of P1, P2, P3 and P4 (this calculation process is completed in the software and stored in the macro variable, which needs to be called and saved).

Lathe tool measurement diagram
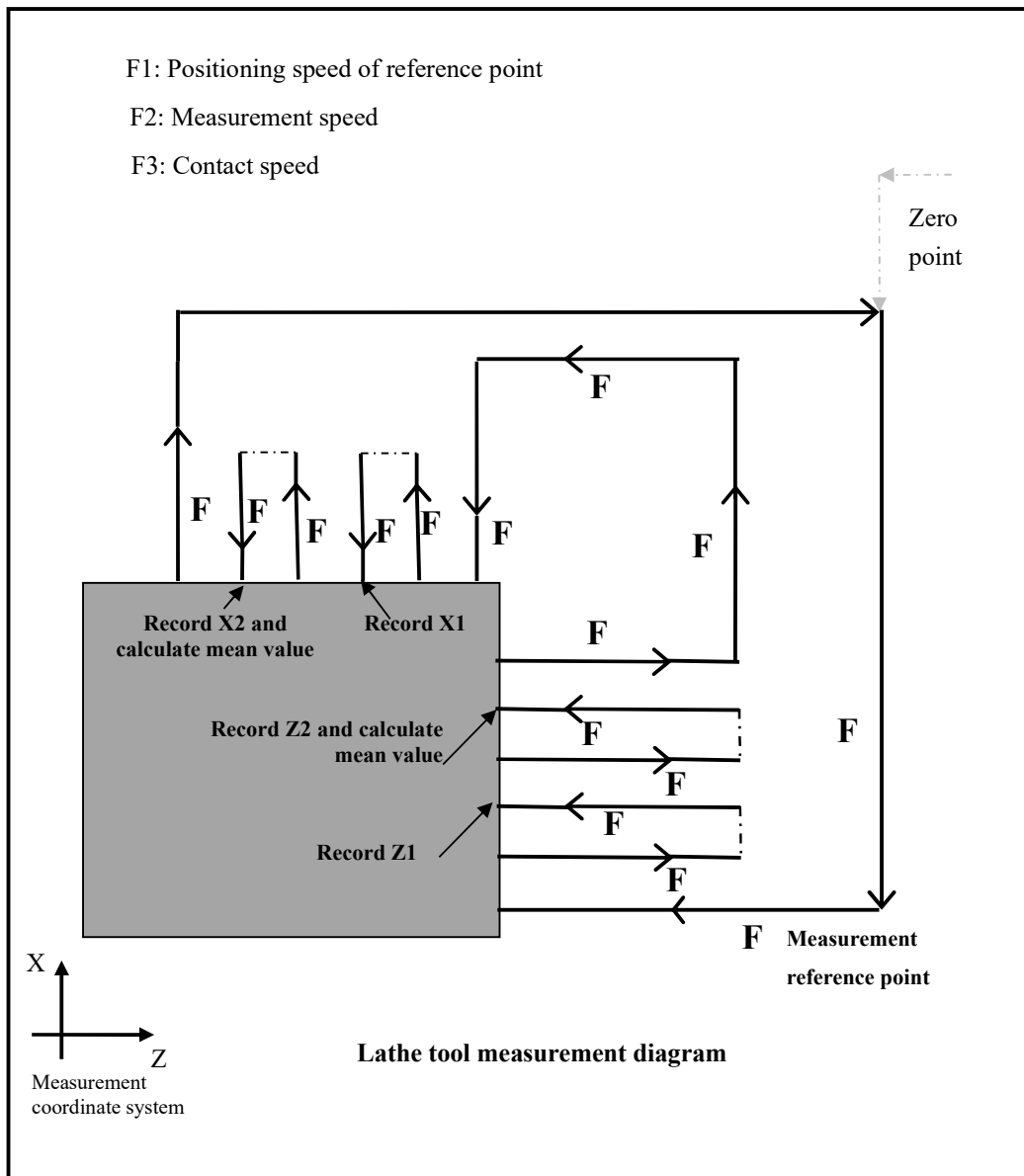
- Lathe tool measurement process:
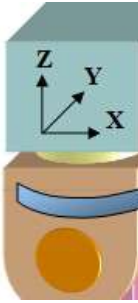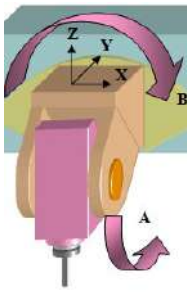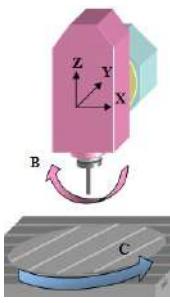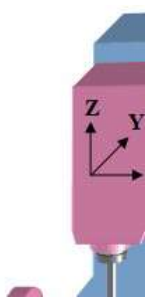
Measurement	Lathe tool measurement
01	Return to the machine zero and locate to Z coordinates of the measurement reference point: Z=Coordinates of P1 point - Half of measuring instrument length; X axis coordinates: X=Coordinates of P2 point - Half of measuring instrument length.
02	Move in Z direction and touch the probe for the first time, and the speed is Q.
03	After touching the surface of the measuring instrument, the tool retracts 20mm, and the speed is Q
04	The tool moves in Z direction and touches the probe, and the speed is K
05	After touching the surface of the measuring instrument, the tool retracts 20mm, and the speed is Q
06	Repeat actions 4-5 (i-2) according to measurement times I filled out by users
07	The tool moves in X direction to above the measuring instrument
08	The tool moves in Z direction to right above the measuring instrument
09	The tool moves in X direction and touches the probe for the first time, and the speed is Q
10	After touching the surface of the measuring instrument, the tool retracts 20mm, and the speed is Q
11	The tool moves in X direction and touches the probe, and the speed is K
12	After touching the surface of the measuring instrument, the tool retracts 20mm, and the speed is Q
13	Repeat actions 11-12(i-2) according to measurement times I filled out by users
14	After the reference point return and the lathe tool measurement are completed, take the mean value of measured values and save it to tool length 1 and tool length 2 (this calculation process is completed in the software and stored in the macro variable, which needs to be called and saved).

4.11 RTCP Calibration of Five-axis Machine Tool

Due to the structural characteristics of the five-axis machine tool, the same machine tool uses different tool lengths or workpiece clamping heights for processing the same parts, and the processing procedures cannot be universal. It is necessary to rebuild the machine model and post-processing in the CAM software to generate the correct tool path program.

Thus, RTCP tool vector programming is proposed. The system calibrates vector direction and space position of ratory axes of machine tools in advance in order to convert the five-axis machining program based on workpiece coordinate system into the machining path suitable for the current machine tool structure to control all axes to complete machining of parts.

Common five-axis machine tools can be classified into double swivel head, swivel head and rotary table, and double rotary table. These three types can be divided into several groups according to axial direction of rotary axis and master-slave movement relation. The RTCP calibration parameter setup methods for common five-axis machine tools, four of which the inclined angle of rotary axis lines is 0°, and one of which the inclined angle of rotary axis lines is not 0°, are described as below.

