MODEL 1. MULTI-AXIS SERVO SYSTEM USING AC SERVO MOTORS AND THE MOTION CONTROL MODULE

1.1. Contents

- ✓ AC servo motors and their drivers
- ✓ PLC Mitsubishi programming
- ✓ Motion control module FX3U-20SSC-H
- ✓ Linear and circular interpolations

1.2 Introduction to device

1.2.1. Hardware system

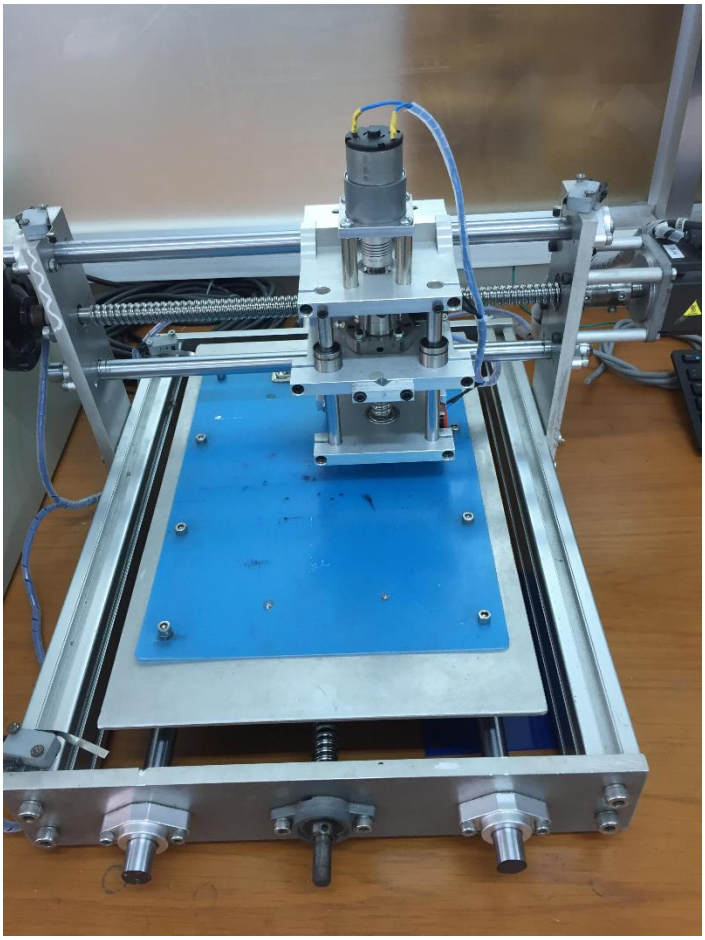


Fig. 1.1: 3-axis servo system using the Mitsubishi modules

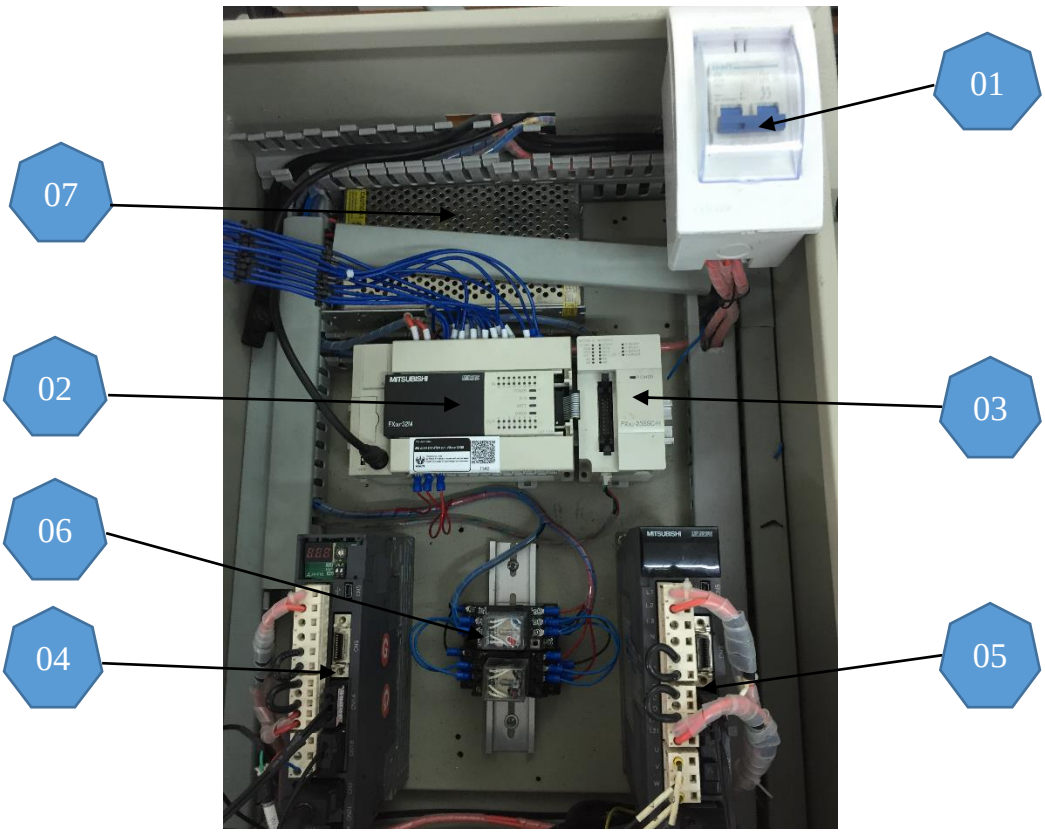


Fig. 1.2: The controller of the system

- **Components in the model**

01: Main CB

02: PLC Mitsubishi (FX_{3U}-32M)

03: Module FX_{3U}-20SSC-H

04, 05: Servo Drivers (MR-J3-□B)

06: Relays

07: Power supply 24VDC, 10A

1.2.2. Motion control module FX3U-20SSC-H

- **Introduction**

FX3U-20SSC-H is a special function block that controls position, speed of AC servo motors via ***SSCNETIII cable***; ***compatible with AC Servo MR-J3- □B***. It can control up to 2 AC servo motors with line and circular interpolations.

Fig. 1.3: Module FX3U-20SSC-H

***Technical specifications*:**

- Number of control axis: 2 axes
- Applicable PLC: FX3U/FX3UC
- Connectable servo amplifiers: MELSERVO J3-□B, J3W-□B, J3-□BS
- Long distance cord length: up to 50m
- Servo bus: SSCNET III

***** *Look up the manual for the detail configuration*

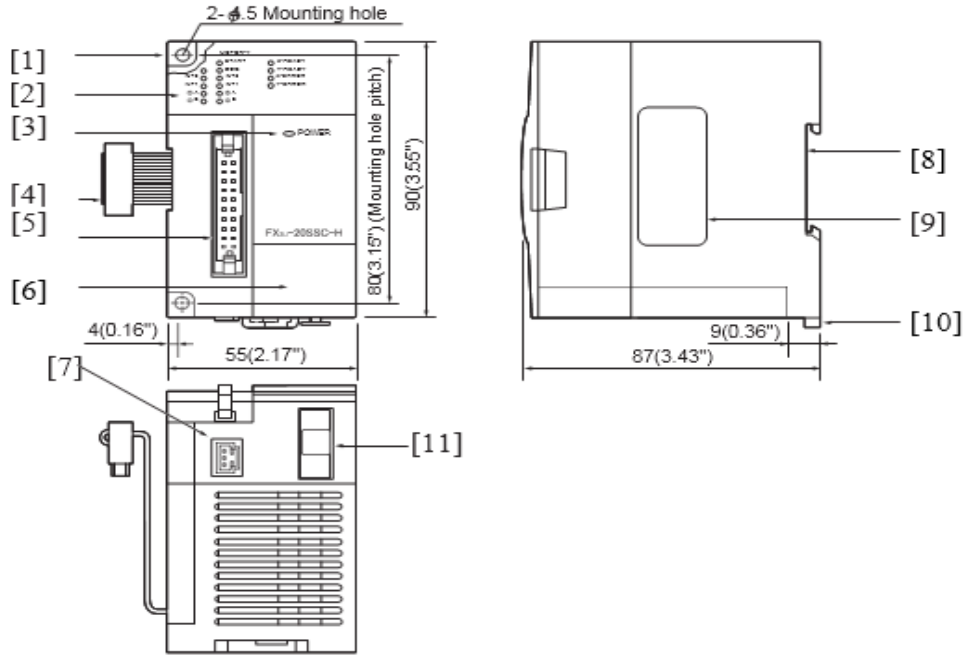


Fig. 1.4: Layout and connections of FX3U-20SSC-H

External dimensions and part names

[1] Direct mounting hole: 2 holes of Ø4.5 (0.18") (mounting screw: M4 screw)

[2] Status LEDs

[3] POWER LED (green)

[4] Extension cable

[5] Input connector

[6] Top cover

[7] Power supply connector

[8] DIN rail mounting groove [DIN rail: DIN46277 35 mm (1.38”) wide]

[9] Name plate

[10] DIN rail mounting hook

[11] SSCNET III connector

Power and Status LED

Table 2.1: *Power and Status LED on FX_{3U}-20SSC-H*

LED display	Color	Status	Description
POWER	Green	OFF	Power is not being supplied from the external power supply or the PLC
		ON	Power is being supplied from the external power supply or the PLC
X-READY Y-READY	Green	OFF	Error is occurring or positioning is being executed on the X/Y axis
		ON	Various operation commands are acceptable on the X/Y axis
X-ERROR Y-ERROR	Red	OFF	X/Y axis is operating normally
		Flicker	Error is occurring on the X/Y axis
		ON	CPU error is occurring on the X/Y axis
X-START	Red	OFF	Start input OFF

Y-START		ON	Start input ON
X-DOG Y-DOG	Red	OFF	DOG input OFF
		ON	DOG input ON
X-INT0 Y-INT0 X-INT1 Y-INT1	Red	OFF	Interrupt input OFF
		ON	Interrupt input ON
X- ø A Y- ø A	Red	OFF	Manual pulse generator A-phase input OFF
		ON	Manual pulse generator A-phase input ON
X- ø B Y- ø B	Red	OFF	Manual pulse generator B-phase input OFF
		ON	Manual pulse generator B-phase input ON

Connection with PLC

FX3U-20SSC-H is connected with PLC by the extension

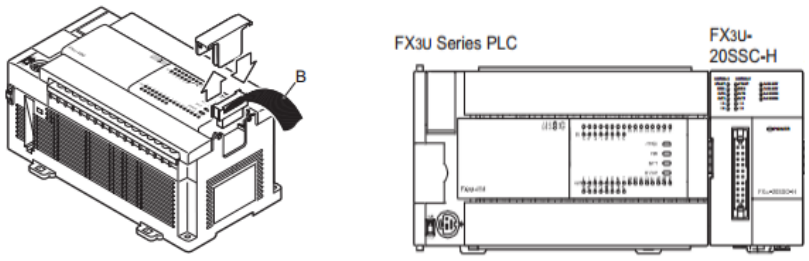


Fig. 1.5: Connection of FX3U-20SSC-H with PLC

Buffer memory (BFM)

The PLC can access the buffer memory directly, using sequence programs. The 20SSC-H uses positioning parameters and data in this area to execute the positioning control. The data types and their applications are described briefly in the following table. For the detail specifications, please look up the 20SSC-H manual.

Data type	Application	BFM number		
		X-axis	Y-axis	X-/Y-axis
Monitor data	Data indicating the control state. The monitor data is stored in the buffer memory. Monitor the data when necessary. → **For details, refer to Section 11.3**	BFM #0 to #99	BFM #100 to #199	-
Control data	The user controls the positioning control system, using the control data. The control data is related to operation-related settings, speed change command during positioning operation, stop operation, restart, etc. → **For details, refer to Section 11.4**	BFM #500 to #599	BFM #600 to #699	-
Positioning parameters	The positioning parameters specify the unit, speed and other features of the positioning control. Enter data according to the mechanical equipment and applicable motor. → **For details, refer to Section 11.1**	BFM #14000 to #14199	BFM #14200 to #14399	-
Servo parameters	The servo parameters depend on the servo amplifier to be used, and are used to control the servomotor. Enter data according to the specifications to be used. → **For details, refer to Section 11.2**	BFM #15000 to #15199	BFM #15200 to #15399	-
Table information	The table information is used for table type positioning control. Positioning control is based on the data specified in each table (operation information, position information, speed information, m code information). Up to 300 positioning table points per table can be defined. → **For details, refer to Section 11.5**	BFM #1000 to #3999	BFM #4000 to #6999	BFM #7000 to #12999

1.2.3. MelServo MR-J3-□B

Introduction

The Mitsubishi MELSERVO-J3 series, the general-purpose AC servo, has further higher performance and higher functions compared to the current MELSERVO-J2-Super series.

The torque limit with clamping circuit is put on the servo amplifier in order to protect the power transistor of main circuit from the over current caused by rapid acceleration/deceleation or overload. In addition, torque limit value can be changed to desired value in the controller.

The MELSERVO MR-J3 has a USB communication function, which uses an installed PC to perform parameter setting, monitoring, status monitoring, gain control, and AC servo via MR Configurator software.

MELSERVO-J3-□B has absolute position coding with ***262144 pulse / loop resolution*** to ensure more accurate control over the MELSERVO-J2-Super.

