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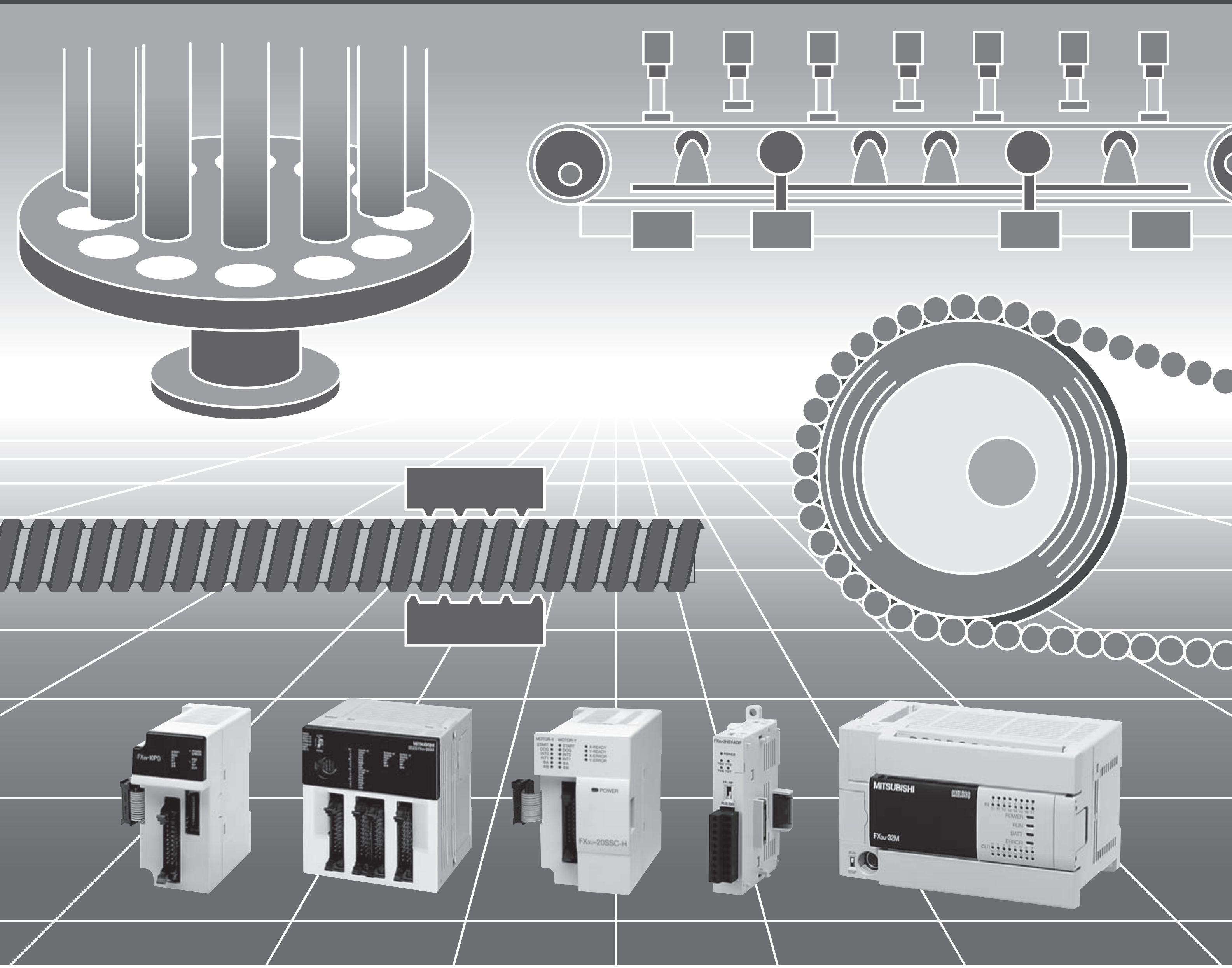
INTRODUCTION TO FX POSITIONING CONTROL SYSTEMS



FX SERIES PROGRAMMABLE CONTROLLERS

FX Series Programmable Controllers

INTRODUCTION TO FX POSITIONING CONTROL SYSTEMS

Foreword

This document contains text, diagrams and explanations to guide the reader in understanding positioning control.
Store this document in a safe place so that you can take it out and read it whenever necessary.