CB swivel head	BA swivel head	B swivel head C rotary table	AC rotary table	B tilt swivel head C rotary table

4.11.1 Relationship Between RTCP Calibration Parameter and Structure Type of Machine Tool

Vector Calibration Method of CB Swivel Head Five-axis Machine Tool

Swivel head structure type:

C B

→ Slave swivel head (second axis of swivel head)

→ Master swivel head (first axis of swivel head)
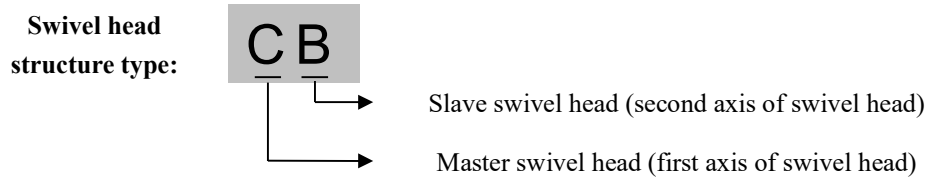
CB swivel head structure diagram:

Vector diagram:

$$\theta_x = 90° \qquad \theta_x$$
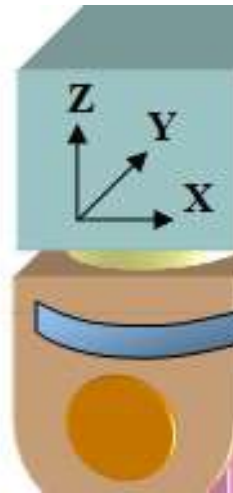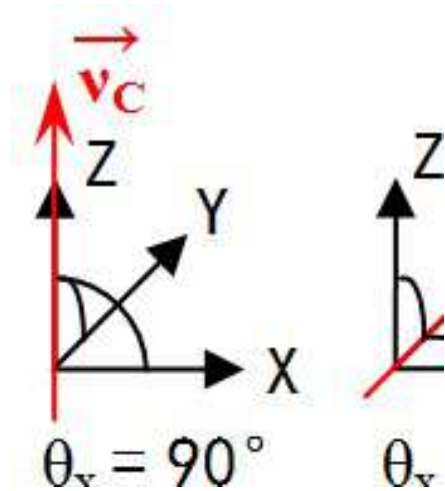
Vector parameter setting:

Parm: 040041 structure type of swivel head【CB】

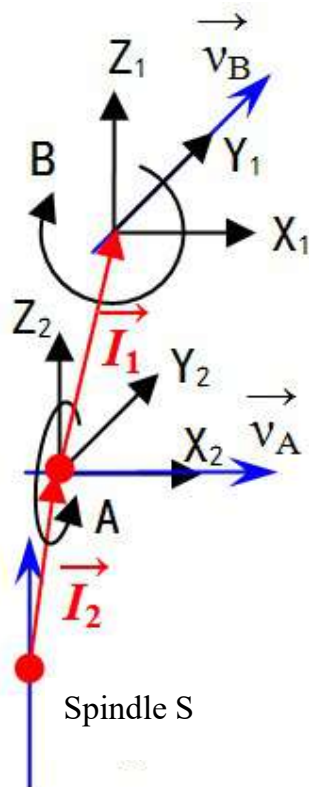Parm: 040042 direction vector X of the first rotary axis of swivel   head 【0】

Parm: 040043 direction vector Y of the first rotary axis of swivel head 【0】

Parm: 040044 direction vector Z of the first rotary axis of swivel head 【1】

Parm: 040045 direction vector X of the second rotary axis of swivel head 【0】

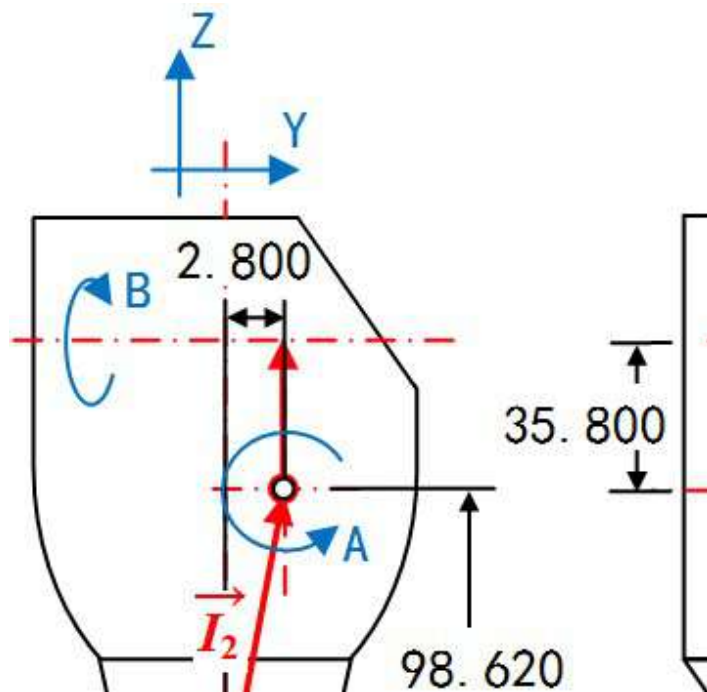Parm: 040046 direction vector Y of the second rotary axis of swivel head 【1】

Parm: 040047 direction vector Z of the second rotary axis of swivel head 【0】

Vector value:

Cosine value of the inclined angle between rotary axis line and linear axis line in the coordinate system

Axis line offset diagram:

Spindle S
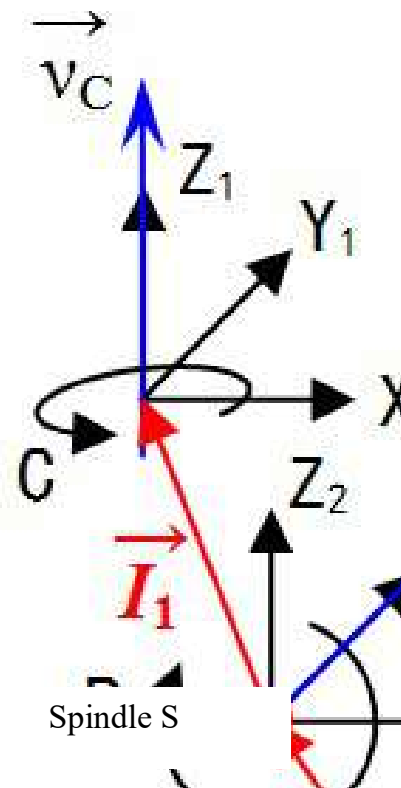
Offset parameter setting:

Parm: 040048 direction vector X of the first rotary axis of swivel head 【I_{1x}】

Parm: 040049 direction vector Y of the first rotary axis of swivel head 【I_{1y}】

Parm: 040050 direction vector Z of the first rotary axis of swivel head 【I_{1z}】

Parm: 040051 direction vector X of the second rotary axis of swivel head 【I_{2x}】

Parm: 040052 direction vector Y of the second rotary axis of swivel head 【I_{2y}】

Parm: 040053 offset vector Z of the second rotary axis of swivel head 【I_{2z}】

Features:

Offset value I2: The distance from the center point of the spindle end face to the axis line of the second swivel head; offset value I1: The spatial distance between two rotary axis lines;
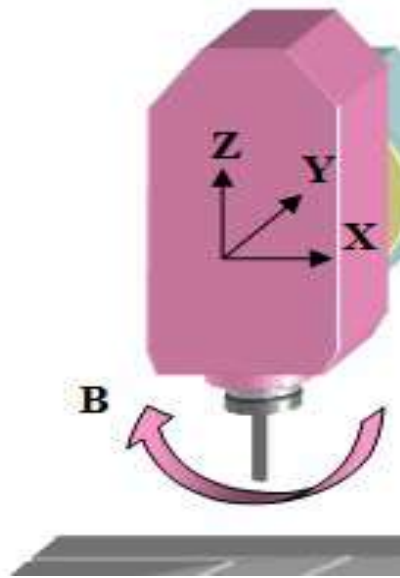
Case

● 1. C, B and S axis lines are intersected, $I_{1x}= I_{1y}= I_{1z}=0$, $I_{2x}= I_{2y}=0$，$I_{2z}=$ the distance from the spindle end face to B axis;

● 2. B and C axis lines are intersected, C and S axis lines share ZX plane, S and B axis lines are not intersected: $I_{1x}= I_{1y}= I_{1z}=0$, $I_{2y}=0$, I_{2x}, $I_{2z}=$component of the distance from the spindle end face to B axis line in the ZX plane;

● 3. C, B and S axis lines are not intersected: $I_{1x}=$ vertical distance of CB axis line, $I_{1y}= I_{1z}=0$, $I_{2y}=$ the distance on Y from the axis of the spindle to the intersection of the BC perpendicular on the B axis, I_{2x}, $I_{2z}=$ component of the distance from the spindle end face to B axis line in the ZX plane;

Motion features:

Motion angle of slave axis is limited, e.g.: C is 0-360°; B is ±110°.

4.11.2 Vector Calibration Method of BA Swivel head Five-axis Machine Tool
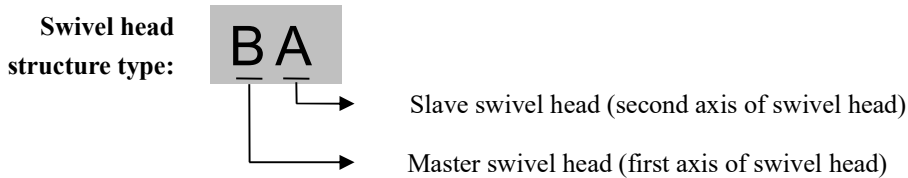
BA swivel head structure diagram:

Vector diagram:

$$\theta_x = 90° \qquad \theta_x =$$
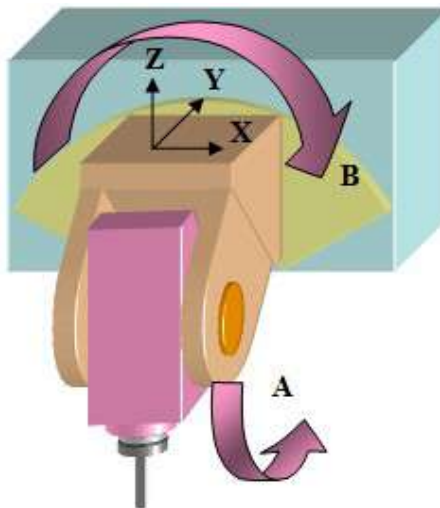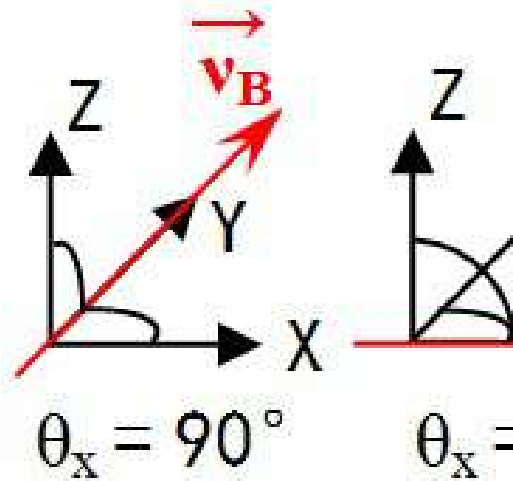
Vector diagram setup:

Parm: 040041 structure type of swivel head 【BA】

Parm: 040042 direction vector X of the first rotary axis of swivel head 　【0】

Parm: 040043 direction vector Y of the first rotary axis of swivel head 　【1】

Parm: 040044 direction vector Z of the first rotary axis of swivel head 　【0】

Parm: 040045 direction vector X of the second rotary axis of swivel head 　【1】

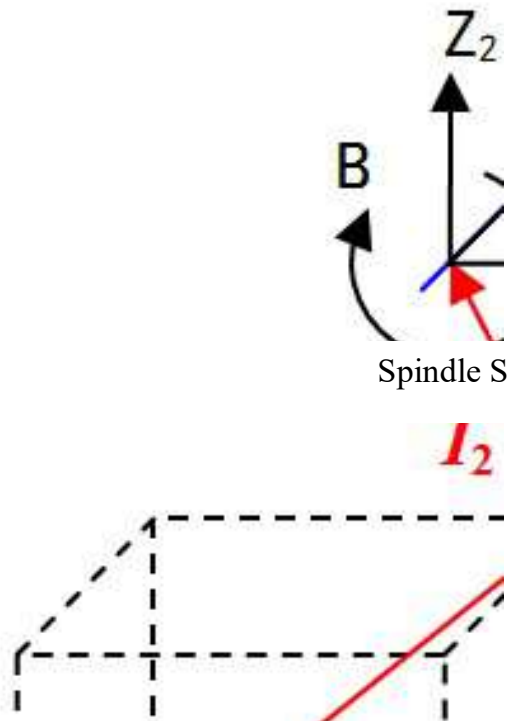Parm: 040046 direction vector Y of the second rotary axis of swivel head 　【0】

Parm: 040047 direction vector Z of the second rotary axis of swivel head 　【0】

Axis line offset diagram:

Spindle S

Offset parameter setup:

Parm: 040048 direction vector X of the first rotary axis of swivel head 【I_{1x}】

Parm: 040049 direction vector Y of the first rotary axis of swivel head 【I_{1y}】

Parm: 040050 direction vector Z of the first rotary axis of swivel head 【I_{1z}】

Parm: 040051 direction vector X of the second rotary axis of swivel head 【I_{2x}】