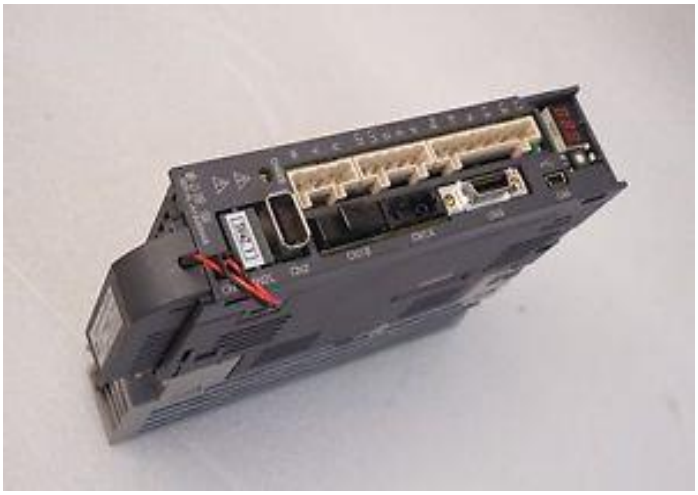


Fig. 1.6: Melservo MR-J3-20B

- **Structure**

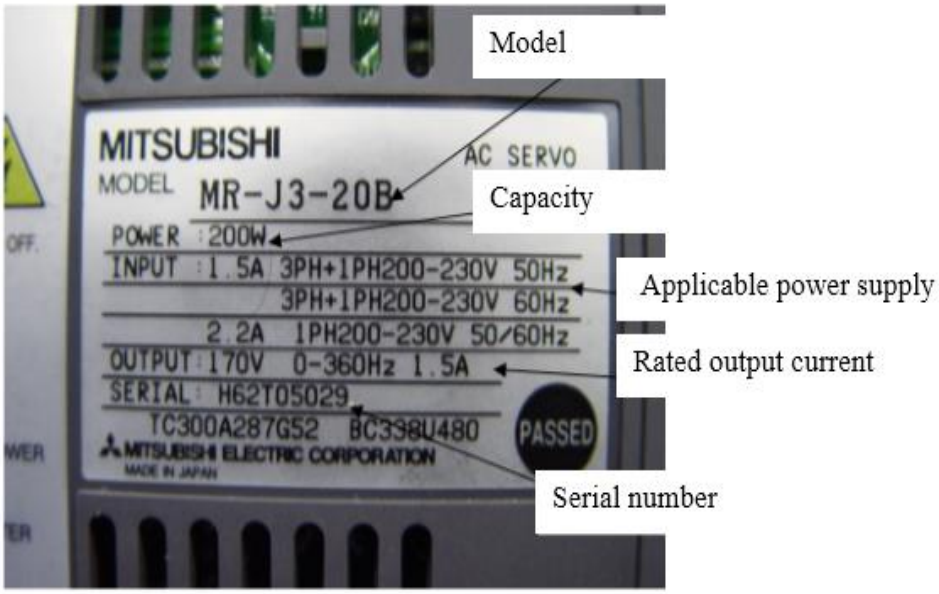


Fig. 1.7: Definition code of an AC Servo MR-J3-20B

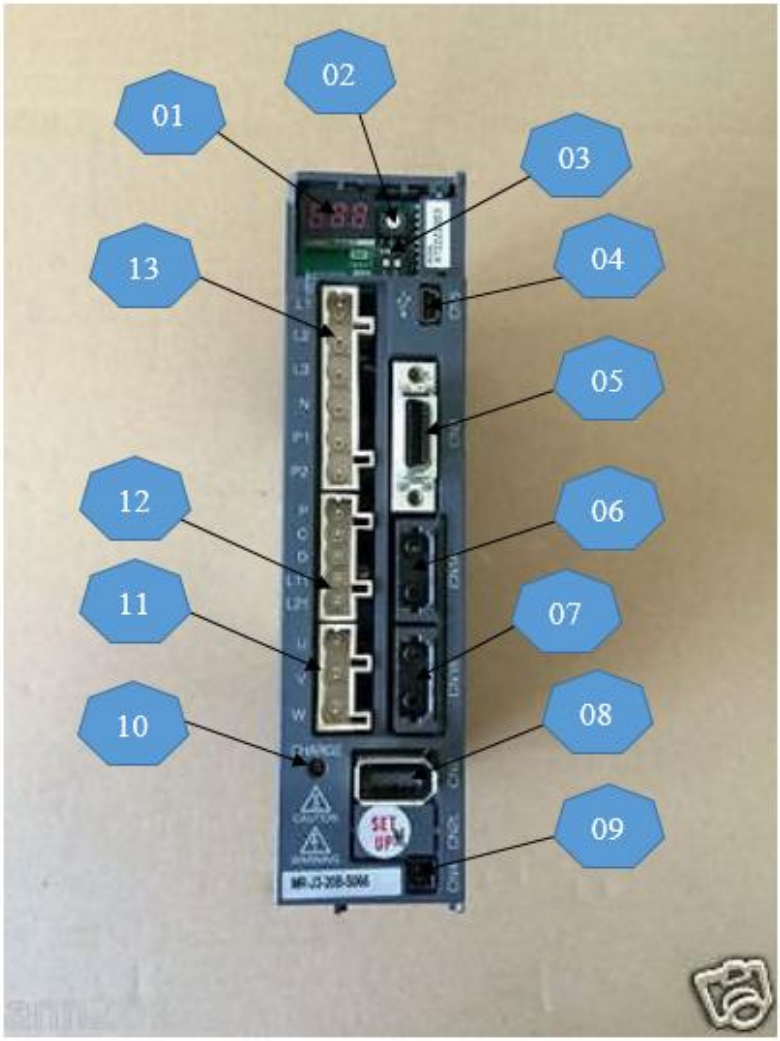


Fig. 1.8: Structure of Melservo MR-J3-20B

01: The 3-digit display, showing the servo status and alarm numbers.

02: Rotary axis setting switch (**SW1**)

Used to set the axis No. of servo amplifier

03: Test operation select switch (**SW2-1**)

Used to perform the test operation mode by using MR Configurator;

SW2-2: *Spare* (be sure to set to the "Down" position)

04: USB communication connector (CN5) (*connect to the personal computer*)

05: I/O signal connector (CN3)

Used to connect digital I/O signals. Moreover an analog monitor is output

06: SSCNET cable connector (CN1A)

Used to connect the servo system controller or the front axis servo amplifier.

07: SSCNET cable connector (CN1B)

Used to connect the rear axis servo amplifier. *For the final axis, putting a cap.*

08: Encoder connector (CN2)

Used to connect the servo motor encoder.

09: Battery connector (CN4)

Used to connect the battery for absolute position data backup.

10: Charge lamp; lit to indicate that the main circuit is charged. *While this lamp is lit, do not reconnect the cables.*

11: Servo motor power connector (CNP3)

12: Control circuit connector (CNP2)

Connect the control circuit power supply/ regenerative option

13: Main circuit power supply connector (CNP1)

Connect the input power supply.

- **Hardware connection to FX_{3U}-20SSC-H**

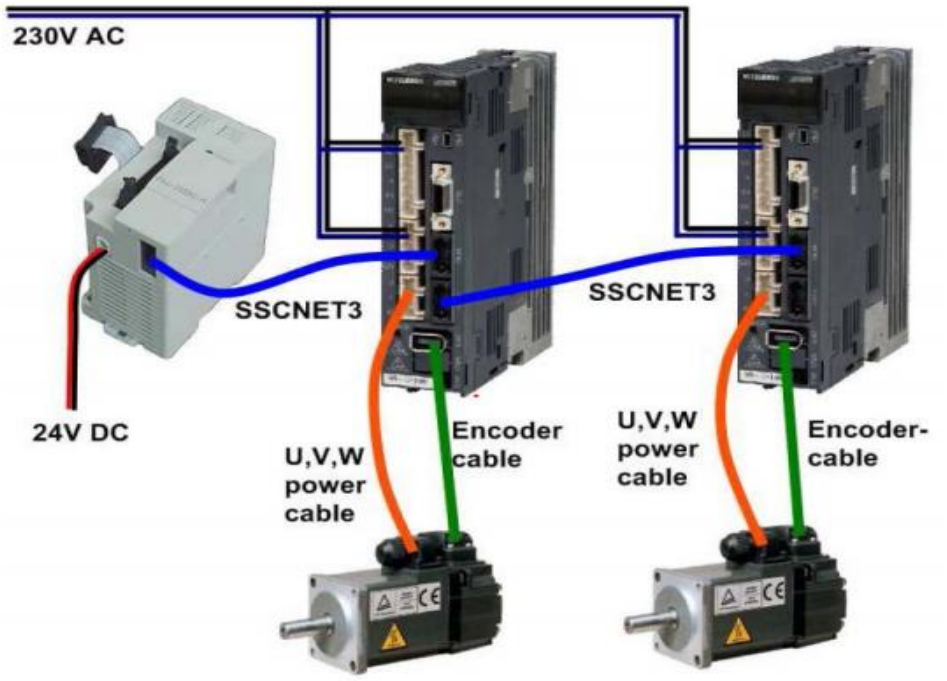


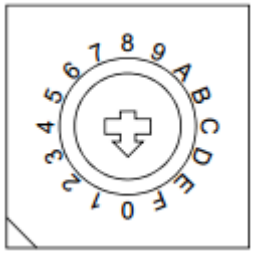
Fig. 1.9: Connection diagram between Melservo and FX_{3U}-20SSC-H

MR-J3-□B servo amplifier directly reads the position data from the encoder. The servo motor's speed /direction control and positioning accuracy with high precision are achieved by reading data from the FX3U-20SSC-H module via the SSCNETIII cable. ***SSCNETIII significantly improves communication speed and noise resistance by using optical communication systems.***

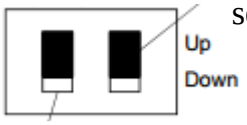
Selection of control axis

Use the rotary axis setting switch (SW1) to set the control axis number for the servo. If the same numbers are set to different control axes in a single communication system, the system will not operater properly. The control axes may be set independently of the SSCNET cable connection sequence.

Rotary axis setting switch (SW1)



SW2



SW2-2: ***Spare*** (be sure to set to the "Down" pos.)

Test operation select switch (SW2-1)
Set the test operation select switch to the "Up" performing the test operation mode by using MR Configurator.

Table 1.2: Status table of the switch on MelServo MR-J3-□B

Spare	Rotary axis setting switch (SW1)	Description	Display
Down (Be sure to set to the "Down" position.)	0	Axis No.1	01
	1	Axis No.2	02
	2	Axis No.3	03
	3	Axis No.4	04
	4	Axis No.5	05

	5	Axis No.6	06
	6	Axis No.7	07
	7	Axis No.8	08
	8	Axis No.9	09
	9	Axis No.10	10
	A	Axis No.11	11
	B	Axis No.12	12
	C	Axis No.13	13
	D	Axis No.14	14
	E	Axis No.15	15
	F	Axis No.16	16

Example:

Table 1.3: Set axis number on the model

Model	Axis Control	Hardware	
		SW1	Axis select
MR-J3-☐B, MR-J3-☐BS, MR-J4-☐B	X-axis	0	Axis No.1
	Y-axis	1	Axis No.2
MR-J3W-☐B, MR-J4W2-☐B	X-axis	0	Axis No.1 (A- Axis)
	Y-axis		Axis No.2 (B- Axis)

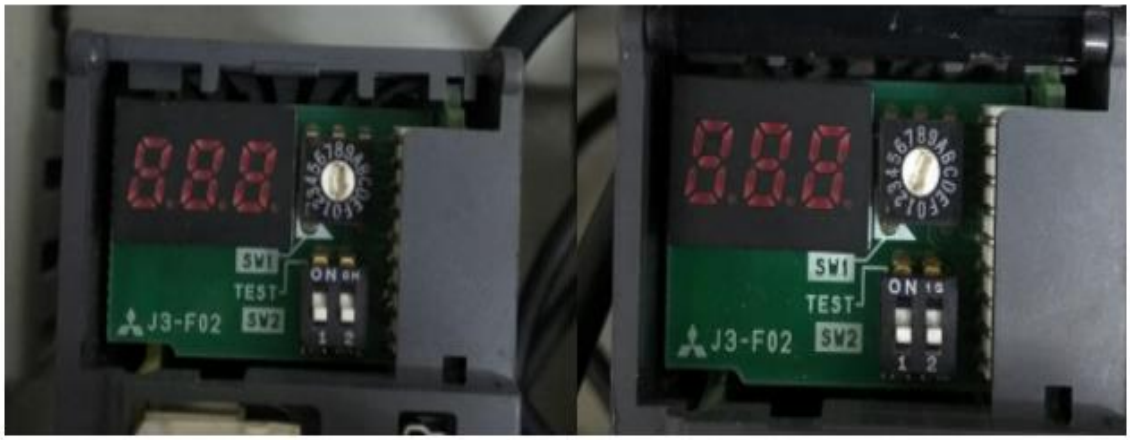


Fig. 1.10: Adjust the number of axis on the model

Note: *When running* ***JOG*** *on the MR-Configrutor software,* ***set SW1 to 0, SW2-1 to ON****.*

- **Servo amplifier display on the Melservo MR-J3-□B**

Ab	Waiting for servo system controller power to switch ON (SSCNET communication)
Ac Ad AE AF AH	Initial data communication with servo system controller (Initialization
b01	Ready OFF/servo OFF
C01	Ready ON/servo OFF
d01	Ready ON/Servo ON
50	Flicker display at occurrence of overload
E1	Flicker display at occurrence of overload warning
E7	Flicker display during controller forced stop
E6	Flicker display during forced stop
AA	Servo system controller power OFF to ON

On the display of a servo amplifier MR-J3-□B, let's check the communication status with a controller when the power is ON; check the no. of axis, and diagnose errors when having alarms.

1.2.4. SSCNET III cable

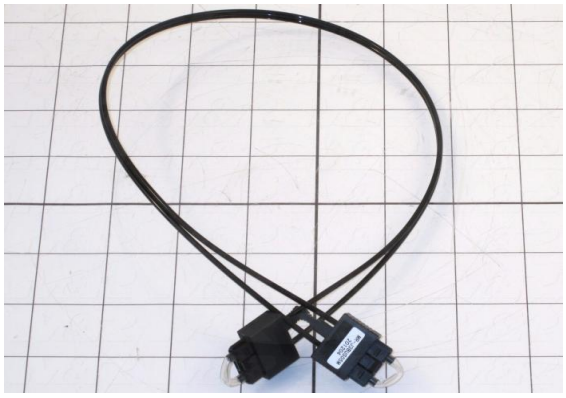


Fig. 2.11: SSCNET III cable

SSCNET III cable uses optical communication, two-way communication with high transfer rate. This is a specialized cable that can be connected and disconnected easily, because using optical communication method should be capable of high interference.

With a ***transfer rate of up to 150 Mbps***, the SSCNET III cable can handle up to three times faster than traditional transmission methods.

Note when using cable SSCNET III:

- ✓ Do not let the SSCNET III cable near the main cable, power lines, and installation standards 100mm (3.94") away from the large power lines, which can cause excitation or interference wave.
- ✓ When removing the SSCNET III cable from the FX3U-20SSC-H port, be sure to attach the protection caps to the cable connectors.
- ✓ Do not remove the SSCNET III cable from its port while not disconnecting the FX3U-20SSC-H or Melservo MR-J3-20B power supply. Do not look directly at the optical fiber head or SSCNET III port, as doing so can cause eye damage.
- ✓ When handling the SSCNET III cable, do not let them be bumped, side pressure, excessive tension. Do not allow oils, solvents near the SSCNET III connector.
- ✓ Do not remove the protection cap from the FX3U-20SSC-H connector until the SSCNET III cable is connected. To avoid the dust coming in, this affects the speed of the cable.

1.3. Operation of the model

1.3.1 General diagram of the system

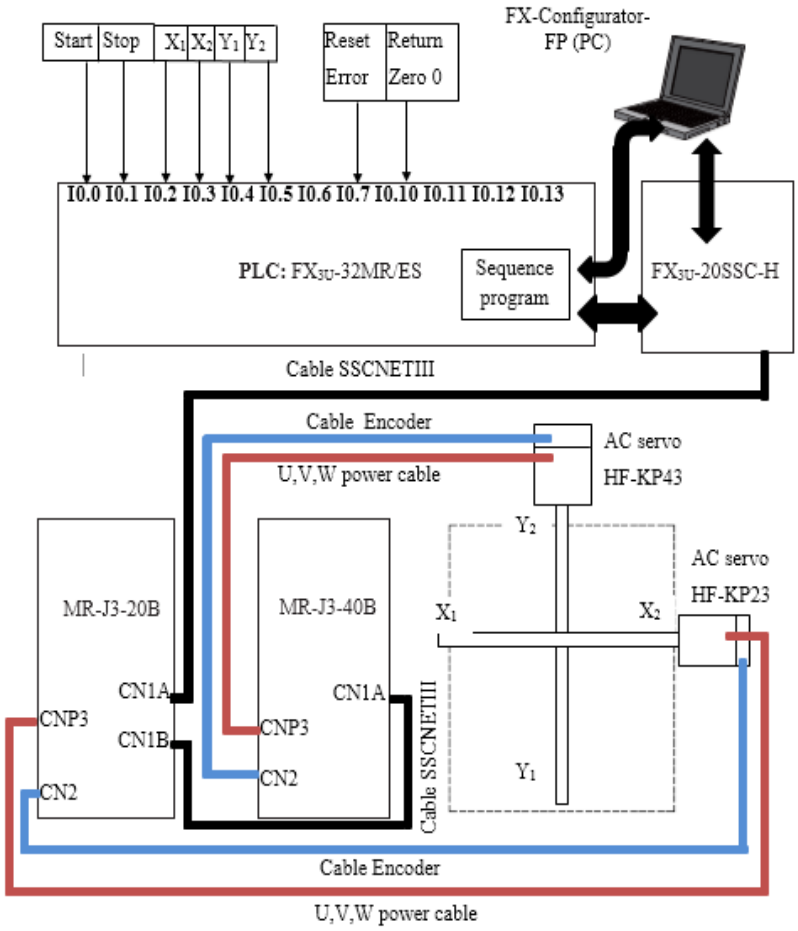


Fig. 1.12: Diagram of the control principle of the model

The X-axis and Y-axis operate in two ways: controlled by FX-Configrutor FP software or PLC programming.

1.3.2 Data transfer process

- ***Power-on data transfer process (A):***
  - ✓ The data in the 20SSC-H flash memory is transferred to the buffer memory (BFM).
  - ✓ The servo parameters are transferred to the servo amplifier.
- ***Data transfer between PLC and BFM (B):***
  - ✓ Applied instructions such as the MOV, or the FROM/TO instruction are used to read/write parameters and data between the PLC and buffer memory.
- ***Writing data to the flash memory (C)***

✓ Using ***FX Configurator-FP*** to modify the buffer memory data including positioning parameters, servo parameters and table information, then activate a save command from the buffer memory to the flash memory.