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Introduction

The purpose of this document is to guide beginners in understanding the basics of positioning control from general system setup examples to specific programming examples using the FX Series positioning family of controllers. After exploring the roles of the necessary positioning components, an overview of each product in the FX Family will be given in order to start programming.

The following manuals are relevant sources and should be referred to when needed.

⊙ Essential manual
○ Manual required depending on application
△ Manual with additional manual for detailed explanation

		Manual name	Manual number	Contents	Model name code
Manuals for PLC main unit					
■Main unit					
△	Supplied with product	FX3U Series Hardware Manual	JY997D18801	I/O specifications, wiring and installation of the PLC main unit FX3U extracted from the FX3U Series User's Manual - Hardware Edition. For detailed explanation, refer to the FX3U Series User's Manual - Hardware Edition.	–
○	Additional Manual	FX3U Series User's Manual - Hardware Edition	JY997D16501	Details about the hardware including I/O specifications, wiring, installation and maintenance of the FX3U PLC main unit.	09R516
○	Supplied with product	FX2N Series Hardware Manual	JY992D66301	Details about the hardware including I/O specifications, wiring, installation and maintenance of the FX2N PLC main unit.	09R508
○	Supplied with product	FX2NC (DSS/DS) Series Hardware Manual	JY992D76401	Details about the hardware including I/O specifications, wiring, installation and maintenance of the FX2NC (DSS/DS) PLC main unit.	09R509
○	Supplied with product	FX2NC (D/UL) Series Hardware Manual	JY992D87201	Details about the hardware including I/O specifications, wiring, installation and maintenance of the FX2NC (D/UL) PLC main unit.	09R509
○	Supplied with product	FX1N Series Hardware Manual	JY992D89301	Details about the hardware including I/O specifications, wiring, installation and maintenance of the FX1N PLC main unit.	09R511
○	Supplied with product	FX1S Series Hardware Manual	JY992D83901	Details about the hardware including I/O specifications, wiring, installation and maintenance of the FX3U PLC main unit.	09R510
■Programming					
○	Additional Manual	FX3U/FX3UC Series Programming Manual - Basic & Applied Instruction Edition	JY997D16601	Items related to programming in PLCs including explanation of basic instructions, applied instructions and various devices in FX3U/FX3UC PLCs.	09R517
○	Additional Manual	FX Series Programming Manual II	JY992D88101	Items related to programming in PLCs including explanation of basic instructions, applied instructions and various devices in FX1S/FX1N/FX2N/FX2NC PLCs.	09R512
Manuals for communication control					
■Common					
When using each product, refer also to the main unit manual for the PLC main unit to be installed.					
○	Additional Manual	FX Series User's Manual - Data Communication Edition	JY997D16901	Details of simple link between PCs, parallel link, computer link and no-protocol communication (RS instructions, FX2N-232IF)	09R715

⊙ Essential manual
○ Manual required depending on application
△ Manual with additional manual for detailed explanation