Parm: 040052 direction vector Y of the second rotary axis of swivel head 【I_{2y}】

Parm: 040053 offset vector Z of the second rotary axis of swivel head 【I_{2z}】

Case

● 1. B, A and S axis lines are intersected, $I_{1x} = I_{1y} = I_{1z} = 0$, $I_{2x} = I_{2y} = 0$, I_{2z} = the distance from the spindle end face to A axis;

● 2. B and S axis lines share YZ plane, S, A and B axis lines are not intersected: $I_{1x}= I_{1y}=0$, I_{1z}=the distance between B and A axis lines, $I_{2x} =0$, I_{2y} and I_{2z} are the component of the distance from the center point of the spindle end face to A axis line in the YZ plane;

● 3. B, A and S axis lines are not intersected: I_{1x} = The distance on X from the axis of the spindle to the intersection of the BA perpendicular on the B axis, $I_{1y}=0$, I_{1z}=vertical distance of BA axis line, I_{2y}, I_{2z}=component of the distance from the center of spindle end face to A axis line in the YZ plane; as shown below:

4.11.3 Vector Calibration Method of B Swivel head C rotary table Five-axis Machine Tool
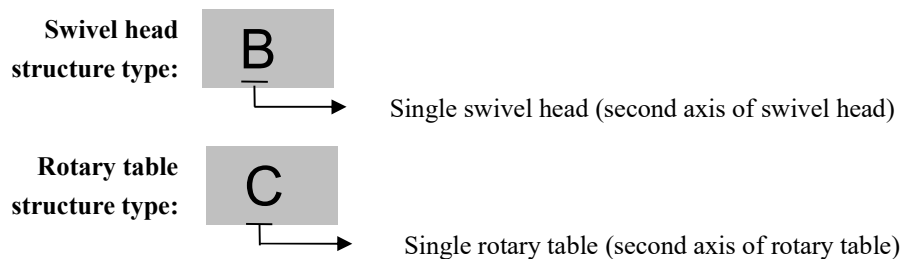
Swivel head structure type: B — Single swivel head (second axis of swivel head)

Rotary table structure type: C — Single rotary table (second axis of rotary table)

B swivel head C rotary table structure diagram:

Vector diagram:

$$\theta_v = 90° \qquad \theta_v$$
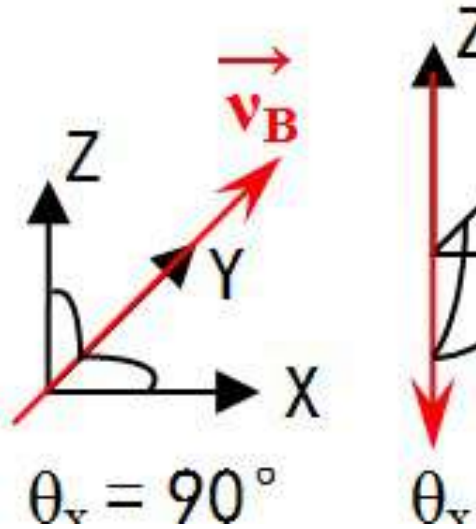
Vector diagram setup:

Parm: 040041 structure type of swivel head 【B】

Parm: 040045 direction vector X of the second rotary axis of swivel head 【0】

Parm: 040046 direction vector Y of the second rotary axis of swivel head 【1】

Parm: 040047 direction vector Z of the second rotary axis of swivel head 【0】

Parm: 040054 structure type of rotary table 【C】

Parm: 040058 direction vector X of the second rotary axis of rotary table 【0】

Parm: 040059 direction vector Y of the second rotary axis of rotary table 【0】

Parm: 040060 direction vector Z of the second rotary axis of rotary table 【-1】

Axis line offset diagram:

Offset parameter setting:

Parm: 040051 direction vector X of the second rotary axis of swivel head 【I_{2x}】

Parm: 040052 direction vector Y of the second rotary axis of swivel head 【I_{2y}】

Parm: 040053 offset vector Z of the second rotary axis of swivel head 【I_{2z}】

Parm: 040064 offset vector X of the second rotary axis of rotary table 【O_{2x}】

Parm: 040065 offset vector X of the second rotary axis of rotary table 【O_{2x}】

Parm: 040066 offset vector X of the second rotary axis of rotary table 【O_{2x}】

Features:

Offset value I2: The distance from the center point of the spindle end face to the axis line of the second swivel head; offset value O2: Machine coordinates of the center of the spindle end face on the working face of the rotary axis center;

Case:

● B and S axis lines are not intersected; $I_{2y}=0$, I_{2x} and I_{2z} are the component of the distance from the center point of the spindle end face to B axis line in the ZX plane; O_{2x}, O_{2y} and O_{2z} are the coordinate value of the machine tool when the center point of the spindle end face coincides with the upper surface of X axis center. As shown below:
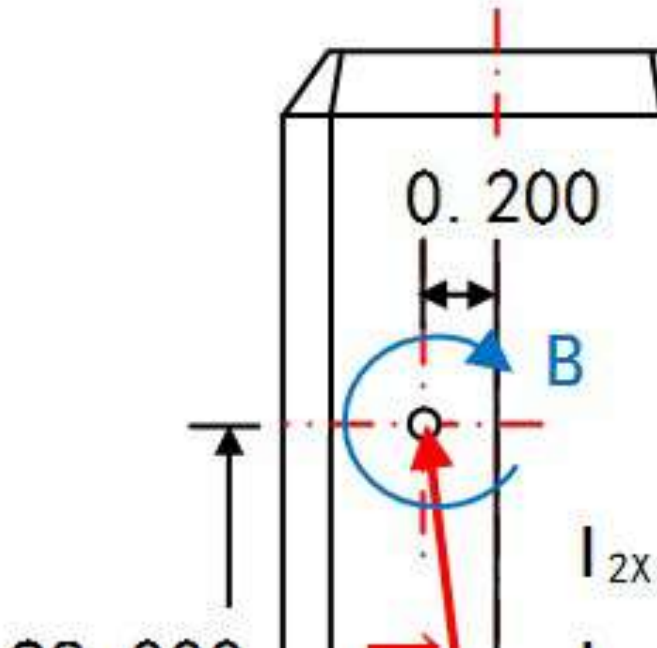
4.11.4 Vector Calibration Method of AC Rotary Table Five-axis Machine Tool

Rotary table structure type:

Slave swivel head (second axis of swivel head)