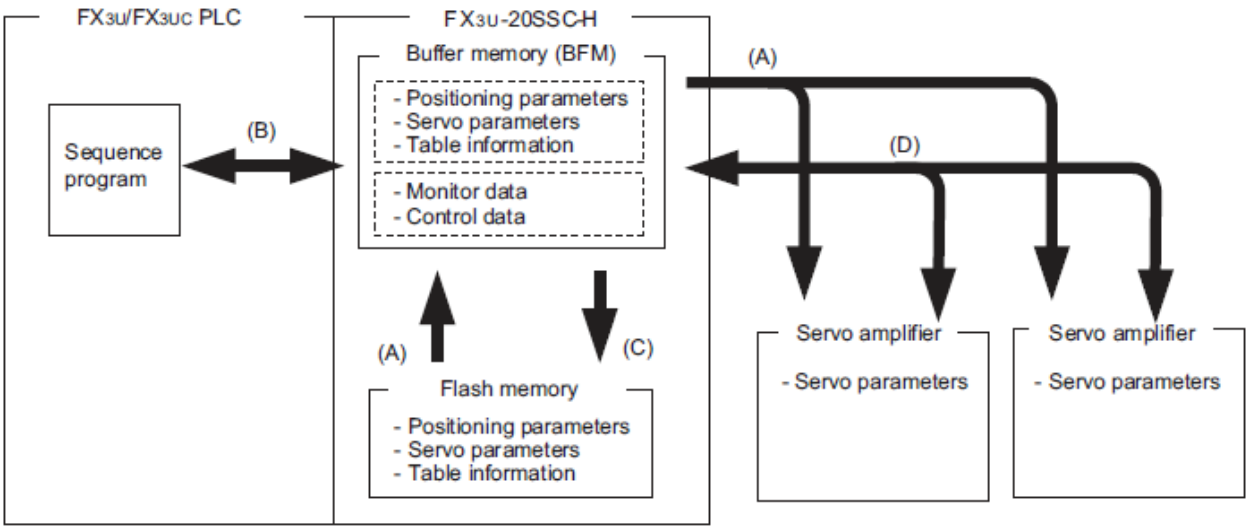


Fig. 1.13: Data transfer process between the modules

➢ ***Data transfer process between 20SSC and servo amplifier (D)***

✓ When servo parameters on the servo amplifier side are modified, the buffer memory of the 20SSC-H is (by default) automatically updated

1.3.3 FX-Configurator FP software

✓ The ***user table data*** are declared on the FX-Configurator FP software and loaded onto the Mitsubishi FX3U-20SSC-H.

✓ The software is switches to "Test Mode" which has control modes (positioning at 1-step speed, linear interpolation, X-axis table operation, XY-axis table operation,...)

✓ Select target address 1, operation step 1, click start -> the model will move to the address you selected via USB to RS422 adapter.

✓ SSCNETIII cables are adopted for data communication with dedicated Melservo (MR-J3-xB)

Note: ***This model uses screw-pitch with 5mm screws that means every rotation of the AC servo will make a displacement of 5mm, and with the dedicated module of FX3U-20SSC-H, 262144 PLS will make the motor turn a round.***

1.3.4 PLC FX3U-32M

- ✓ User program written on GX-Developer/Work2 software is loaded into the PLC.
- ✓ When users press the START button on the control pannel, the table data that the ones have declared will be extracted from the memory area of the FX3U-20SSC-H, and control the movements of axes according to given information. SSCNETIII cables are used for data communication.
- ✓ We also use PLC to communicate with the FX-Configurator FP software and read the whole information that input by users such as positions' coordinates, linear or circular movements.

1.4. Experiment

1.4.1. FX_{3U}-20SSC-H with FX Configurator-FP

➢ **<u>Step 1</u>:** Configuration for FX_{3U}-20SSC-H

- When setting up the FX_{3U}-20SSC-H for the first time or beginning a new project, it is recommended to ***clear the servo parameters, positioning parameters and table information, and then write the desired settings (as needed by the user application) to the controller***.
- The purpose of this section is to define basic settings for the initial testing of the FX_{3U}-20SSC-H using the FX Configurator-FP software. Using FX-Configurator FP to configure the system as follows:

1) Turn on the power

Confirm that the hardware is set up correctly and the PLC is in STOP mode. Turn the power ON. (Both of the servos should display 'Ab' when the power is turned ON for the very first time.)

2) Load the software

Open FX Configurator-FP from the Start menu [Start] → [MELSOFT Application] → [FX Configurator-FP] or from the Tools menu of GX Developer [Tools] → [FX special function utility] → [FX Configurator-FP] and create a New file by clicking on  in the Toolbar.

3) ***Expend the tree of folders*** in the [File data list] panel on the left-hand side by double clicking on [Unset file], [Edit], and [Monitor].

4) Verify communication

Go to [Online] → [Connection setup] → [Comm. Test]. Verify that the devices are communicating properly.

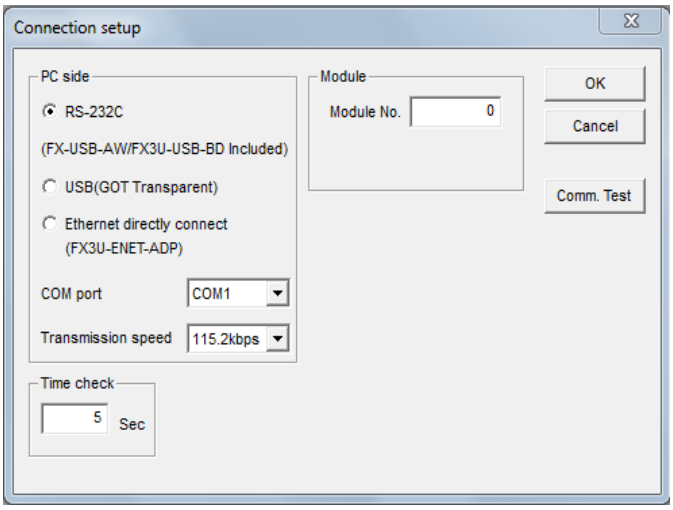


Fig. 1.14: Connection setup with FX_{3U}-20SSC-H

5) Initialize the module

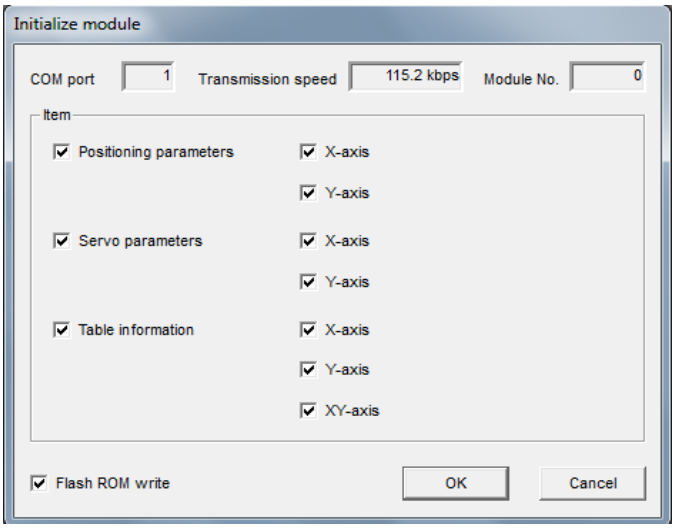


Fig. 1.15: Initialize the module

Go to [Online] → [Initialize module]. Select all servo parameters, positioning parameters and table information and place a check mark in [Flash ROM write]. Click the OK button and proceed with selecting 'Yes' and then 'OK'.

This overwrites all data in the FX_{3U}- 20SSC-H buffer memory and Flash ROM with the default.

6) Set the positioning parameters

Double click on [Positioning parameters] in the [File data list] panel on the left-hand side to modify the positioning parameters.

Change the following items from the [Item] column:

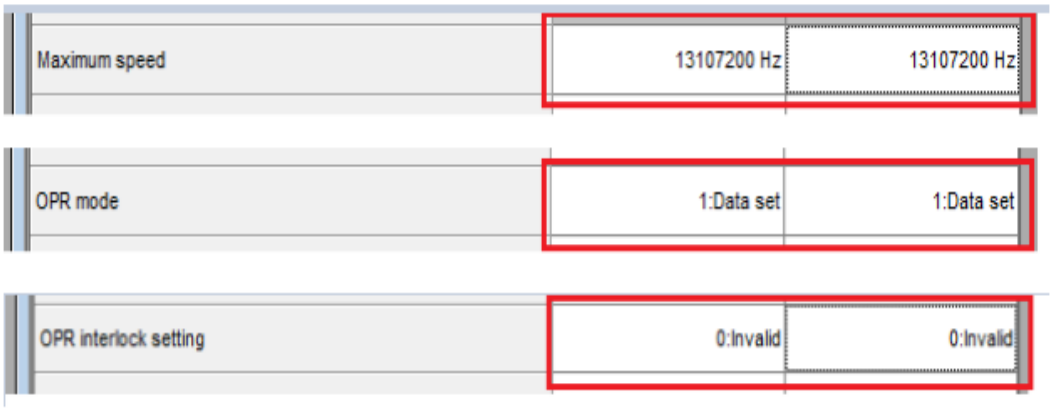


Fig. 1.16: Positioning parameters

(Note: Maximum speed = $V_{AC\ servo}$ x 262144 x $\frac{1}{60}$ = 3000 x262144:60 = 13107200)

7) Set the servo parameters

Assuming a forced stop switch is not used with the MR-J3-B servos, double click on [Servo parameters] in the [File data list] panel on the left-hand side to modify the servo parameters.

Set the following items from the [Kind] column for both the X- and Y- axes:

Unset file / FX3U-20SSC-H / Servo parameters (module:0)

Kind	Item		X-axis	Y-axis
Servo amplifier series	Servo amplifier series		1:MR-J3-B	1:MR-J3-B
Basic setting parameters	Control mode	Control loop composition selection	0:standard control 350 maximum torque setting of HF-KP servo motor(Invalid)	0:standard control 350 maximum torque setting of HF-KP servo motor(Invalid)
	Regenerative brake option	Selection of regenerative brake option	00: Regenerative brake option is not used	00: Regenerative brake option is not used
	Absolute position detection system	Selection of absolute position detection system	0:Used in incremental system	0:Used in incremental system
	Function selection A-1	Servo forced stop selection	1:Invalid (Do not use the forced stop signal.) /01:Not using EM1 or EM2 The electromagnetic brake interlock (MBR) turns off without the forced stop deceleration.	1:Invalid (Do not use the forced stop signal.) /01:Not using EM1 or EM2 The electromagnetic brake interlock (MBR) turns off without the forced stop deceleration.

Fig. 1.17: Servo parameters

8) *Write the servo and positioning parameters*

Write the servo parameters and positioning parameters to the FX_{3U}-20SSC-H by pressing the 'Write to module' button or by using [Online] → [Write to module (Ctrl+T)]. ***Select only the servo and positioning parameters and put a check mark in the [Flash ROM write] box as shown below***. The servos may lose communication since a power reset is needed.

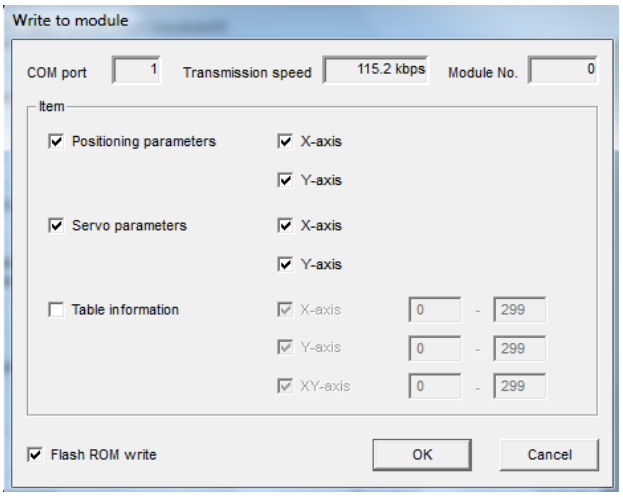


Fig. 1.18: Write parameters to module

9) *Reset the power*

Reboot the power to the system to enable communication to the MR-J3 servos. This can be done with a hard boot, or by pressing the 'System reset' button. Once communication is established, the servos will read '**d01**' and '**d02**'. If communication is not established, check the servo hardware and servo parameters again.

➢ <u>Step 2</u>: Using TEST MODE

Verify that the PLC is in STOP mode before proceeding with this section.

To enter TEST MODE, press the 'Test On/Off' button in the Test toolbar or go to [Online] →[Test] → [Test On/Off]. Select 'Yes' and then 'OK'.

Open up the X- and Y- axis Operation test windows by clicking on the two buttons: and .

➢ **<u>Step 3</u>: JOG operation, X-axis**

In the [X-axis Operation test] window, click on the [JOG/MPG] tab. Click and hold down the FWD JOG button. Try changing the JOG speed and JOG instruction evaluation time.

(For more information on the JOG instruction evaluation time, refer to Chapter 8.2.1 in the FX$_{3U}$-20SSC-H User's Manual (JY997D21301E))

If positioning does not begin, verify that Positioning and Servo parameters are set for the X- and Y- axes as described in (6) and (7) of *Step 1*.

➢ **<u>Step 4</u>: Setting the zero point**

When the zero-point is set, the current address data gets set to the zero-point value. This is accomplished by directly changing the current address to 0 (or some other address), or by activating the zero return command in the data-set type OPR mode.

Click on the X-axis and Y-axis [OPR] tabs and then click the [REQ. OPR] button and select 'Yes' anh 'OK'.

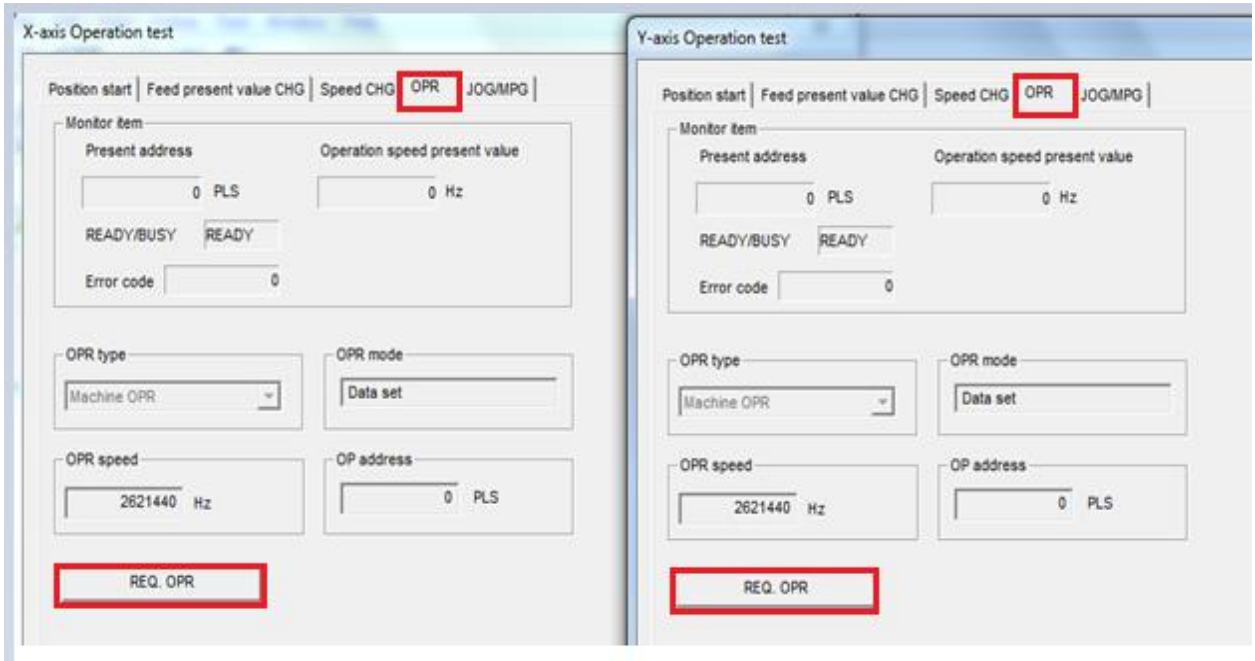


Fig. 1.19: Setting the zero point

➢ **<u>Step 5</u>: Positioning patterns, X-axis**

By default, the FX3U-20SSC-H is set to absolute positioning. If you want to place a relative position, use a table program (declared on FX-Configrutor FP software) or PLC program to specify [Incremental mode]. The following are some of the control modes on the

FX-Configrutor FP software

Positioning at 1-step speed

- ✓ Set the zero-point according to *Step 4: Setting the Zero Point* above if you haven't already done so.
- ✓ Click on the [Position start] tab and select [Positioning at 1-step speed] in the X-axis Pattern drop-down menu. Set the following X-axis information:

Target address 1:	5,000,000 PLS
Operation speed 1:	1,000,000 Hz

- ✓ Click on the [Start] button and observe the motor. Click 'Yes' and 'OK'.
- ✓ If positioning does not begin, verify that Positioning and Servo parameters are set for the X and Y axes as described in (6) and (7) of *Step 1*.