		Manual name	Manual number	Contents	Model name code
Manuals for positioning control					
■Common When using each product, refer also to the main unit manual for the PLC main unit to be installed.					
○	Additional Manual	FX3U/FX3UC Series User's Manual - Positioning Control Edition	JY997D16801	Details of positioning functions of FX3U/FX3UC Series	09R620
■Pulse output and positioning When using each product, refer also to the main unit manual for the PLC main unit to be installed.					
△	Supplied with product	FX3U-2HSY-ADP Installation Manual	JY997D16401	Procedures for handling the high-speed output special adapter When using, refer also to FX3U/FX3UC Series User's Manual - Positioning Control Edition.	–
○	Supplied with product	FX2N/FX-1PG User's Manual	JY992D65301	Procedures for handling the 1-axis pulse output special function block	09R610
△	Supplied with product	FX2N-10PG Installation Manual	JY992D91901	Procedures for handling the 1-axis pulse output special function block When using, refer to FX2N-10PG User's Manual.	–
○	Additional Manual	FX2N-10PG User's Manual	JY992D93401	Details of 1-axis pulse output special function block	09R611
△	Supplied with product	FX2N-10GM User's Guide	JY992D77701	Procedures for handling the 1-axis positioning special function unit When using, refer to FX2N-10GM/FX2N-20GM Hardware/Programming Manual.	–
△	Supplied with product	FX2N-20GM User's Guide	JY992D77601	Procedures for handling the 2-axis positioning special function unit When using, refer to FX2N-10GM/FX2N-20GM Hardware/Programming Manual.	–
○	Additional Manual	FX2N-10GM/FX2N-20GM Hardware/Programming Manual	JY992D77801	Procedures for handling the 1-axis/2-axis positioning special function unit	09R612
○	Additional Manual	FX-PCS-VPS/WIN-E Software Manual	JY993D86801	Procedures for handling the 1-axis/2-axis positioning special function unit	09R612
Manuals for FX3U-20SSC-H Positioning Block					
■SSCNET-III When using each product, refer also to the main unit manual for the PLC main unit to be installed.					
△	Supplied with product	FX3U-20SSC-H Installation Manual	JY997D21101	Procedures for handling the 2-axis positioning special function block When using, refer to FX3U-20SSC-H User's Manual.	-
○	Additional Manual	FX3U-20SSC-H User's Manual	JY997D21301	Describes FX3U-20SSC-H Positioning block details.	09R622
○	Supplied with product	FX Configurator-FP Operation Manual	JY997D21801	Describes operation details of FX Configurator-FP Configuration Software.	09R916

1. The Basics of Positioning Control

1.1 What is positioning control?

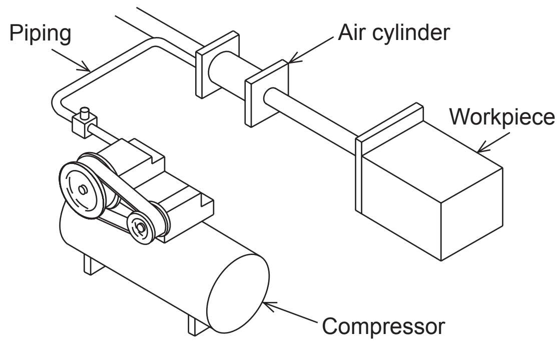
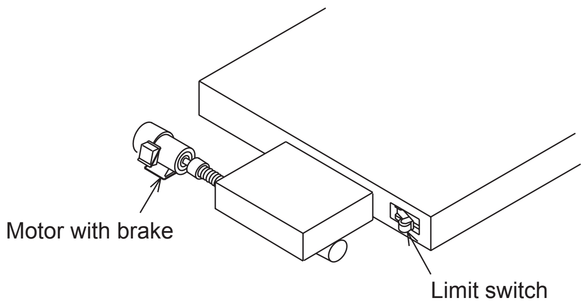
The positioning controller, together with the programmable logic controller, personal computer and operator interface, is one of the four main units of FA (factory automation).
Among these units, the positioning controller plays an important role and is regarded as the center of the mechatronics field in which many senior engineers have been playing active roles.