Master swivel head (first axis of swivel head)
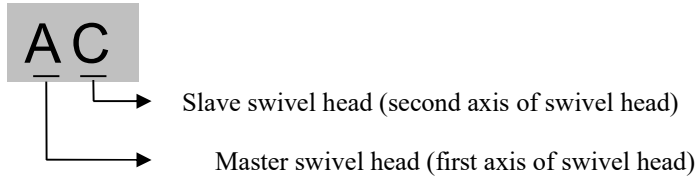
AC (swivel head) rotary table structure diagram:
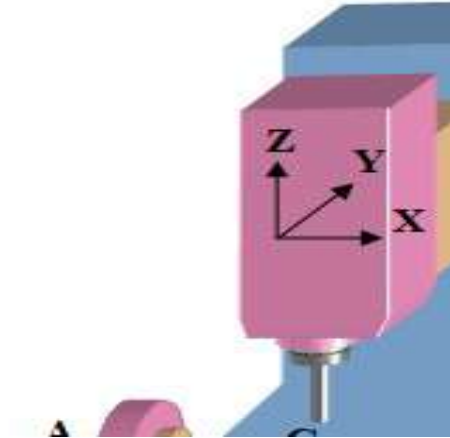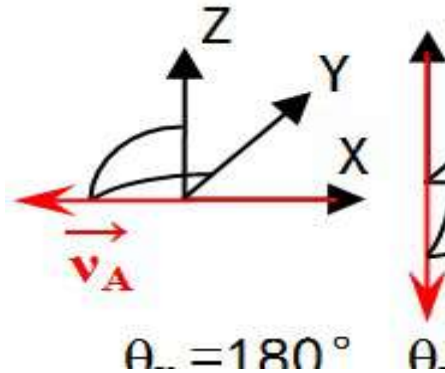
Vector diagram:

Vector diagram setting:

Parm: 040054 structure type of rotary table 【AC】

Parm: 040055 direction vector X of the first rotary axis of rotary table 【-1】

Parm: 040056 direction vector Y of the first rotary axis of rotary table 【0】

Parm: 040057 direction vector Z of the first rotary axis of rotary table 【0】

Parm: 040058 direction vector X of the second rotary axis of rotary table 【0】

Parm: 040059 direction vector Y of the second rotary axis of rotary table 【0】

Parm: 040060 direction vector Z of the second rotary axis of rotary table 【-1】

Axis line offset diagram:

Spindle S
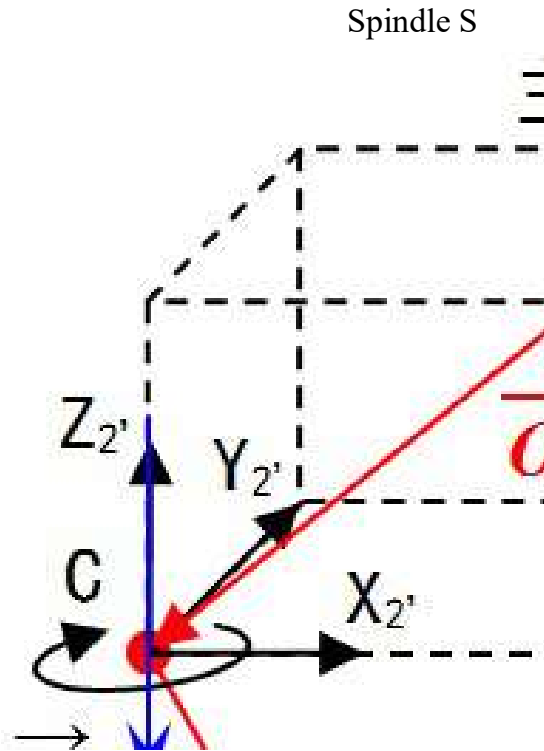
Offset parameter setting:

Parm: 040061 offset vector X of the first rotary axis of rotary table 【O_{1x}】

Parm: 040062 offset vector Y of the first rotary axis of rotary table 【O_{1y}】

Parm: 040063 offset vector Z of the first rotary axis of rotary table 【O_{1z}】

Parm: 040064 offset vector X of the second rotary axis of rotary table 【O_{2x}】

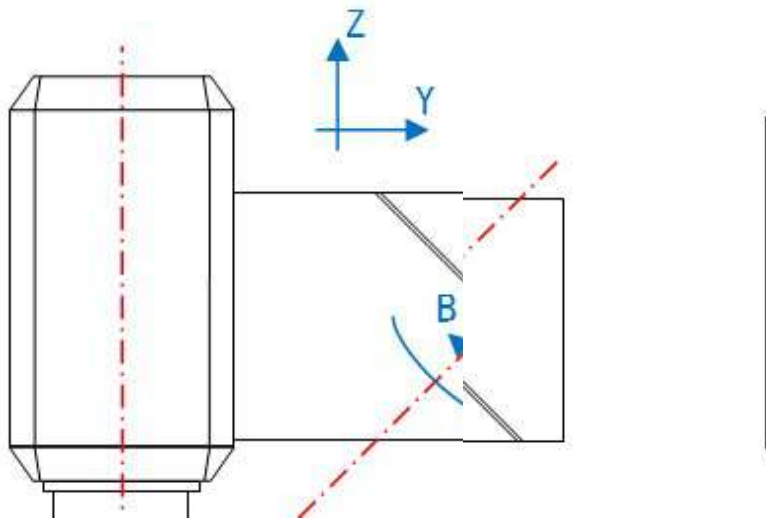Parm: 040065 offset vector Y of the second rotary axis of rotary table 【O_{2y}】

Parm: 040066 offset vector Y of the second rotary axis of rotary table 【O_{2z}】

Features:

Offset value O_2: Machine coordinates when the center of the spindle end face at the center point of rotary axis; offset value O_1: The spatial distance from the center point of the second rotary axis to the spindle axis line;

Case:

● A and C axis lines are not intersected; O_{1x} =0, O_{1y} is the vertical distance of A and C axis lines, O_{1z} is the distance from A axis line to the working table face of C axis; O_{2x}, O_{2y} and O_{2z} are the machine coordinate values when the center point of the spindle end face on A axis is 0° and it coincides with the upper surface of C axis center. As shown below:

$$O_{1Y} = 0.150$$

$$O_{1Z} = 0.580$$

$$0.150$$

A'
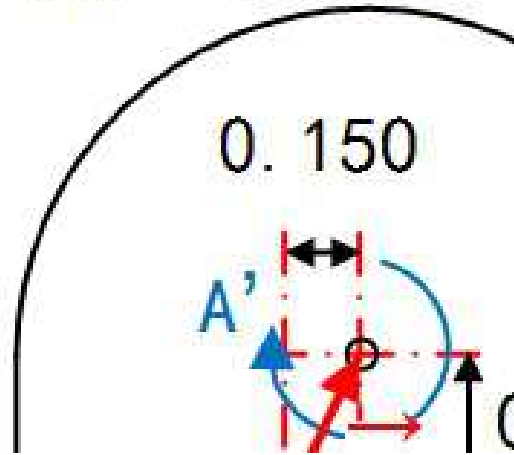
4.11.5 Vector Calibration of B Tilt Swivel head C Rotary Table Five-axis Machine Tool
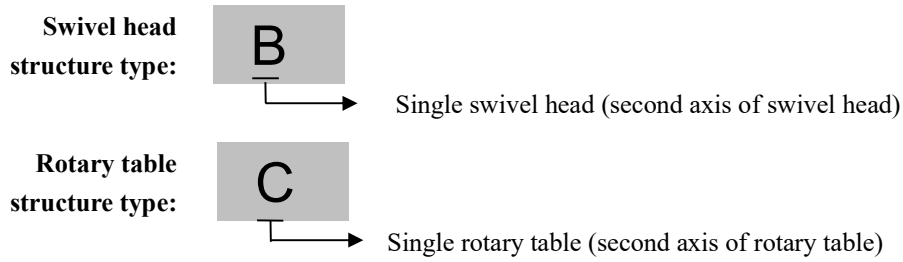
Swivel head structure type:
B