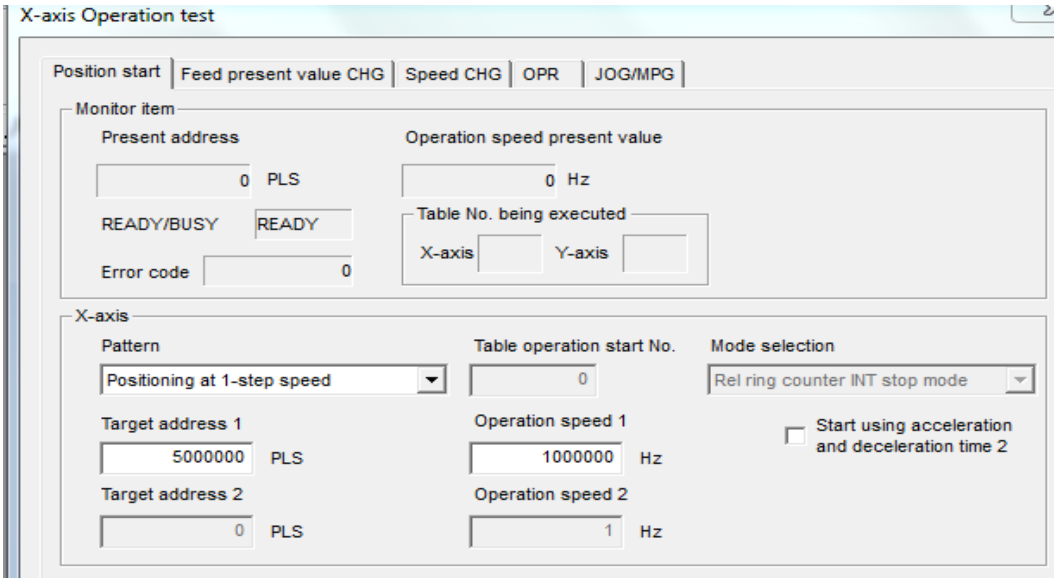


Fig. 1.20: Positioning at 1-step speed, X-axis

Positioning at 2-step speed

- ✓ Select [Positioning at 2-step speed] in the X-axis Pattern drop-down menu of the [Position start] tab. Set the following X-axis information:

Target address 1:	-2,000,000 PLS
Operation speed 1:	2,000,000 Hz
Target address 2:	0 PLS

Operation speed 2:	1,000,000 Hz

✓ Click on the [Start] button and observe the motor. Click 'Yes' and 'OK'.

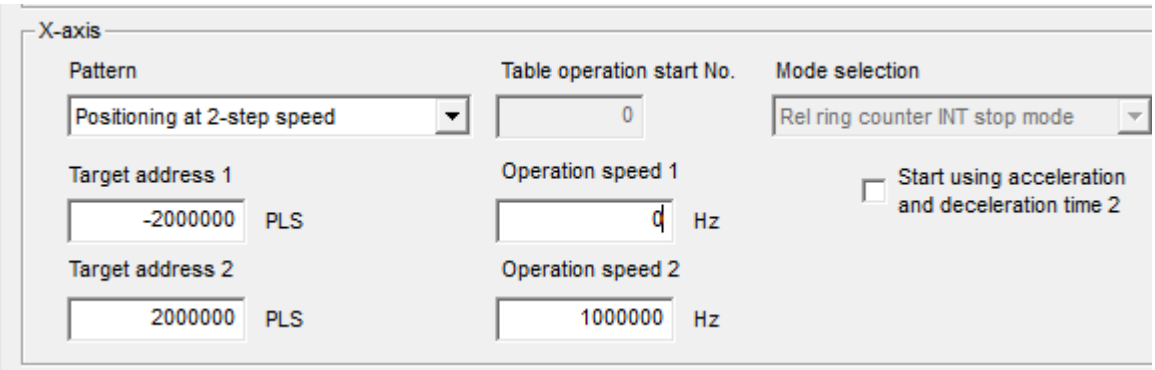


Fig. 1.21: Positioning at 2-step speed, X-axis

Variable speed operation

✓ Select [Variable speed operation] in the X-axis Pattern drop-down menu of the [Position start] tab. Set the following X-axis information:

Operation speed 1:	5,000,000 Hz

✓ Click on the [Start] button and then 'Yes' and 'OK'.

✓ Now click on the [Speed CHG] tab to adjust the speed during operation. Try adjusting the [Speed override] setting by entering the following values into the [Speed override] box and pressing the [REQ. speed override] button.

3,000 (x0.1%)

500 (x0.1%)

10 (x0.1%)

Note: the speed changes that occur with each setting. Finally, click the [Stop] button, 'Yes,' and 'OK'.

Linear interpolation

✓ Return the X- and Y- addresses to '0' by setting the zero-point according to ***Step 4: Setting the Zero Point.***

✓ Select [Linear interpolation] in the X-axis Pattern drop-down menu of the [Position start] tab. Set the following X-axis information:

X-axis

Target address 1:	1,000,000 PLS
Operation speed 1:	1,000,000 Hz

Y-axis

Target address 1:	5,000,000 PLS

- ✓ Click on the [Start] button and observe the motors. Click ‘Yes’ and ‘OK’.
- ✓ If positioning does not begin, verify that Positioning and Servo parameters are set for the X and Y axes as described in (6) and (7) of *Step 1*.

XY-axis table operation

- ✓ To operate the XY axis table, enter the data in the "XY- axis Table information" on the FX-Configrutor FP software. And write to the PLC. You can refer to the example table below

No.	Command Code	Address x:[PLS] y:[PLS]	Speed fx:[Hz] fy:[Hz]	Arc center i:[PLS] j:[PLS]	Time [10ms]	Jump No.	m code
0	Incremental address specification						-1
1	X-axis positioning at 1-step speed	2,000,000	1,000,000				-1
2	Y-axis positioning at 1-step speed						-1
		2,000,000	1,000,000				
3	XY-axis positioning	5,000,000	1,000,000				-1

	at 1-step speed	-5,000,000	1,000,000				
4	Circular interpolation (CNT,CW)	0	1,500,000	500,000			-1
		0		500,000			
5	Dwell				30		-1
6	XY-axis positioning at 2-step speed	1,000,000	1,000,000				-1
		-1,000,000	1,000,000				
7	XY-axis positioning at 2-step speed	-1,000,000	1,000,000				
		1,000,000	1,000,000				
8	Dwell				30		-1
9	XY-axis positioning at 2-step speed	1,000,000	1,000,000				-1
		-1,000,000	1,000,000				
10	XY-axis positioning at 2-step speed	-1,000,000	1,000,000				
		1,000,000	1,000,000				
11	Dwell				30		-1
12	Circular	0	700,000	500,000			-1

	interpolation (CNT,CCW)	0		500,000			
13	Dwell				30		-1
14	XY-axis positioning at 2-step speed	1,000,000	1,500,000				-1
		5,000,000	750,000				
15	XY-axis positioning at 2-step speed	-5,000,000	750,000				
		-1,000,000	1,500,000				
16	Dwell				30		-1
17	Linear interpolation	2,000,000	262,144				-1
		-2,000,000					
18	Dwell				150		-1
20	End						

With PLS addresses, the numbers can be very large. To reduce the number size, the

Position data magnification item can be changed to "3:x1000 times" in the **[Positioning parameters]**. If this is changed with data already entered in a table information window, the fields with addresses that lay outside the range –2,147,483,648 to 2,147,483,647 will be highlighted in RED, indicating they must be changed.

After entering the above table, click on the  button or use **[Online] →[Write to module (Ctrl+T)]**. Remove checkmarks from [Positioning parameters] and [Servo parameters] and put a checkmark in [Table information]. Unselect the [X-axis] and [Y-axis], put a checkmark in [XY- axis], and modify the table number range (table rows) to 0 – 25. This will decrease the download time to the FX_{3U}-20SSC-H. Unselect the [Flash ROM write] checkbox, click 'OK' and then 'OK' again.

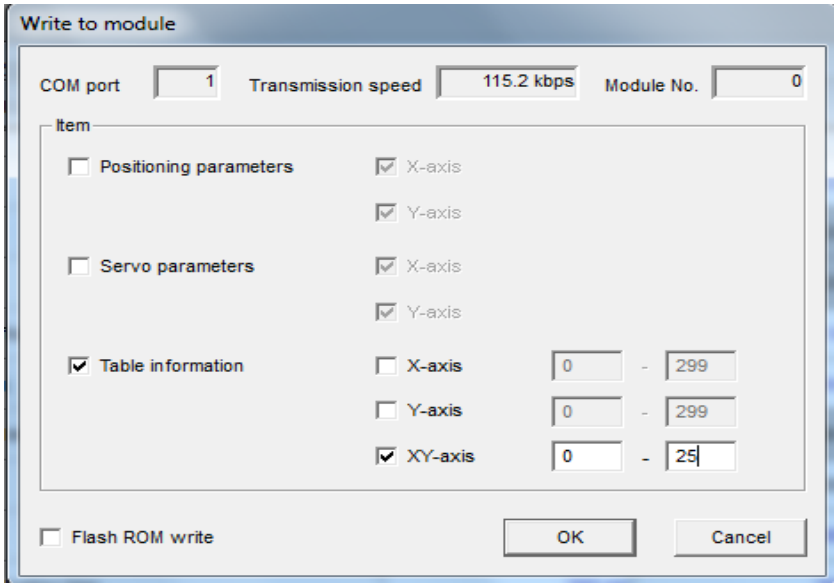


Fig. 1.22: Write information stable to PLC

Select [XY-axis table operation] in the X-axis Pattern drop-down menu of the [Position start] tab. Set the [Table operation start No.] as desired (0 in this example) and begin positioning by pressing the [Start] button, 'Yes,' and 'OK'.

If positioning does not begin, verify that Positioning and Servo parameters are set for the X and Y axes as described in (6) and (7) of ***Step 1***.

➢ **<u>Step 6</u>:** Using Monitor Model

- To use operation monitor during positioning, first enable the XY-operation Table pattern in TEST MODE and begin its operation by following *Section XY-axis table operation* above. Do not stop the operation. Instead, click on the Close button to exit the X-axis Operation test window.

Press the ‘Test On/Off’ button in the Test toolbar and click ‘Yes’ to turn TEST MODE off. Double-click on [Operation monitor] in the [File data list] panel on the left-hand side. Click on the [Monitor Start] button and experiment with the [X-axis Operation status] and [Y-axis Operation status] buttons to monitor axis control data such as target addresses and operation speeds and servo status. By clicking on the [Signal] button, the FX_{3U}-20SSC-H monitor data can be displayed for useful feedback. The Operation Monitor is also helpful for determining positioning errors.

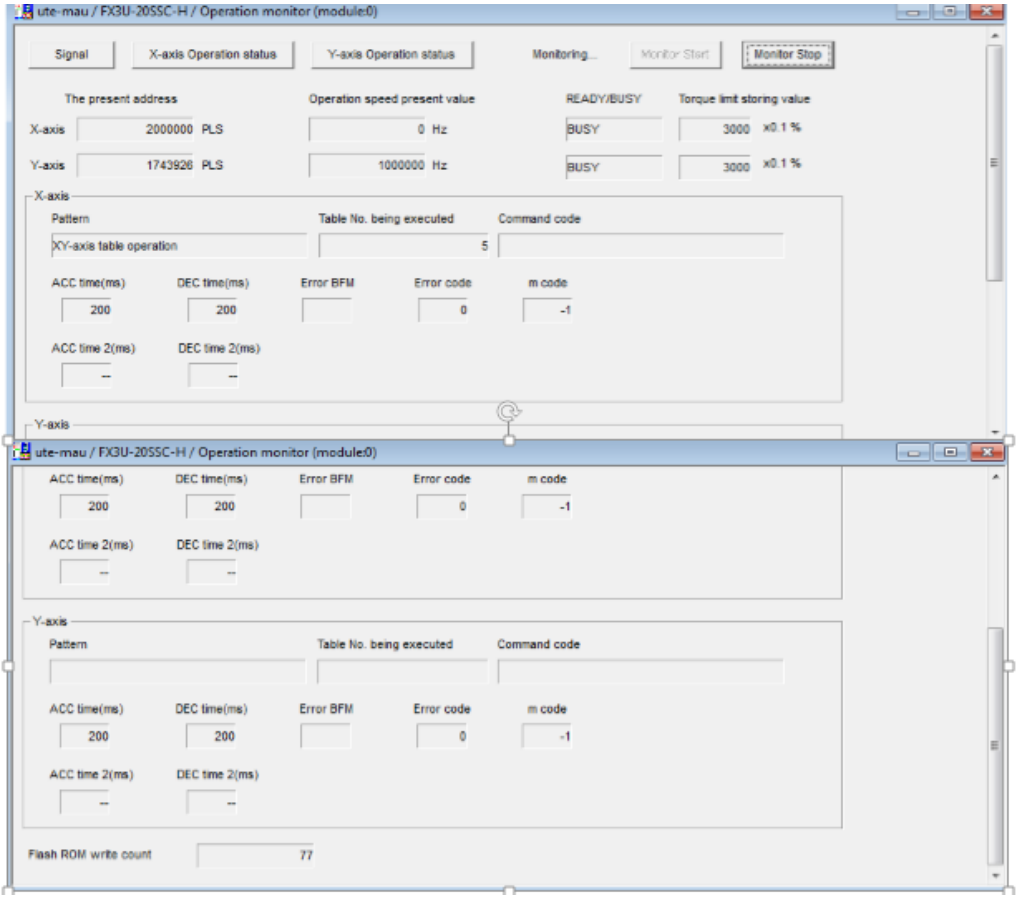


Fig. 1.23: Operation Monitor

1.4.2. FX3U-20SSC-H with GX Developer/Work2.

- **<u>Step 1</u>: Creat a new Project**
  - ✓ Open GX-Developer by clicking [Start] → [GX-Developer] or double-clicking on the GX-Developer software icon on the desktop. Click on display GX-Developer software or press ***“Ctrl+N”***

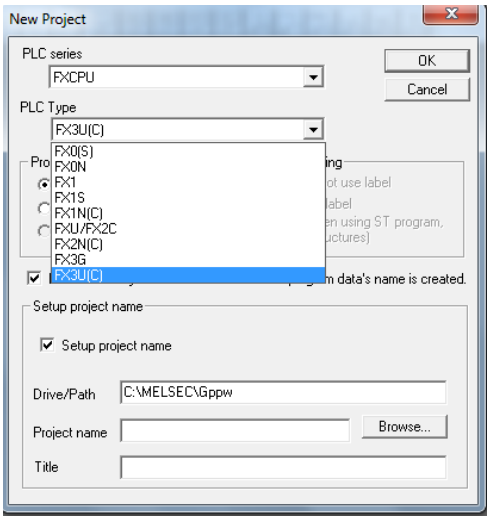


Fig. 1.24: Choose PLC series (FX3U)

- ✓ Select ***"FXCPU"*** in the item *"PLC series"*. Then select ***"FX3U(C)"*** in the item *"PLC Type"*
- ✓ Check ***'Ladder'***, choose setup project name then enter the project name, after that choose address of the folder you want to save this project. Then press Creat new

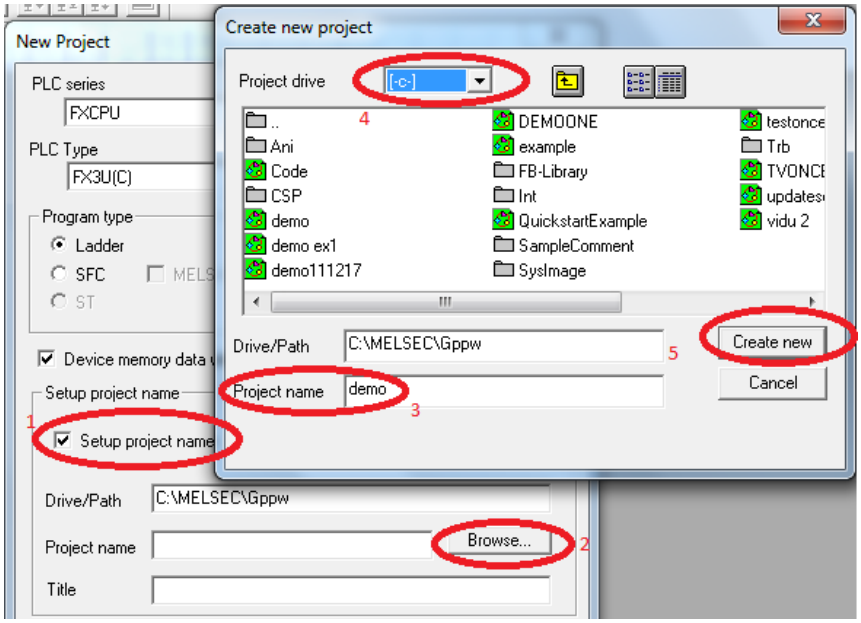


Fig. 1.25: Create a new project on GX-Developer

- ➢ **<u>Step 2</u>: PLC programming**
  - ✓ This is a sample program written on the GX-Developer software using: Start (X000), Stop (X001), Reset error (X007), Return Zero 0 (X010).
  - ✓ ***When press Start:*** The data information that you installed on the desk will be read from FX3U-20SSC-H, via SSCNETIII cable, transfer to Melservo MR-J3-20B; the