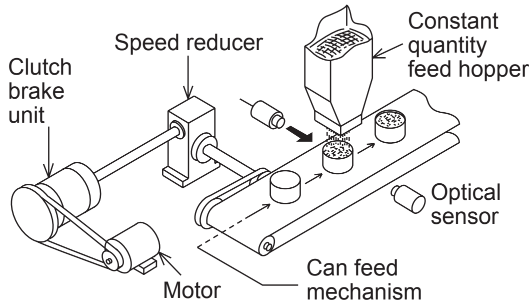
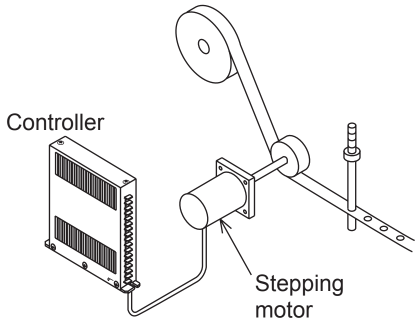
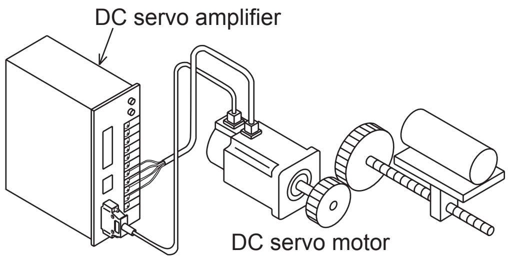
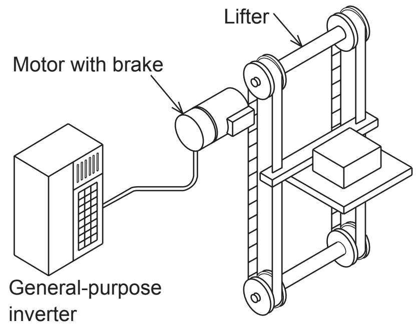
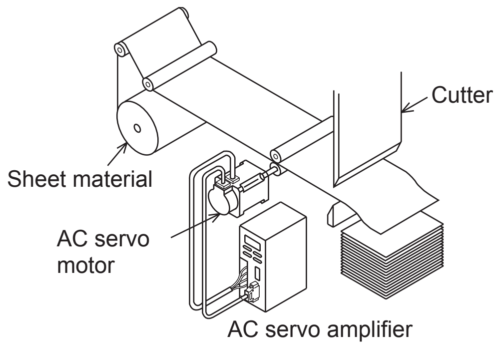
Positioning is all about motion, and motion often involves speed and precision. And since speed can be directly related to productivity, positioning is an area of much development. When the speed of a machine increases, a problem with the stop precision is often generated. In order to solve this problem, diversified grades of positioning controllers have been required and developed.

Improving machine efficiency generates immeasurable added value, including reduced labor costs and improved conservation of machine floor space for the same quantity of production. If there are no problems related to the positioning aspect of a machine, it may mean that the machine is not running as efficiently as it could be. This is where the science of developing and retrofitting an optimum positioning control system comes in.

1.2 Actuators for positioning

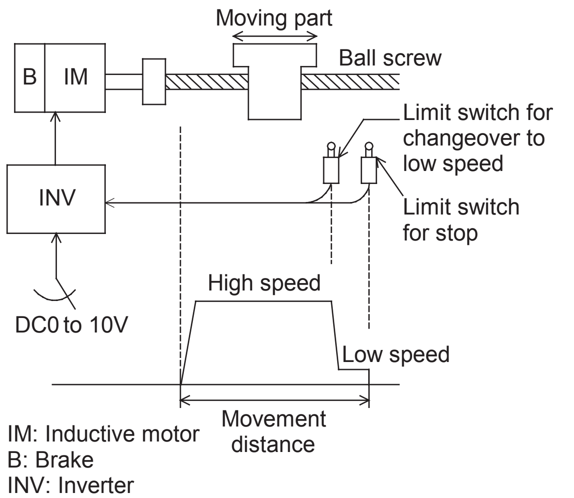
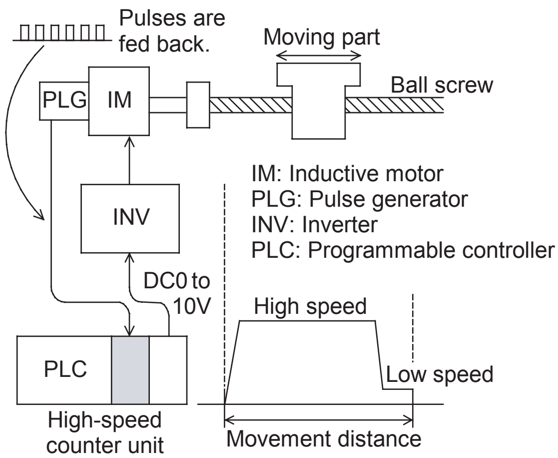
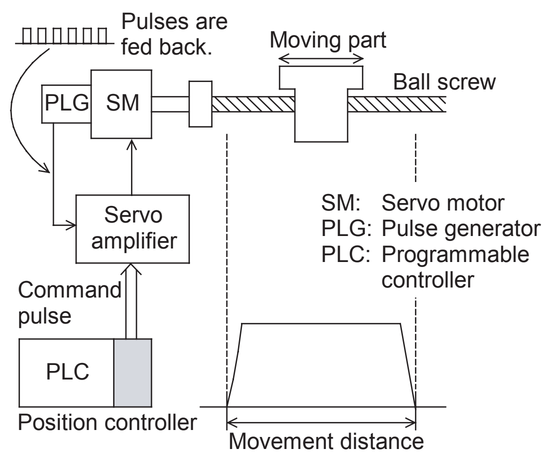
The options available for positioning control depend on the type of actuator driving the system. An actuator is a mechanical device that moves or controls a specific element or a series of elements within a system.
In a mechanical system, an actuator is often used with a sensor to detect the motion or position of a workpiece. The following illustrations provide examples of diversified actuators, their features and their weak points.