→ Single swivel head (second axis of swivel head)

Rotary table structure type:
C

→ Single rotary table (second axis of rotary table)

B tilt swivel head C rotary table structure diagram:
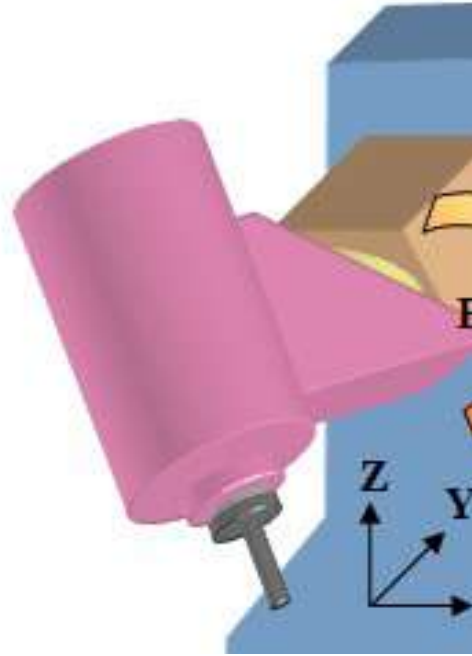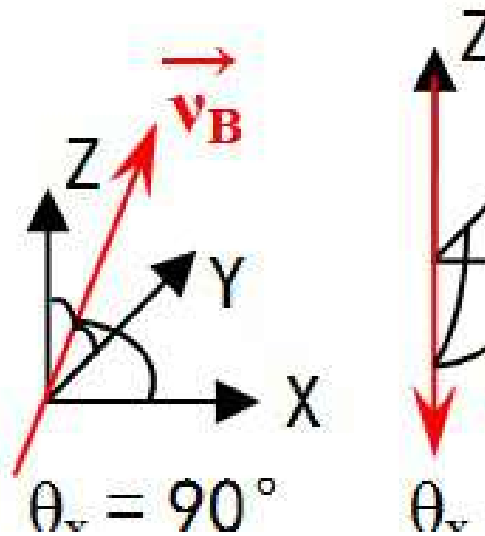
Vector diagram:

Vector diagram setup:

Parm: 040041 structure type of swivel head　【B】

Parm: 040045 direction vector X of the second rotary axis of swivel head　【0】

Parm: 040046 direction vector Y of the second rotary axis of swivel head　【0.707】

Parm: 040047 direction vector Z of the second rotary axis of swivel head　【0.707】

Parm: 040054 structure type of rotary table　【C】

Parm: 040058 direction vector X of the second rotary axis of rotary table　【0】

Parm: 040059 direction vector Y of the second rotary axis of rotary table　【0】

Parm: 040060 direction vector Z of the second rotary axis of rotary table　【-1】

Offset parameter setup:

Parm: 040051 offset vector X of the second rotary axis of swivel head　【I_{2x}】

Parm: 040052 offset vector Y of the second rotary axis of swivel head　【I_{2y}】

Parm: 040053 offset vector Z of the second rotary axis of swivel head　【I_{2z}】

Parm: 040064 offset vector X of the second rotary axis of rotary table 【O_{2x}】

Parm: 040065 offset vector X of the second rotary axis of rotary table 【O_{2x}】

Parm: 040066 offset vector X of the second rotary axis of rotary table 【O_{2x}】

Features:

Offset value I_2: The distance from the center point of the spindle end face to the axis line of the second swivel head; offset value O_2: Machine coordinates of the center of the spindle end face on the working face of the rotary axis center;

Case:

● B and S axis lines are not intersected and the spindle axis line is parallel with Z axis when B axis is 0°. I_{2x} is the vertical distance from the spindle axis line to B axis line, I_{2y} and I_{2z} are the component of the distance between the center point of the spindle end face and B axis line in the YZ plane; O_{2x} , O_{2y} and O_{2z} are the machine coordinate values when the center point of the spindle end face coincides with the upper surface of C axis center when B axis is 0°. As shown below:

4.11.6 Offset Vector Measurement of Swivel head And Rotary Table

1) Offset Measurement of Spindle Axis Line And Center Line Of Swivel head

Offset vector of the second rotary axis of swivel head: Offset vector of the center point of slave axis relative to the center of the spindle end face.
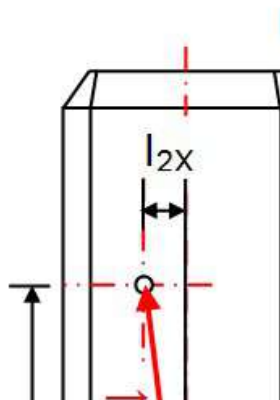
Measurement of "040051 offset vector X of the second rotary axis of swivel head"

● Step 1:
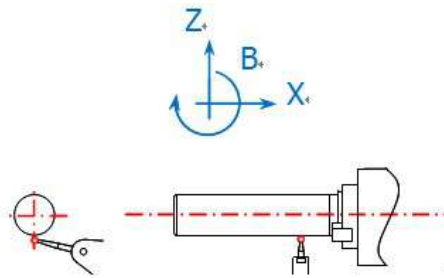
①Install standard bar on the spindle and rotate B axis to "90°";

②Measure the highest point on the bottom of datum bar using dial indicator, as shown in the left figure. Then, press the dial indicator so that the pointer points to zero;

③Reset relative coordinates of Z axis;

④Move the dial indicator away. (Lift Z axis by handwheel, do not move Y axis randomly or remember to restore the position of Y axis)

● Step 2:
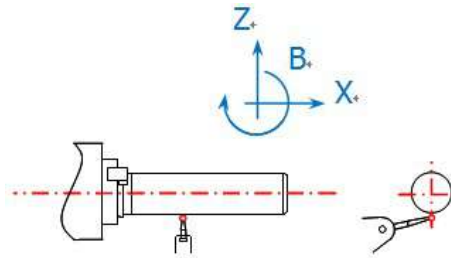
①Rotate B axis to "-90°";

②Then, move the machine tool (lower Z axis by handwheel) so that the probe of the dial indicator touches the bottom of the datum bar, as shown in the left figure. Slowly rotate the handwheel at low magnification and press the dial indicator so that the pointer points at zero;