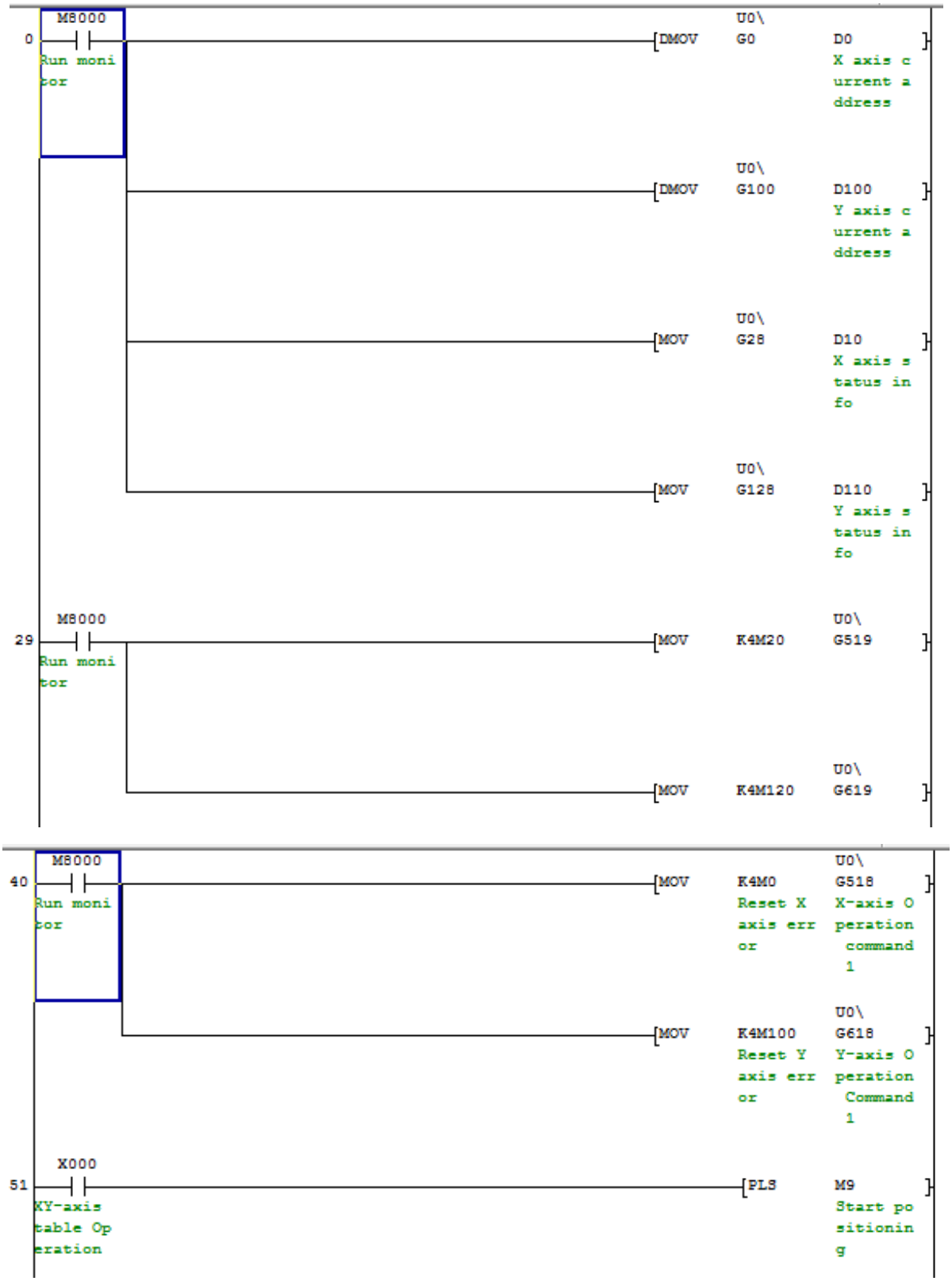
control signal from encoder returned makes the AC servo rotate → The machine moves to the installed position on the FX-Configrutor-FP configuration.

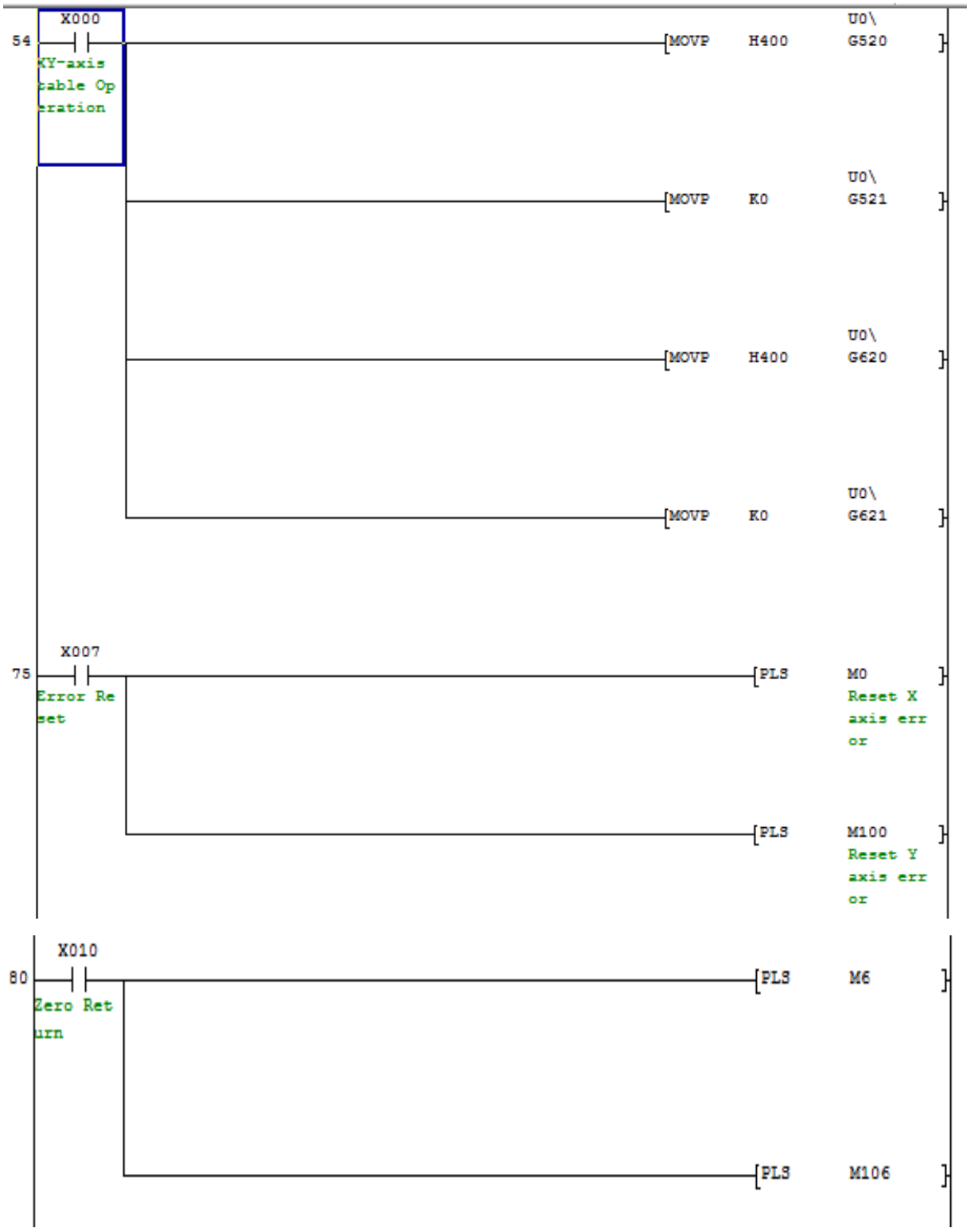
Table 1.5: PLC address assignments

Address	Device name	Remark
X000	Start	NO
X001	Stop	NC
X002	Forward rotation limit (X-axis)	NO
X003	Reverse rotaion limit (X-axis)	NO
X004	Forward rotation limit (Y-axis)	NO
X005	Reverse rotaion limit (Y-axis)	NO
X006	X-axis JOG (+)	NO
X007	Reset Error	NO
X010	Return Zero 0	NO
X011	X-axis JOG (-)	NO
X012	Y-axis JOG (+)	NO
X015	Y-axis JOG (-)	NO
D0	X-axis current address	
D100	Y-axis current address	
U0\G28	X-axis status information	BFM#
U0\G128	Y-axis status information	BFM#
M9	Table operation	

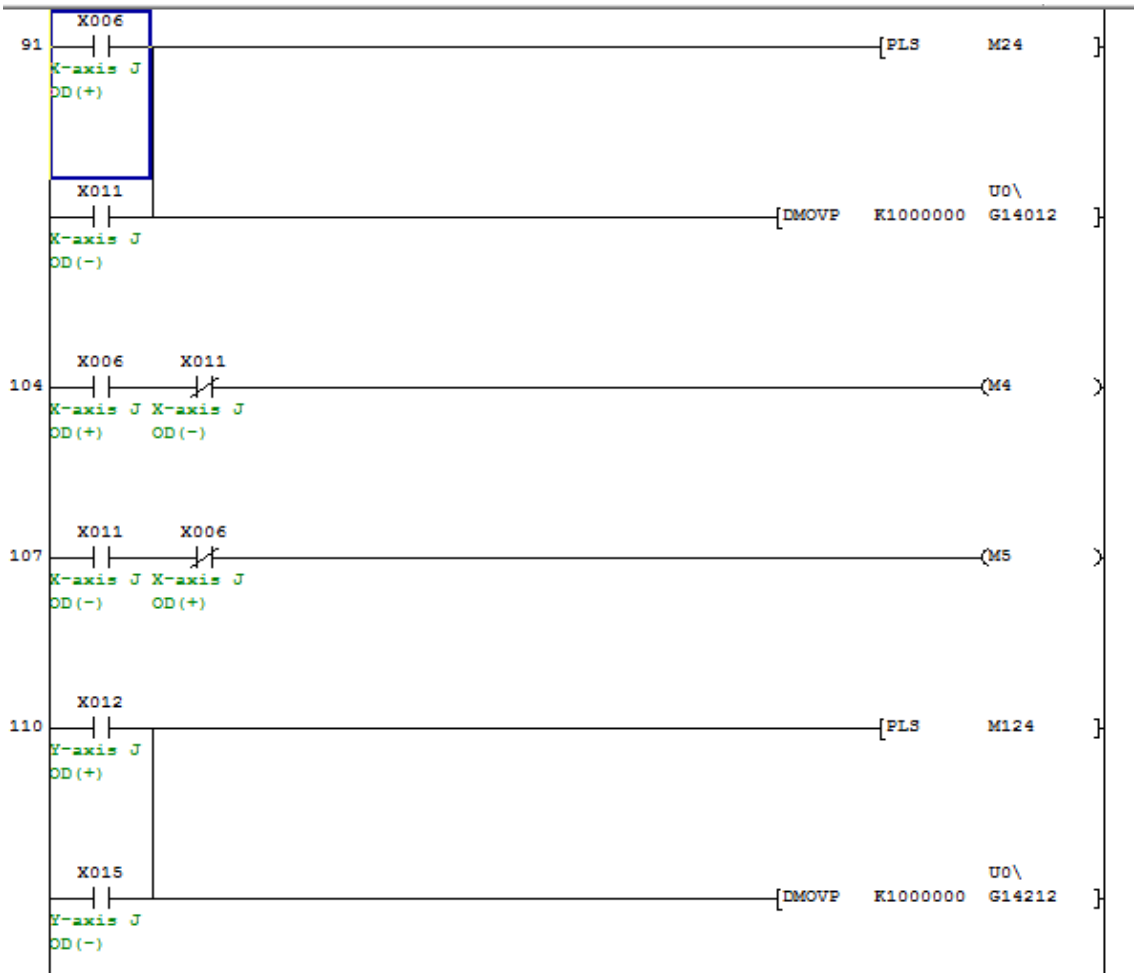
M24	Position, parameter anable command	Enable the X-axis JOG speed
M124	Position, parameter anable command	Enable the Y-axis JOG speed
U0\G14012	BFM# (JOG speed)	X-axis (BFM#14012, #14013)
U0\G14212	BFM# (JOG speed)	Y-axis (BFM#14212, #14213)
M4	X-axis JOD(+) operation is being performed	
M5	X-axis JOD(-) operation is being performed	
M6	X-axis zero return	
M104	Y-axis JOD(+) operation is being performed	
M105	Y-axis JOD(-) operation is being performed	
M106	Y-axis zero return	
U0\G521	Table operation start No.	X-axis
U0\G621	Table operation start No.	Y-axis
U0\G519	Opertion command 2	X-axis
U0\G619	Opertion command 2	Y-axis

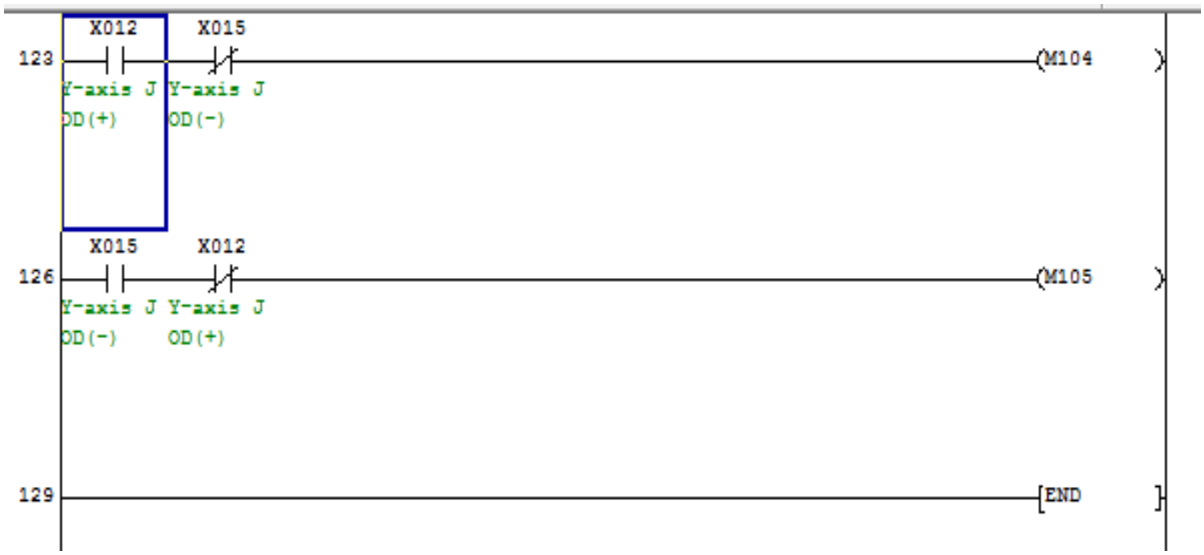
PLC program


0
M8000
Run monitor
DMOV
U0\G0
D0
X axis current address
DMOV
U0\G100
D100
Y axis current address
MOV
U0\G28
D10
X axis status info
MOV
U0\G128
D110
Y axis status info
29
M8000
Run monitor
MOV
K4M20
U0\G519
MOV
K4M120
U0\G619
40
M8000
Run monitor
MOV
K4M0
Reset X axis error
U0\G518
X-axis Operation command 1
MOV
K4M100
Reset Y axis error
U0\G618
Y-axis Operation Command 1
51
X000
XY-axis table Operation
PLS
M9
Start positioning


54
X000
XY-axis table Operation
MOVP H400 U0\G520
MOVP K0 U0\G521
MOVP H400 U0\G620
MOVP K0 U0\G621
75
X007
Error Reset
PLS M0 Reset X axis error
PLS M100 Reset Y axis error
80
X010
Zero Return
PLS M6
PLS M106


85
X001
Stop Ope
ration
M1
X002
Forward
rotation
limit X
X003
Reverse
rotation
limit X
X004
Forward
rotation
limit Y
X005
Reverse
rotation
limit Y


91
X006
X-axis J
OD(+)
PLS M24
X011
X-axis J
OD(-)
DMOVP K1000000 U0\
G14012
104
X006
X-axis J
OD(+)
X011
X-axis J
OD(-)
M4
107
X011
X-axis J
OD(-)
X006
X-axis J
OD(+)
M5
110
X012
Y-axis J
OD(+)
PLS M124
X015
Y-axis J
OD(-)
DMOVP K1000000 U0\
G14212



Note that the M8000 is always ON when the PLC is running

- **<u>Step 3</u>: Select the PLC connection method**
  - ✓ **Go online → Transfer Setup → Serial USB**. A PC side I/F serial setting will appear, select the COM port and data transfer speed..