Actuator(s)	Features and Drawbacks	Schematic drawing
Pneumatic	• Air source and high grade piping are required. • High torque is not available. • Multi-point positioning is complex and very difficult to achieve. • Change in positioning is difficult.	
Brake motor	• Positioning mechanism is simple. • Repeatability is poor. • Change in positioning is difficult. (When optical sensors or limit switches are used for stop)	

Actuator(s)	Features and Drawbacks	Schematic drawing
Clutch brake	• Frequent positioning is possible. • Life of friction plate is limited. • Change in positioning is difficult. (When optical sensors or limit switches are used for stop)	
Stepping motor	• Simple positioning mechanism. • If load is heavy, motor may step out and displacement can occur. • Motor capacity is small. • Precision is poor at high speed.	
DC servo system	• Positioning precision is accurate. • Maintenance is required for motor brushes. • It is not suitable for rotation at high speed.	
General purpose inverter and general purpose motor	• Multi-speed positioning is available using a high-speed counter. • High precision positioning is not available. • Large torque is not available at start. (Specialized inverter is required)	
AC servo system	• Positioning precision is good. • Maintenance is not required. • Positioning address can be easily changed. • It is compact, and offers high power.	

1.3 Positioning method type

In general, there are two methods to control the movement of a workpiece: speed control and position control. For basic, more rudimentary positioning, speed control can be used with an inverter and general purpose motor. For systems where precision is a must, servo systems are required for the advanced handling of pulse commands.

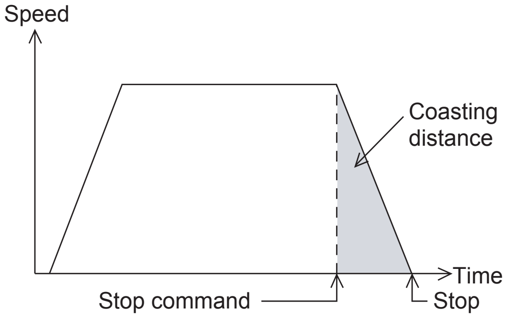
Control method		Description	Schematic drawing
Speed control	**Limit switch method**	Two limit switches are provided in places where a system's moving part passes. At the first limit switch, the motor speed is reduced. At the second limit switch, the motor turns off and the brake turns on to stop the moving part. In this method, because position controllers are not required, the system configuration can be realized at reasonable cost. (Guideline of stopping precision: Approximately ±1.0 to 5.0 mm)*1	
	Pulse count method	A position detector (such as a pulse encoder) is set up in a motor or rotation axis. The pulse number generated from the position detector is counted by a high-speed counter. When the pulse number reaches the preset value, the moving part stops. In this method, because limit switches are not used, the stop position can be easily changed. (Guideline of stopping precision: Approximately ±0.1 to 0.5 mm)*1	
Position control	**Pulse command method**	An AC servo motor which rotates in proportion to the input pulse number is used as the drive motor. When the pulse number corresponding to the movement distance is input to the servo amplifier of the AC servo motor, positioning can be performed at high speed in proportion to the pulse frequency. (Guideline of stopping precision: Approximately ±0.01 to 0.05 mm)*1	

*1. The stop precision shows a value in a case where the low speed is 10 to 100 mm/s.