③Read relative coordinate value of Z axis;

④Divide this value by 2 and fill in "040051 Offset vector X of the second rotary axis of swivel head". (With symbols)

Note: The shortest distance from the spindle axis line to B axis line in X axis direction

"040052 Offset vector Y of the second rotary axis of swivel head"

Generally, the inclined angle between B axis line and Y axis line is 0°, namely offset vector is "0"
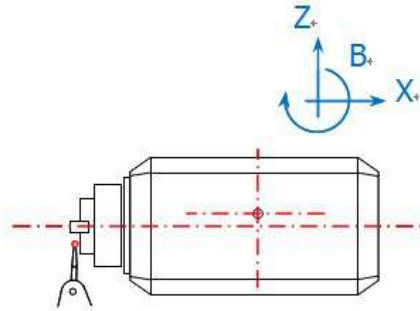
Measurement of "040052 Offset vector Z of the second rotary axis of swivel head":

● Step 1:
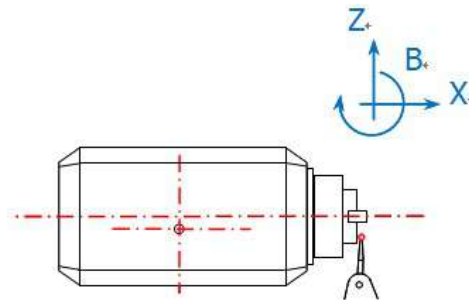
①Rotate B axis to "-90°";

②Measure the spindle end face using dial indicator along X axis direction, as shown in the left figure. Then, press the dial indicator so that the pointer points at "0";

③Reset relative coordinates of X axis and Z axis;

④Move the dial indicator away. (Move X axis in the negative direction by handwheel and lift Z axis, do not move Y axis arbitrarily)

● Step 2:

①Rotate B axis to "90°";

②Then, move the machine tool (Z axis arrives at the relative zero point) along X axis to the spindle end face, as shown in the left figure. Press the meter so that the pointer of the dial indicator points at zero;

③Read relative coordinate value of X axis;

④Subtract this value by the diameter of the indicator probe and "divide it by 2" and fill in "040053 Offset vector Z of the second rotary axis of swivel head". (With symbols)

Note: Fill in a positive value when the spindle end face is lower than B axis line

4.11.7 Offset Measurement of Two Rotary axis lines for Double Cradle

Offset vector of the first rotary axis of rotary table: Offset vector of the master axis relative to the slave axis.
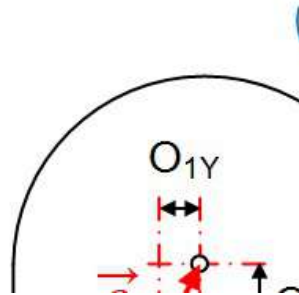
1) "040061 Offset Vector X of The First Rotary Axis Of Rotary Table":

Generally, the inclined angle between A axis line and X axis line is 0°, namely offset vector is "0"

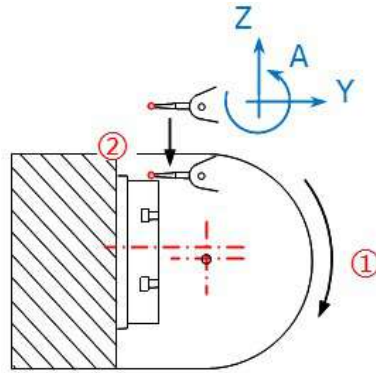2) Measurement of "040062 Offset Vector Y of the First Rotary Axis of Rotary Table":

● Step 1:
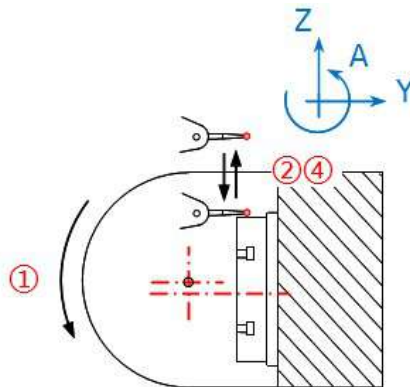
①Rotate A axis to "-90°";

②Measure the highest point on the side wall of the rotary table of C axis using dial indicator, as shown in the left figure. Then, press the dial indicator so that the pointer points at "0";

③Reset relative coordinates of Z axis;

④Move the dial indicator away. (Lift Z axis by handwheel, do not move Y axis and Y axis arbitrarily)

● Step 2:

①Rotate A axis to "90°";

②Then, move the machine tool (lower Z axis by handwheel) so that the probe of the dial indicator touches the highest point on the side wall of the rotary table of C axis, as shown in the left figure. Slowly rotate the handwheel at low magnification and press the dial indicator so that the pointer points at zero;

③Read relative coordinate value of Z axis;

④"Divide the value by 2" and fill in "040062 Offset vector Y of the first rotary axis of rotary table". (With symbols)

Note: The shortest distance from C axis line to A axis line in Y axis direction

4.11.8 Measurement of "040063 Offset Vector Z of the First Rotary Axis of Rotary Table"

● Step 1:
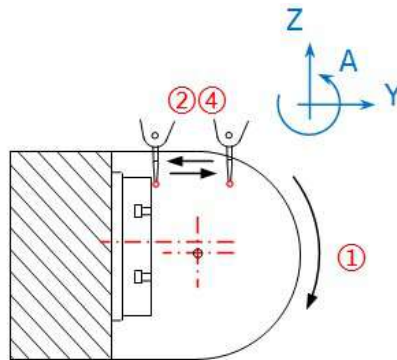
①Rotate A axis to "90°";

②Measure the rotary table plane of C axis using dial indicator along Y axis direction, as shown in the left figure. Then, press the dial indicator so that the pointer points at "0";

③Reset relative coordinates of Y axis and Z axis;

④Move the dial indicator away. (Move Y axis in the negative direction by handwheel and lift Z axis, do not move X axis arbitrarily)
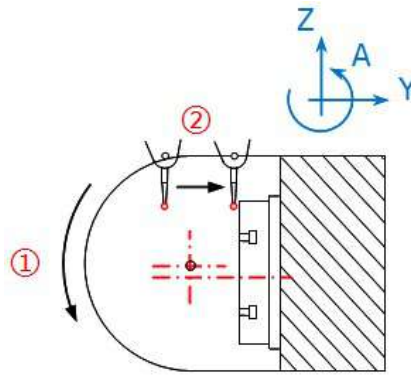
● Step 2:

①Rotate A axis to "-90°";

②Then, move the machine tool (Z axis arrives at the relative zero point) along Y axis to the rotary table on C axis, as shown in the left figure. Press the dial indicator so that the pointer points at zero;

③Read relative coordinate value of Y axis;

④Add the value to the diameter of indicator probe and "divide it by 2" and fill in "040063 Offset vector Z of the first rotary axis of rotary table". (With symbols)