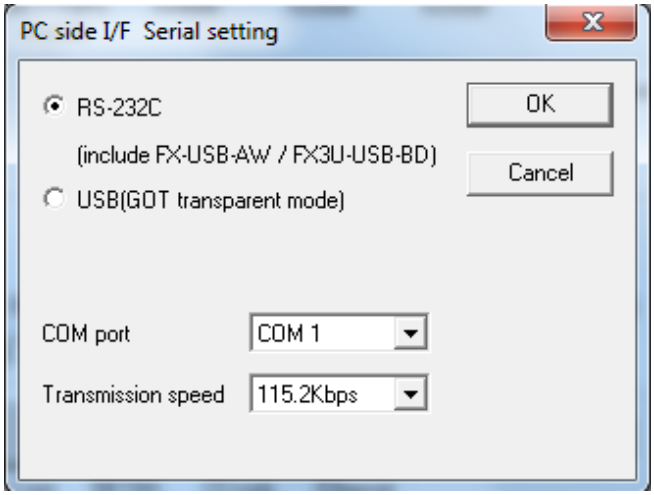


Fig. 1.26: PC side I/F serial setting

- **<u>Step 4</u>: Write a program to PLC**
  - ✓ **Click online→ chose Write to PLC**. Write to PLC will appear, tick main. Press Exucute → Yes → OK. Then click Close

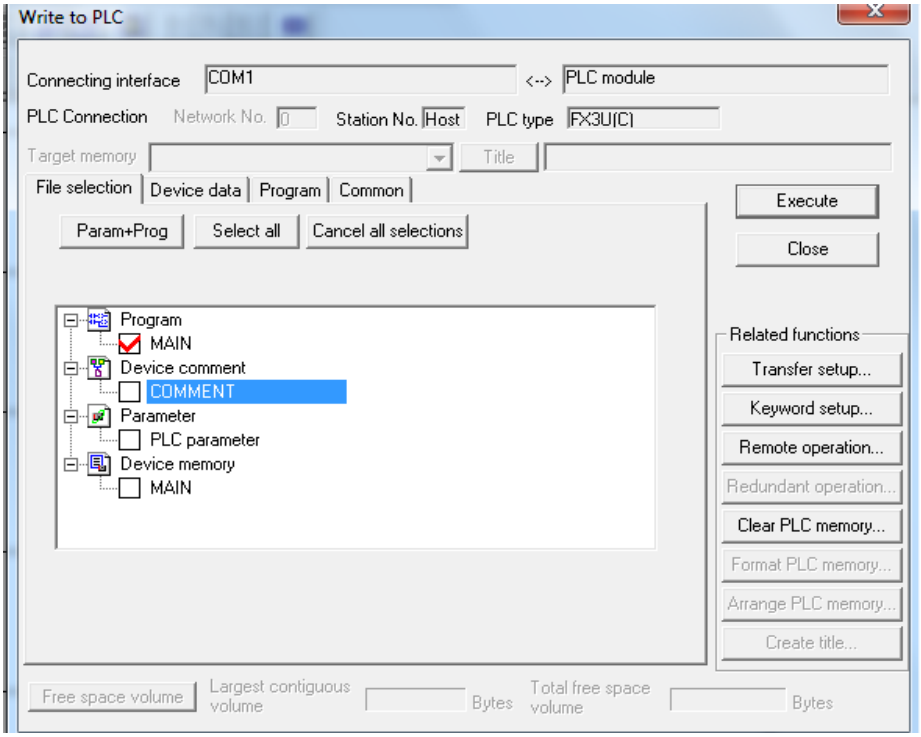


Fig. 1.27: Write a program to PLC

- **<u>Step 5</u>: Use device comment to set up input and output addresses**

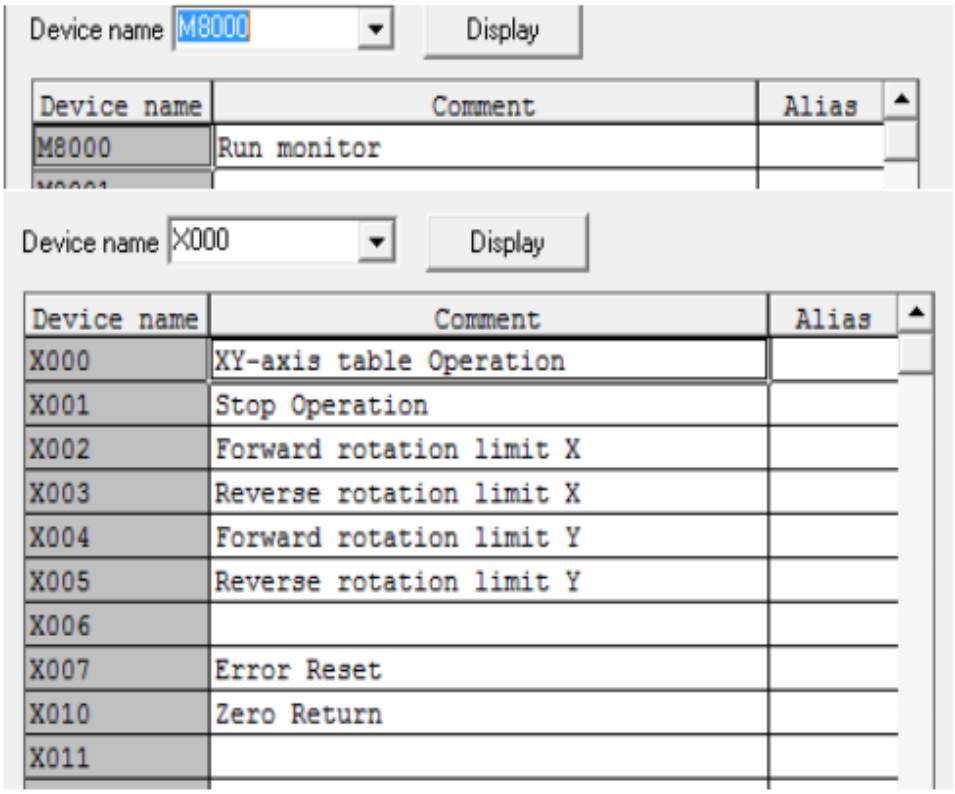


Fig. 1.28: Set up input and output addresses

An example of the interpolation results

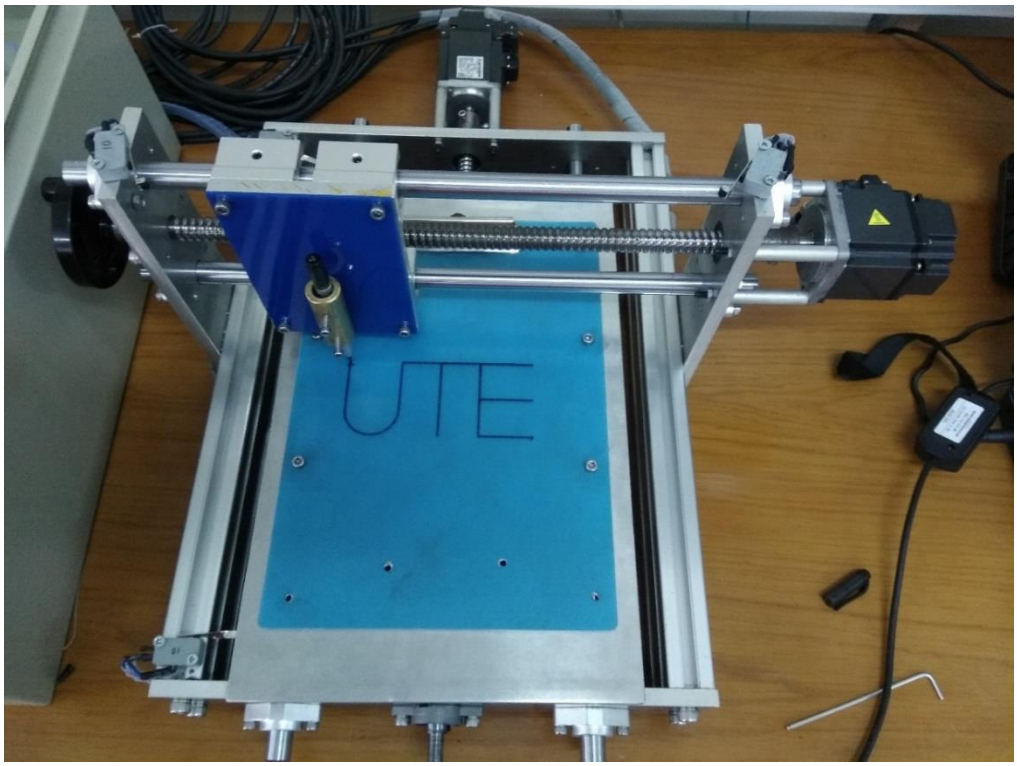


Figure 1.29: The 2 axis interpolation result

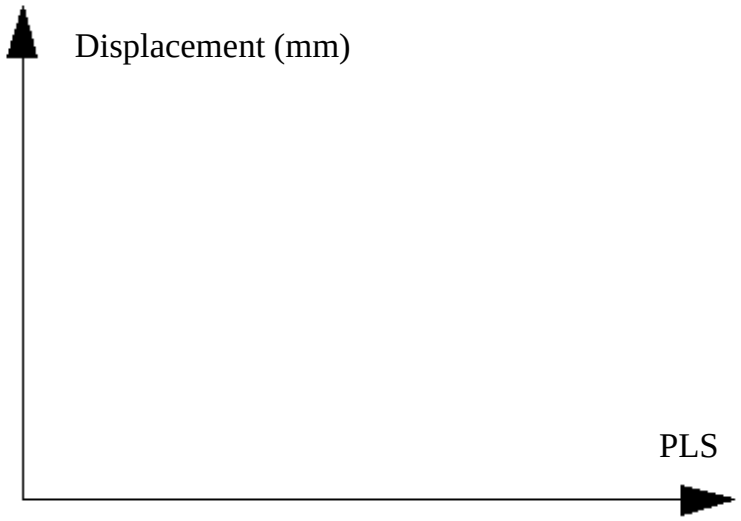
1.5. Calculating BLU

Enter the position and frequency values of some points, measure the distance traveled on the model's table and fill in the following table:

No.	Position and frequency (PLS; Hz)	Measure the distance traveled (mm)	**BLU**
1	200,000PLS; 1000000Hz		
2	500,000PLS; 1000000Hz		
3	600,000PLS; 1000000Hz		
4	700,000PLS; 1000000Hz		
5	900,000PLS; 1000000Hz		
6	1,000,000PLS; 1000000Hz		

7	1,200,000PLS; 1000000Hz		
8	1,500,000PLS; 1000000Hz		
9	2,000,000PLS; 1000000Hz		
10	2,500,000PLS; 1000000Hz		

Plot and comment on the results from the data obtained in exe. 1



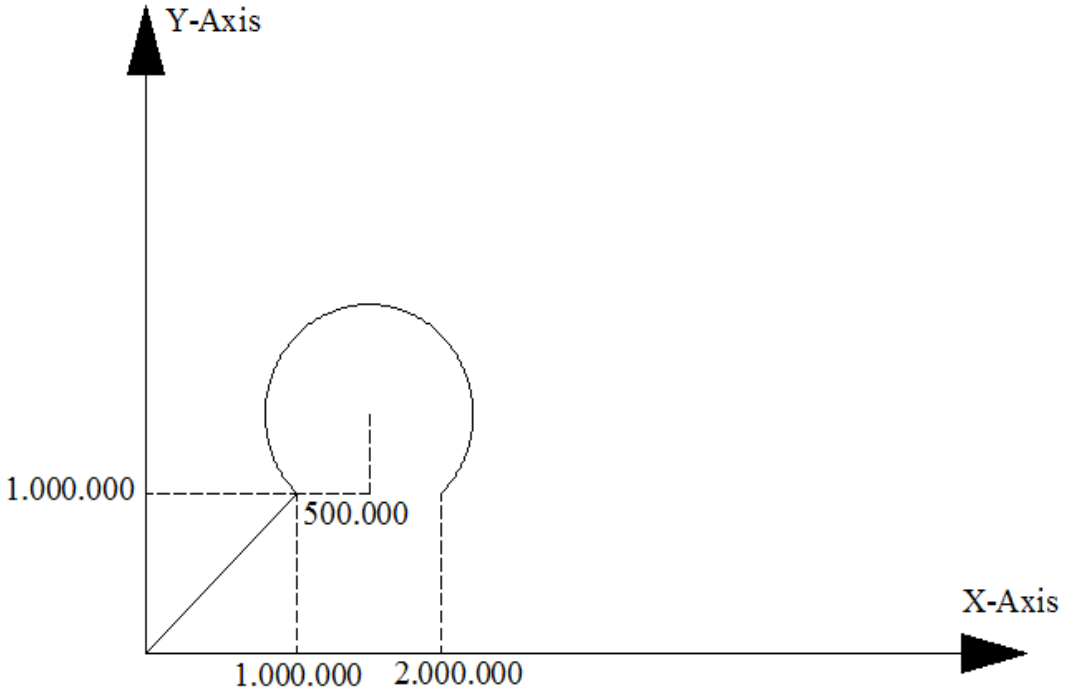
(With 262144 PLS will make AC servo turn 1 round. All vitmes have a screw pitch of 0.5mm)

1.6 Programming PLC to interpolate figures

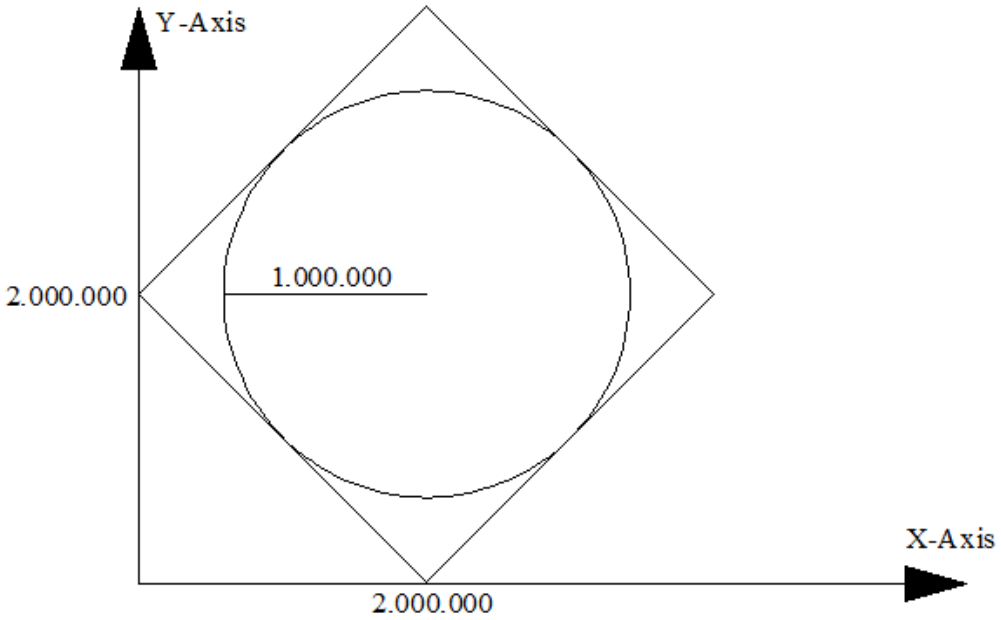
Students have to draw some following figures by two methods (manual control on FX-Configrutor-FP software and programming on GX-Developer/Work2).

The obtained results (figures, data tables, PLC code) have to be included in the report.