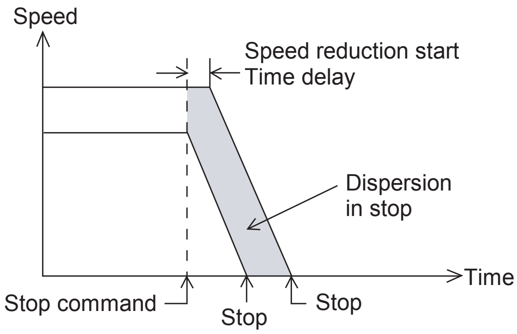
1. Speed Control

In speed control applications with inverters, stop precision is not very accurate. With the limit switch method, a system operates without any feedback to the controller to indicate the location of the workpiece. With the pulse count method, the speed can be changed and the stop command can be executed at specific distances (at specific timings) according to the feedback from the pulse generator connected to the motor. Both the limit switch method and the pulse count method, however, are subject to a loss in stop precision due to the dispersion of distance that occurs for workpieces at different speeds.

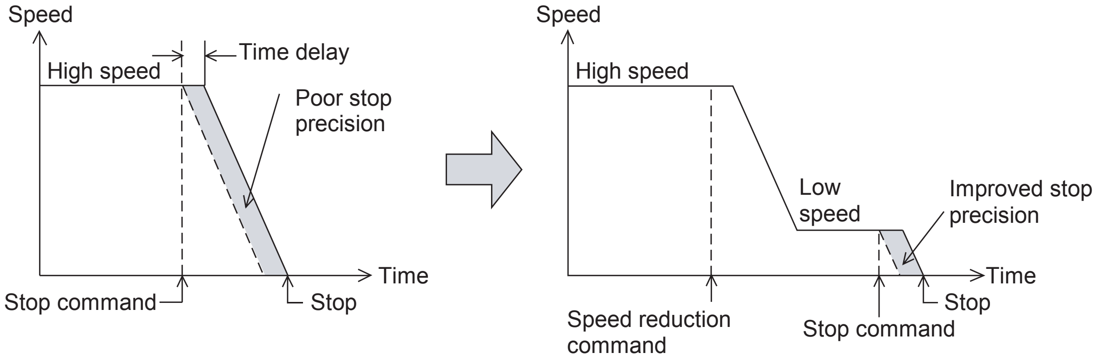
- When automatically stopping a moving part driven by a motor, stop the motor by a position signal (using a limit switch or pulse count comparison). In general conditions, turn on the brake at the same time.
- The moving part continues by a coasting distance until it completely stops, after the stop command is given. The coasting distance is not controlled and it is represented as the shaded part in the figure below.



- Dispersion in the stop distance changes as shown below. Dispersion is affected by the speed of the workpiece when the stop command is given and the speed reduction time delay after stop.



- If the required stop precision is not satisfactory when stopping from the normal operation speed, the most effective method to improve the stop precision is to reduce the operation speed. However, if the operation speed is simply reduced, the machine efficiency may also be reduced. Therefore, in actual operation, the motor speed can be reduced from a high speed to a low speed before the motor is stopped, as shown below.