Note: Fill in a positive value when the worktable is lower than A axis line

In order to ensure motion rigidity during machining, some large or very small double cradle structures are limited to volume of the second rotary axis motor and structural size of reduction mechanism and consequently the design rotation angle cannot reach above ±90°.
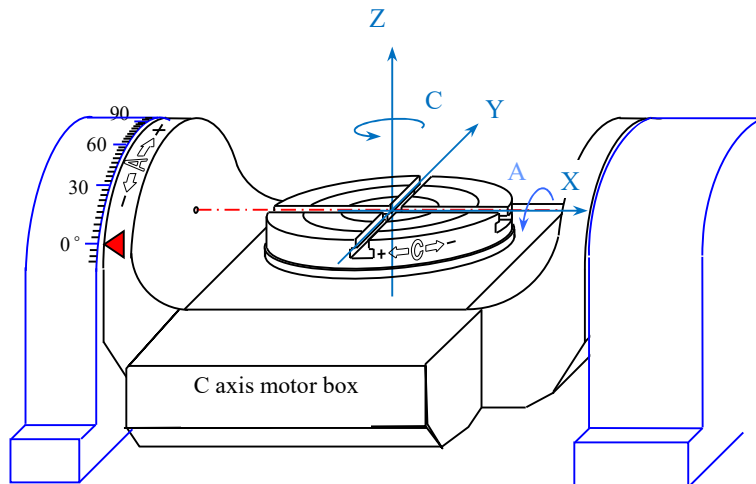
AC cradle structure with A axis rotation ranging from -20° to 110°

### 4.11.9 Measurement Of "040062 Offset Vector Y of The First Rotary Axis Of Rotary Table"

● Step 1:
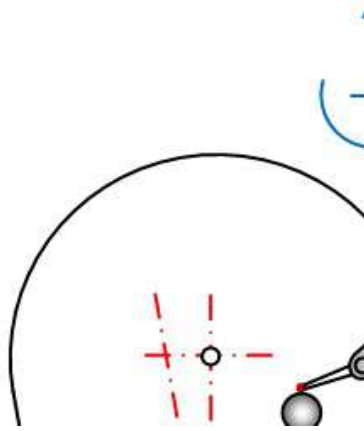
①Fix a cylindrical test bar on the edge of the worktable along A axis and pull the dial indicator to make it parallel with A axis.
②Rotate A axis to -20°;
③Measure the highest point of test bar in Z direction using dial indicator, as shown in the left figure. Then, lift Z axis and press the dial indicator so that the pointer points at "0";
④Reset relative coordinates of Z axis;
⑤Move the dial indicator away. (Lift Z axis by handwheel, do not move X axis and Y axis arbitrarily)
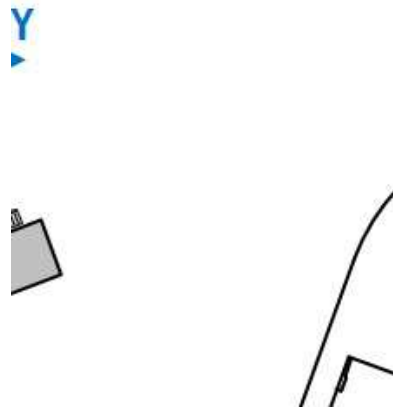
● Step 2:
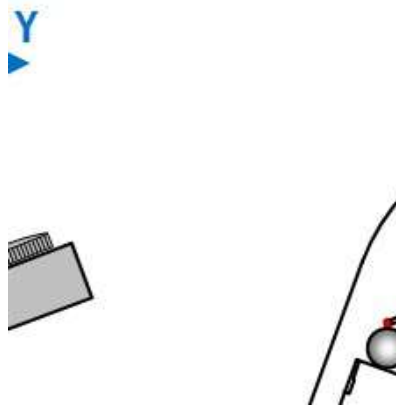
①Rotate C axis to 180° and A axis to 20°;
②Then, move Y and Z axes of the machine tool and measure the highest point of test bar in Z direction with dial indicator, as shown in the left figure. Press the dial indicator along Z direction so that the pointer points at "0";
③Read relative coordinate value of Z axis;
④"Divide this value by 2" and "Divide it by Sin20°" and fill in "040062 Offset vector Y of the first rotary axis of rotary table". (With symbols)
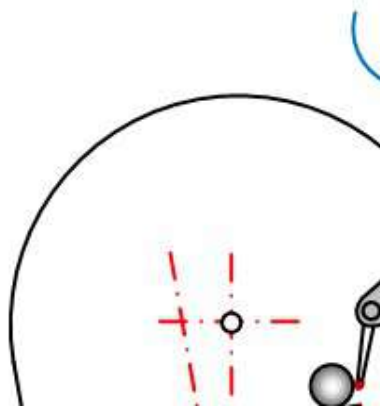Note: The shortest distance from C axis line to A axis line in Y axis direction

4.11.10   Measurement of "040063 Offset Vector Z of The First Rotary Axis Of Rotary Table"

● Step 1:

①Fix a cylindrical test bar on the worktable close to the edge of the positive direction of Y axis along A axis and pull the dial indicator to make it parallel with A axis line.
②Rotate A axis to 20°;
③Measure the highest point of test bar in Y direction using dial indicator, as shown in the left figure. Then, Press the dial indicator along Y direction so that the pointer points at "0";
④Reset relative coordinates of Y axis;
⑤Move the dial indicator away. (Move the dial indicator away from the test bar along the positive direction of Y axis and do not move X axis and Z axis arbitrarily)

● Step 2:

①Rotate A axis to -20°;
②Then, move Y and Z axes of the machine tool and measure the highest point of test bar in Y direction using dial indicator, as shown in the left figure. Press the dial indicator along Y direction so that the pointer points at "0";
③Read relative coordinate value of Y axis;
④"Divide this value by 2" and "Divide it by Sin20°" and fill in "040063 Offset vector Z of the first rotary axis of rotary table". (With symbols)
Note: The shortest distance from C axis line to A axis line in Y axis direction

4.11.11 Verification after Calibration

Replace the tool with ball-end milling tool, press the dial indicator in X, Y and Z directions, execute RTCP function manually at fixed points and maintain actual contact point between the tool and the workpiece surface as well as the tool center point. At this time, the tool center point is on the normal line of the actual contact

point between the tool and the workpiece surface, and the shank will rotate around the center point of the tool. For ball-end tool, the tool center point is the target path point of CNC code.

In order that the shank can rotate around the target path point (namely the tool center point) simply when RTCP function is executed, it is necessary to compensate for the offset of the linear coordinates of the tool center point caused by the rotation of the tool shank in real time. It can change the angle between the tool shank and the normal at the actual contact point of the tool and the workpiece surface while keeping the relative position of the tool center point and the actual contact point of the tool and the workpiece surface unchanged, and play the best good cutting efficiency of the ball-end tool, and effectively avoid interference.