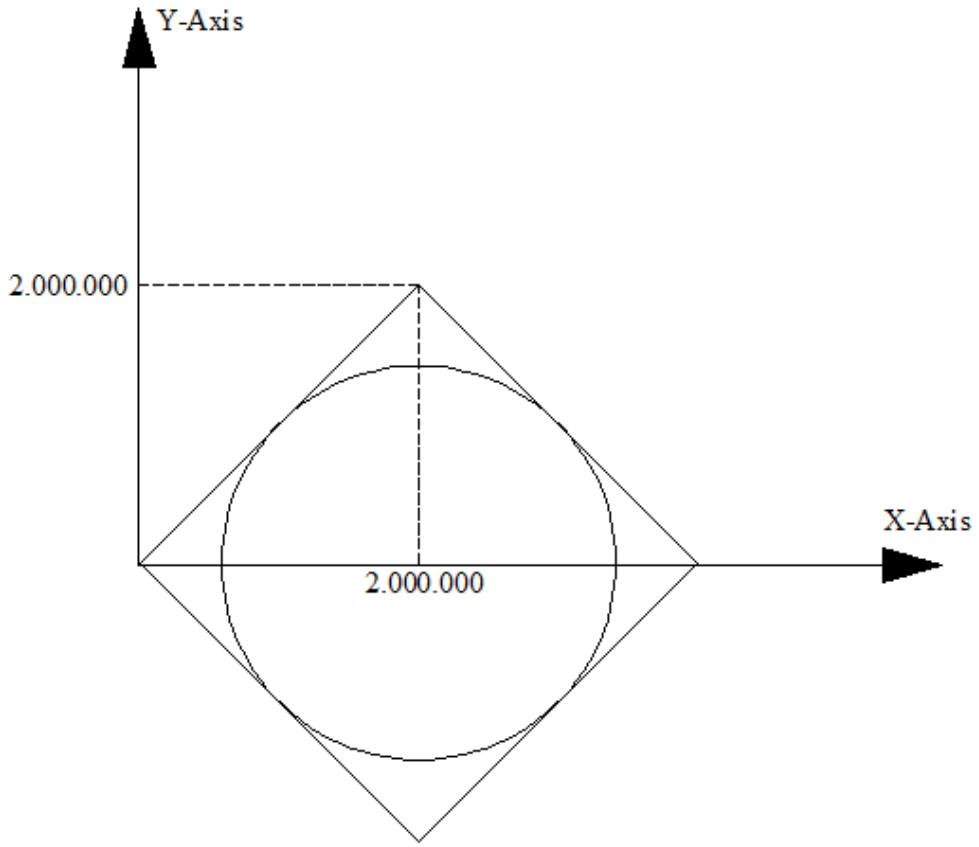
a.


Y-Axis
1.000.000
500.000
X-Axis
1.000.000
2.000.000

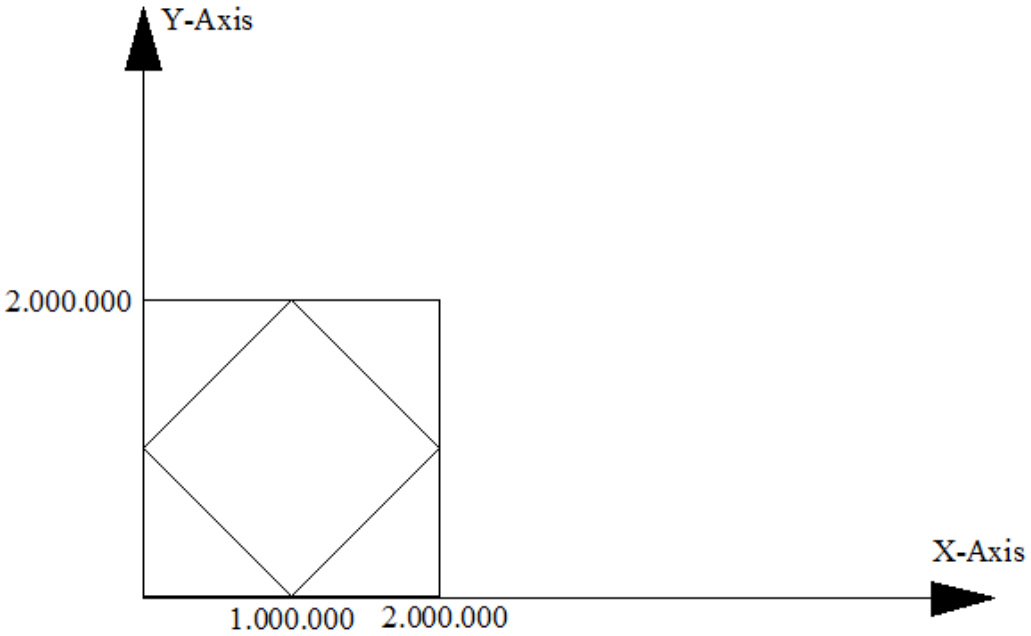
b.


Y-Axis
2.000.000
1.000.000
X-Axis
2.000.000

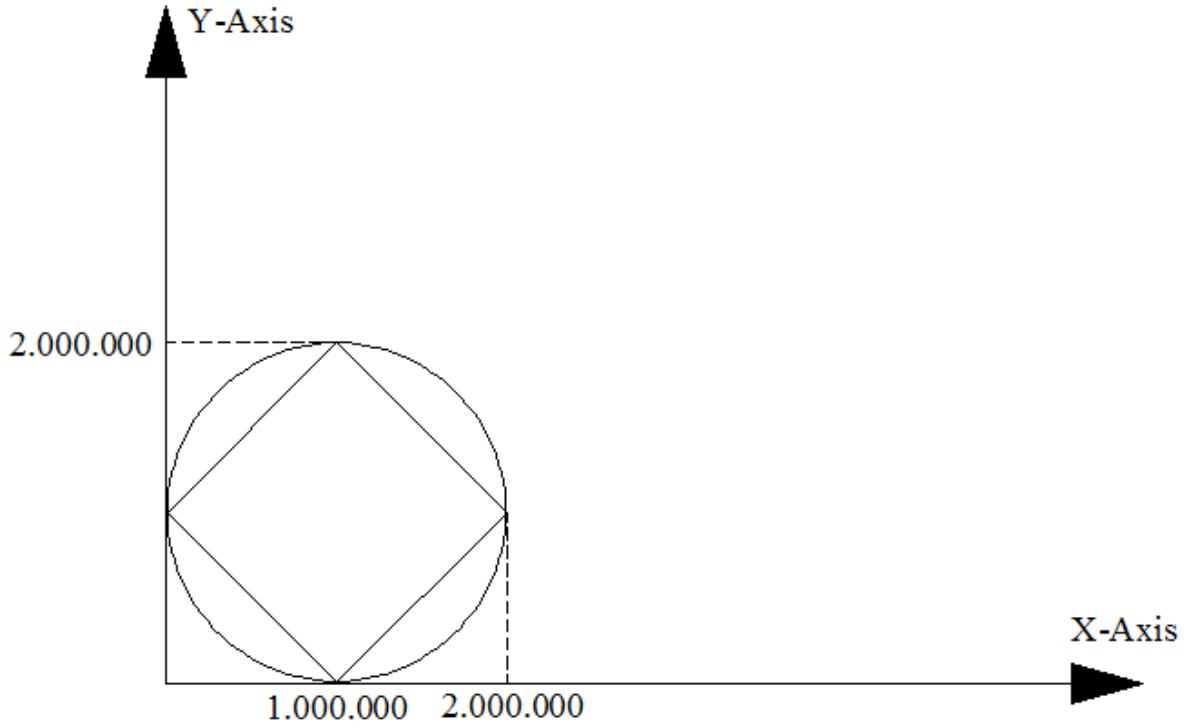
c.


Y-Axis
2.000.000
X-Axis
2.000.000

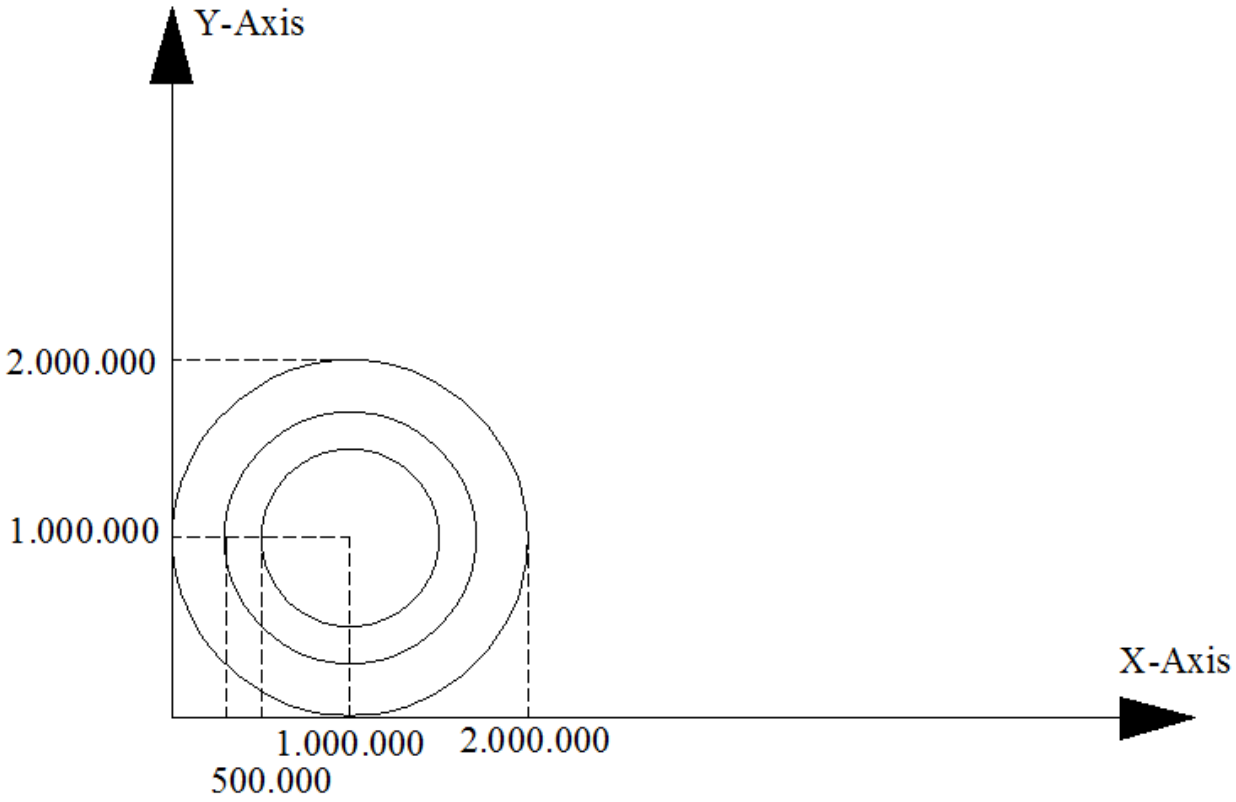
d.


Y-Axis
2.000.000
X-Axis
1.000.000
2.000.000

e.


Y-Axis
2.000.000
X-Axis
1.000.000
2.000.000

f.


Y-Axis
2.000.000
1.000.000
X-Axis
1.000.000
2.000.000
500.000

APPENDIX.

1. Device number list of FX3U/FX3UC

Device name	Description		
I/O relay			
Input relay	X000 to X367*1	248 points	Device numbers are octal. The total number of inputs and outputs is 256.
Output relay	Y000 to Y367*1	248 points	
Auxiliary relay			
General type [variable]	M0 to M499	500 points	The setting can be changed between the latched (battery backed) type and the non-latched type using parameters.
Latched (battery backed) type [variable]	M500 to M1023	524 points	
Latched (battery backed) type [fixed]	M1024 to M7679*2	6656 points	
Special type*3	M8000 to M8511	512 points	
State relay			
Initial state (general type [variable])	S0 to S9	10 points	The setting can be changed between the latched (battery backed) type and the non-latched type using parameters.
General type [variable]	S10 to S499	490 points	
Latched (battery backed) type [variable]	S500 to S899	400 points	
Annunciator (latched (battery backed) type [variable])	S900 to S999	100 points	
Latched (battery backed) type [fixed]	S1000 to S4095	3096 points	
Timer (on-delay timer)			
100 ms	T0 to T191	192 points	0.1 to 3,276.7 sec
100 ms [for subroutine or interrupt routine]	T192 to T199	8 points	0.1 to 3,276.7 sec
10 ms	T200 to T245	46 points	0.01 to 327.67 sec
Retentive type for 1 ms	T246 to T249	4 points	0.001 to 32.767 sec
Retentive type for 100 ms	T250 to T255	6 points	0.1 to 3,276.7 sec
1 ms	T256 to T511	256 points	0.001 to 32.767 sec
Counter			
General type up counter (16 bits) [variable]	C0 to C99	100 points	Counts 0 to 32,767 The setting can be changed between the latched (battery backed) type and the non-latched type using parameters.
Latched (battery backed) type up counter (16 bits) [variable]	C100 to C199	100 points	
General type bi-directional counter (32 bits) [variable]	C200 to C219	20 points	–2,147,483,648 to +2,147,483,647 counts The setting can be changed between the latched (battery backed) type and the non-latched type using parameters.
Latched (battery backed) type bi-directional counter (32 bits) [variable]	C220 to C234	15 points	

Data register (32 bits when used in pair form)			
General type (16 bits) [variable]	D0 to D199	200 points	The setting can be changed between the latched (battery backed) type and the non-latched type using parameters.
latched (battery backed) type (16 bits) [variable]	D200 to D511	312 points	
latched (battery backed) type (16 bits) [fixed] <file register>	D512 to D7999 <D1000 to D7999>	7488 points <7000 points>	Among the 7488 fixed latched (battery backed) type data registers, D1000 and later can be set as file registers in units of 500 points.
Special type (16 bits)*2	D8000 to D8511	512 points	
Index type (16 bits)	V0 to V7, Z0 to Z7	16 points	
Extension register/Extension file register			
Extension register (16 bits)	R0 to R32767	32768 points	latched (battery backed)
Extension file register (16 bits)	ER0 to ER32767	32768 points	Available only while a memory cassette is mounted
Pointer			
For jump and branch call	P0 to P4095	4096 points	For CJ and CALL instructions
Input interrupt Input delay interrupt	I0□□ to I5□□	6 points	
Timer interrupt	I6□□ to I8□□	3 points	
Counter interrupt	I010 to I060	6 points	For HSCS instruction
Nesting			
For master control	N0 to N7	8 points	For MC instruction
Constant			
Decimal (K)	16 bits	−32768 to +32767	
	32 bits	−2,147,483,648 to +2,147,483,647	
Hexadecimal (H)	16 bits	0 to FFFF	
	32 bits	0 to FFFFFFFF	
Real number (E)	32 bits	-1.0×2^{128} to -1.0×2^{-126}, 0, 1.0×2^{-126} to 1.0×2^{128} Both the decimal point expression and the exponent expression are available.	

1.1 I/O relays [X, Y]

	Model name	FX3U-16M	FX3U-32M	FX3U-48M	FX3U-64M	FX3U-80M	FX3U-128M	When extended
FX3U PLC	Input	X000 to X007 8 points	X000 to X017 16 points	X000 to X027 24 points	X000 to X037 32 points	X000 to X047 40 points	X000 to X077 64 points	X000 to X367 248 points
	Output	Y000 to Y007 8 points	Y000 to Y017 16 points	Y000 to Y027 24 points	Y000 to Y037 32 points	Y000 to Y047 40 points	Y000 to Y077 64 points	Y000 to Y367 248 points

1.2 Auxiliary relays [M]

FX3U/FX3UC PLCs

General type	Latched (battery backed) type	Fixed latched (battery backed) type	Special type
M0 to M499 500 points*2	M500 to M1023 524 points*3	M1024 to M7679 6656 points*4	M8000 to M8511 512 points

***2**. This area is not latched (battery backed). It can be changed to a latched (battery backed) area by setting the parameters.

***3**. This area is latched (battery backed). It can be changed to a non-latched (non-battery-backed) area by setting the parameters.

***4**. The characteristics of latch (battery backup) cannot be changed in the parameters.

1.3 Timer [T]

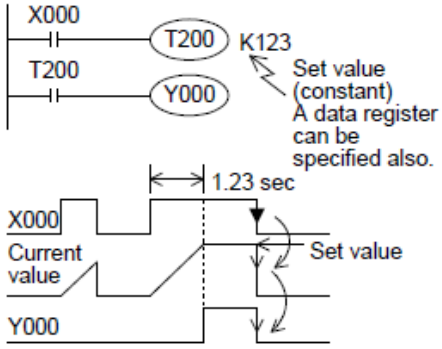
FX3U/FX3UC PLCs

For 100 ms pulses 0.1 to 3276.7 sec	For 10 ms pulses 0.01 to 327.67 sec	Retentive type for 1 ms pulses*4 0.001 to 32.767 sec	Retentive type for 100 ms pulses*4 0.1 to 3276.7 sec	For 1 ms pulses 0.001 to 32.767 sec
T0 to T199 200 points ---------- Routine program type T192 to T199	T200 to T245 46 points	T246 to T249 4 points for Interrupt execution Latched (battery backed) type*4	T250 to T255 6 points Latched (battery backed) type*4	T256 to T511 256 points

***4**. In FX3U/FX3UC PLCs, retentive type timers are backed up by the battery.

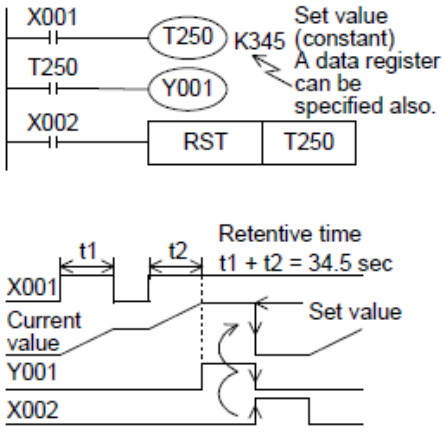
Example:

1. General type



When the drive input X000 of the timer coil T200 turns ON, the current value counter for T200 adds and counts clock pulses of 10 ms. When the counted value becomes equivalent to the set value K123, the output contact of the timer turns on.
In other words, the output contact turns on 1.23 seconds after the coil is driven.
When the drive input X000 turns OFF or when the power is turned off the timer is reset and the output contact returns.

2. Retentive type



When the drive input X001 of the timer coil T250 turns ON, the current value counter for T250 adds and counts clock pulses of 100 ms.
When the counted value becomes equivalent to the set value K345, the output contact of the timer turns on.
Even if the drive input X001 turns OFF or the power is turned off during counting, the timer continues counting when the operation restarts. The retentive operating time is 34.5 seconds.
When the reset input X002 turns ON, the timer is reset and the output contact is returned.

1.4 Data Register and File Register [D]

FX3U/FX3UC PLCs

Data registers				File registers (latched (battery backed) type)
General type	Latched (battery backed) type (backed up by battery against power failure)	Fixed latched (battery backed) type (backed up by battery against power failure)	Special type	
D0 to D199 200 points*3	D200 to D511 312 points*4	D512 to D7999 7488 points*1*5	D8000 to D8511 512 points	D1000*1 and later 7000 points maximum

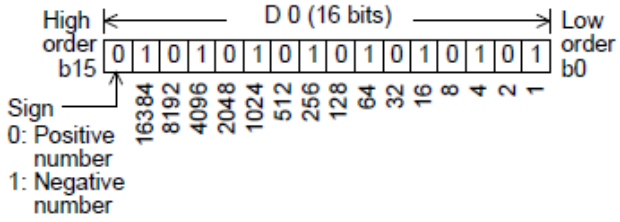
1. Data registers D1000 and later can be used as file registers in units of 500 points by setting parameters.

3. This area is not latched (battery backed). It can be changed to the latched (battery backed) area by setting parameters.

4. This area is latched (battery backed). It can be changed to the non-latched (non-battery-backed) area by setting parameters.

5. The latch (battery backup) characteristics cannot be changed using parameters.

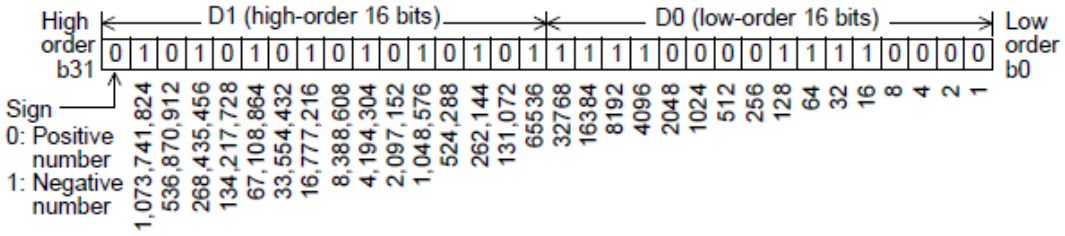
1) 16-bit type
One (16-bit) data register or file register can store a numeric value ranging from -32,768 to +32,767.



A numeric value can be read from or written to a data register by an applied instruction usually.
Or a numeric value can be directly read from or written to a data register from a display unit, display module, or programming tool.

2) 32-bit type
Two serial data registers or file registers can express 32-bit data.
- A data register with a larger device number handles high-order bits, and a data register with a smaller device number handles low-order bits.
- In the index type, V handles high-order bits, and Z handles low-order bits.

Two data registers or file registers can store a numeric value ranging from -2,147,483,648 to +2,147,483,647.



In the case of 32-bit type, when a data register or file register on the low-order side (example: D0) is specified, the subsequent number on the high-order side (example: D1) is automatically occupied.

1.5 Index Register [V and Z]

Numbers of index registers

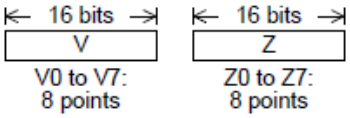
The table below shows numbers of index registers (V and Z). (Numbers are assigned in decimal.)
When only "V" or "Z" is specified, it is handled as "V0" or "Z0" respectively.

Index type
V0 (V) to V7, Z0 (Z) to Z7 16 points*1

*1. The characteristics related to protection against power failure cannot be changed by parameters.

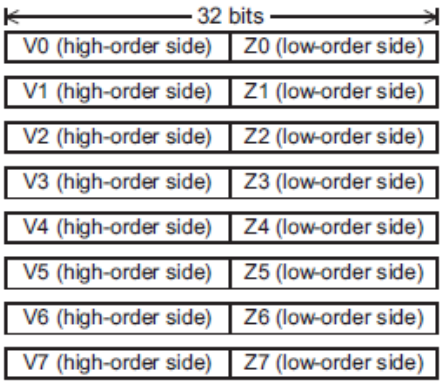
1. 16-bit type

Index registers have the same structures as data registers.



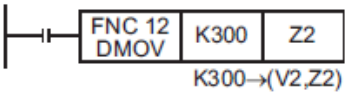
2. 32-bit type

Make sure to use Z0 to Z7 when indexing a device in a 32-bit applied instruction or handling a numeric value outside the 16-bit range.



This is because FX PLCs handle Z as the low-order side of a 32-bit register as shown in combinations of V and Z in the figure on the left. Even if V0 to V7 on the high-order side is specified, indexing is not executed.
When index registers are specified as a 32-bit device, both V (high-order side) and Z (low-order side) are referred to at the same time. If a numeric value for another purpose remains in V (high-order side), consequently the numeric value here becomes extremely large, thus an operation error occurs.

Example of writing to 32-bit index registers



Even if an index value in a 32-bit applied instruction does not exceed the 16-bit numeric range, use a 32-bit operation instruction such as DMOV for writing a numeric value to Z as shown in the above figure so that both V (high-order side) and Z (low-order side) are overwritten at the same time.

Example:

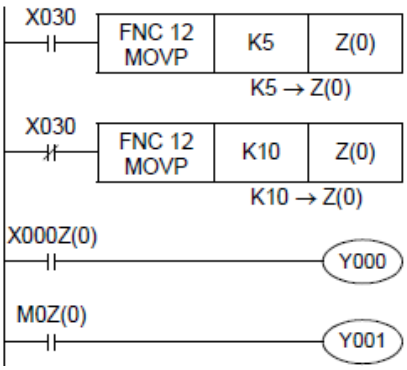
In the case of bit devices

Bit devices [X, Y, M (except special auxiliary relays), T, and C (C0 to C199)] used in LD, LDI, AND, ANI, OR, ORI, OUT, SET, RST, PLS, and PLF instructions can be indexed with index registers.
The figure shown on the right explains an indexing operation with the index register Z(0) for X000 and M0 in the LD instruction.
Transfer K5 or K10 to the index register Z(0) in advance.
If Z(0) is "5", "X(0+5) = X005". When X005 turns ON, Y000 turns ON and "M(0+5) = M5". When M5 turns ON, Y001 turns ON.
If Z(0) is "10", "X(0+10) = X012*1". When X012*1 turns ON, Y000 turns ON and "M(0+10) = M10". When M10 turns ON, Y001 turns ON.

*1. Refer to the caution 3) below.

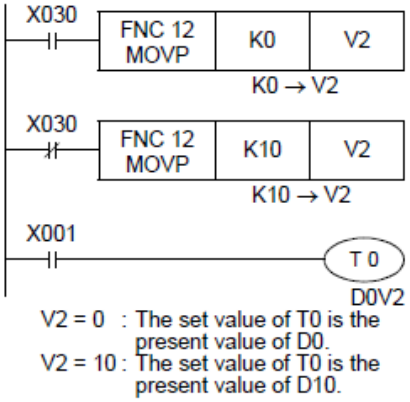
- The index registers Z0 to Z7 and V0 to V7 can be used for indexing.
- In OUT instruction for a timer or counter, the timer number (or counter number) and the device specified for the set value can be indexed.

Cautions



In the case of word devices and constants

The set value of word devices used in OUT instruction of T and C(0~199) can be indexed with index registers.
The indexing operation is explained in an example in which the set value D0 of T0 used in the index register V2 indexes OUT instruction (as shown in the right figure).
Transfer K0 or K10 to the index register V2 in advance.
When X001 is set to ON, "D(0+0) = D0" if V2 is "0", and T0 operates with the set value D0.
When X001 is set to ON, "D(0+10) = D10" if V2 is "10", and T0 operates with the set value D10.



Caution

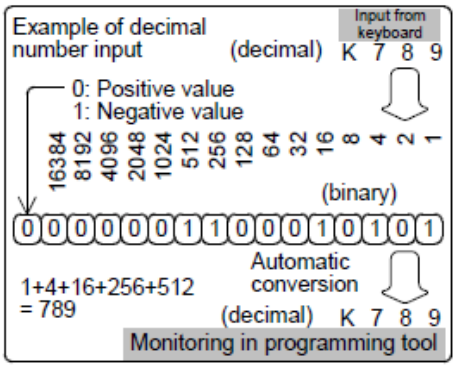
1) When a 32-bit counter is used in OUT instruction, the set value cannot be indexed with an index register.

2. Numeric Values Handled in PLC

2.1 Types of numeric values

1. **Decimal numbers (DEC)**
   - Set value (constant K) of timers and counters
   - Device numbers of auxiliary relays (M), timers (T), counters (C), state relays (S), etc.
   - Numeric values in operands and instruction operations in applied instructions (constant K)
2. **Hexadecimal numbers (HEX)**
   - Numeric values in operands and instruction operations in applied instructions (constant H)
3. **Binary numbers (BIN)**

   For a timer, counter or data register, a numeric value is specified in decimal or hexadecimal as described above. But all of these numeric values are handled in binary format inside PLCs.
   When these devices are monitored in peripheral equipment, they are automatically converted into the decimal format as shown in the figure on the right (or can be converted into the hexadecimal format).

   - Handling of negative value
     A negative value is expressed in complement of PLCs.
     For details, refer to the explanation of NEG (FNC 29)
   - instruction.
4. **Octal numbers (OCT)**

   In FX PLCs, device numbers of input relays and output relays are assigned in octal.
   Because "8" and "9" do not exist in octal, device numbers are carried in the way "0 to 7, 10 to 17, 70 to 77, 100 to 107".
5. **Binary coded decimal (BCD)**

   BCD format expresses each numeric value from 0 to 9 constructing each digit of a decimal number in a 4-bit binary number.
   Because handling of each digit is easy, this format is adopted in controlling digital switches of BCD output type and seven-segment display units.
6. **Real numbers (floating point data)**

   FX3S, FX3G, FX3GC, FX3U and FX3UC PLCs have the floating point operation function to achieve high accuracy operation.

2.2 Types of constant values

Constant K (decimal number)

"K" indicates a decimal integer, and is mainly used to specify the set value of timers and counters and numeric values as operands in applied instructions. (Example: K1234)
The decimal constant specification range is as follows:

- When word data (16 bits) is used ..... K-32768 to K32767
- When double data (32 bits) is used ... K-2,147,483,648 to K2,147,483,647

Constant H (hexadecimal number)

"H" indicates a hexadecimal number, and is mainly used to specify numeric values as operands in applied instructions. (Example: H1234)
When using digits 0 to 9, the bit status (1 or 0) of each bit is equivalent to the BCD code, so BCD data can be specified also.
(Example: H1234 ... When specifying BCD data, specify each digit of hexadecimal number in 0 to 9.)
The hexadecimal constant setting range is as follows:

- When word data (16 bits) is used ..... H0 to HFFFF (H0 to H9999 in the case of BCD data)
- When double data (32 bits) is used ... H0 to HFFFFFFFF (H0 to H99999999 in the case of BCD data)

Constant E (real number)

FX3S Ver.1.00 ➡ FX3G Ver.1.10 ➡ FX3GC Ver.1.40 ➡ FX3U Ver.2.20 ➡ FX3UC Ver.1.00 ➡

"E" indicates a real number (floating point data), and is mainly used to specify numeric values as operands in applied instructions. (Example: E1.234 or E1.234 + 3)
The real number setting range is from -1.0×2^{128} to -1.0×2^{-126}, 0 and 1.0×2^{-126} to 1.0×2^{128}.
In a sequence program, a real number can be specified in two methods, "normal expression" and "exponent expression".

- Normal expression: ..... Specify a numeric value as it is.
  For example, specify "10.2345" in the form "E10.2345".
- Exponent expression: ..... Specify a numeric value in the format "(numeric value) $\times 10^{n}$".
  For example, specify "1234" in the form "E1.234 + 3".
  "+3" in "E1.234 + 3" indicates "10^{3}".

2.3 Specification of Digits for Bit devices (Kn[]***)

The number of digits Kn indicates 4-bit units (digits), for example: K1 to K4 are used for 16-bit data, K1 to K8 are used for 32-bit data

Example: K2M0 indicates two-digits data (a byte) expressed by M0 to M7

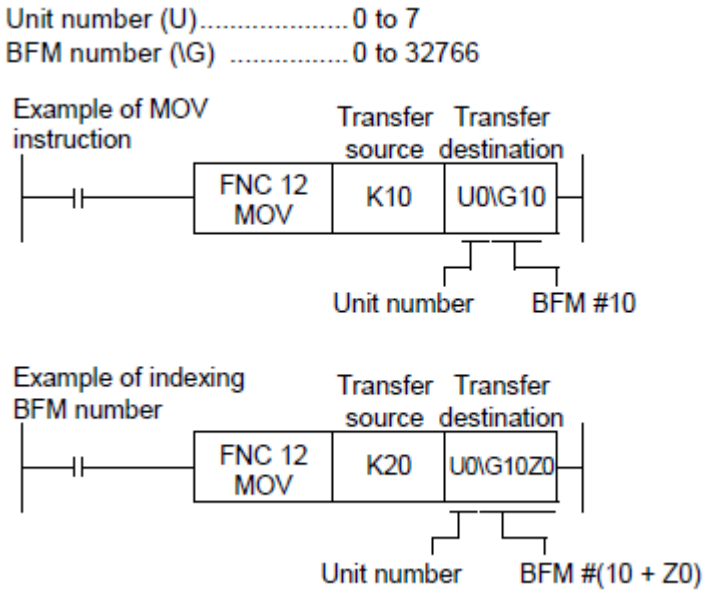
K4M20 indicates 4-digits data (a word) expressed by M20 to M35

2.4 Direct Specification of Buffer Memory (U[]\G[])

A buffer memory (BFM) of a special function units/blocks can be specified directly. BFM is 16-bit or 32-bit word data, and is mainly used for operands in applied instructions. For specifying a BFM, specify the unit number (U) of a special function units/blocks and the BFM number (\G) consecutively.

Example: U0\G0 ... Indicates the BFM #0 in the special function units/blocks whose unit number is 0.) Indexing is available for BFM numbers.

The specification range is as follows:



References

1. Mitsubishi Electric, FX3x Series Programmable Controller – Programming Manual: Basic and Applied Instruction Manual.

2. Mitsubishi Electric, FX3U-20SSC-H User's Manual.