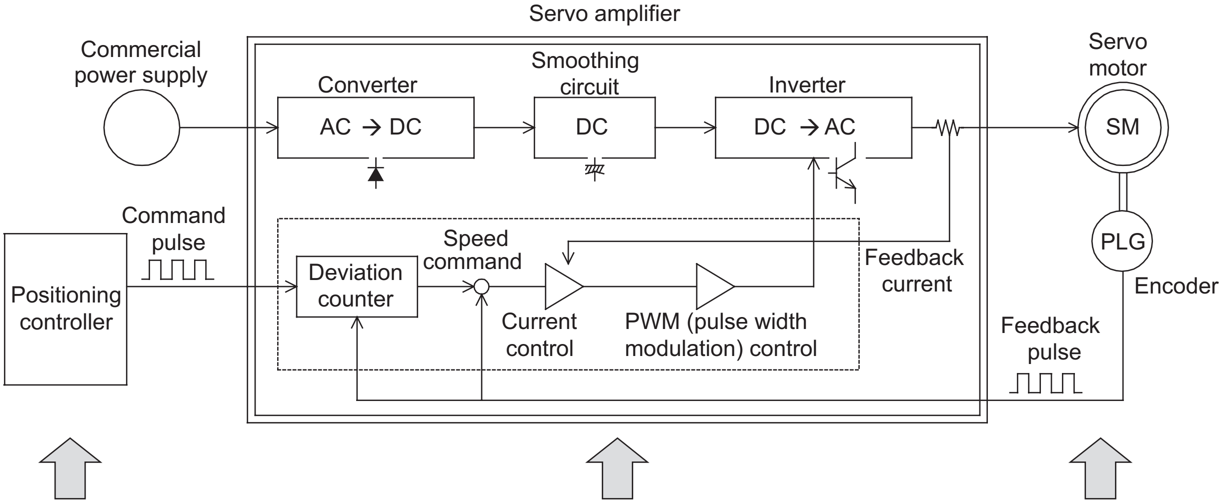
2. Position control

Using the pulse command method with a servo amplifier, the weak points described above for speed control are improved. A pulse encoder is attached to the servo motor to detect the motor rotation quantity (workpiece movement distance) and feed the information directly to the servo amplifier in order to continuously and directly control the high-speed positioning operation to the target position. This method allows the workpiece to stop with better precision and eliminates the coasting and dispersion distance at stop. Furthermore, limit switches to stop normal positioning operations, along with counting methods from the PLC are not needed.

2. Positioning by AC Servo System

2.1 Advantages for using an AC servo system

With an AC servo system, positioning can be performed by many diversified methods. Typically, a position controller, servo amplifier and servo motor are required for positioning with an AC servo system. The representative servo system configuration is shown below.



The positioning controller generates a specified quantity of forward rotation (or reverse rotation) pulses at a specified frequency.

The command pulse number is subtracted by the feedback pulse number, and the speed command to drive the servo motor is made from the deviation (accumulated pulse number).
When the accumulated pulse number becomes 0, the servo motor stops.

The servo motor is equipped with a built-in encoder (pulse generator), dedicated to high speed response, and suitable for positioning control.

In the latest AC servo systems, conventional weak points have been improved as follows:

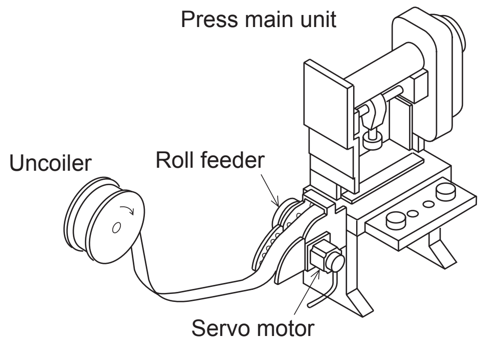
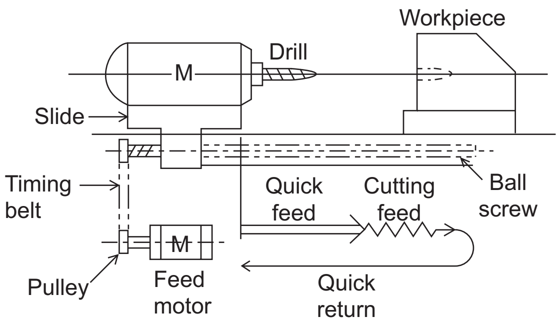
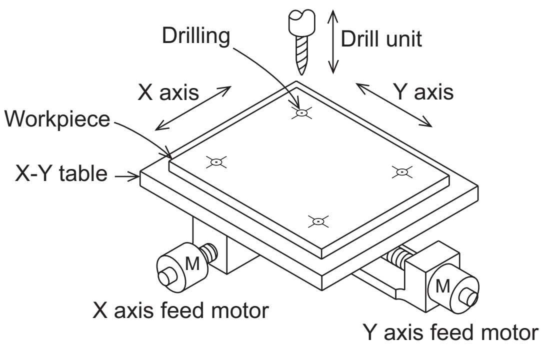
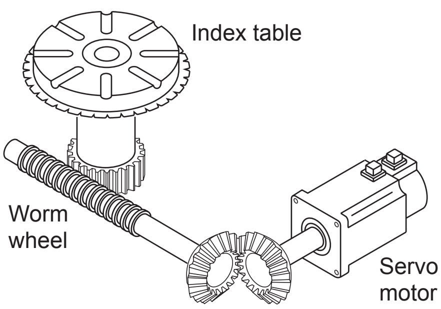
- Although the latest systems are completely digital, they are equipped with parameters in conformance to diversified mechanical specifications and electrical specifications so that simple set-up is possible.
- As frequent operation is enabled by a low inertia motor, the maximum torque is increased and the system can be applied to a wide variety of machines.
- The latest systems are equipped with an auto tuning function, with which the servo amplifier automatically detects the load inertia moment and adjusts the gain. This is possible even if the load inertia moment is unknown.
- The command communication cycle from the controller to the servo amplifier is improved for synchronization accuracy and better speed/positioning accuracy.
- The latest systems also allow for long-distance wiring, reduced noise resistance, and simplified wiring.

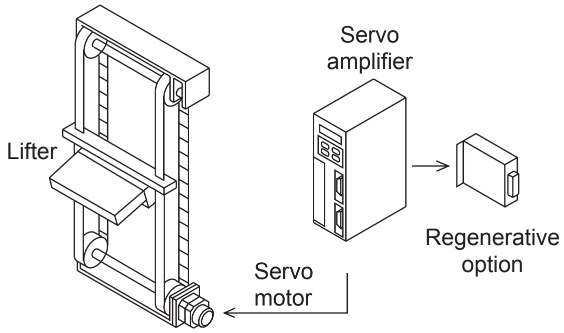
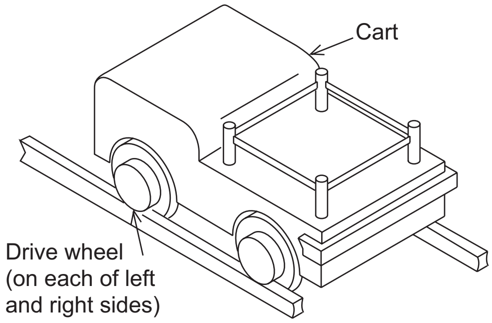
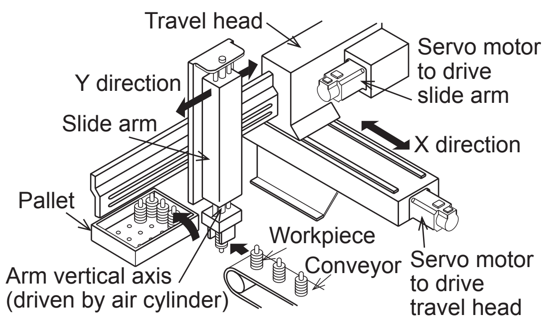
The top advantages to using an AC servo system are described below.

Compact and light servo system	Robust servo system	Easy servo system	Good cost performance servo system
In the FA workplace, a downsized AC servo system occupying less space is beneficial.	In accordance with severe operation conditions, a tougher AC servo system is often required.	AC servo systems are easier to handle than hydraulic equipment. Easy systems are also flexible for new staff.	An AC servo system with good cost performance saves a company in overall engineering costs.

2.2 Examples of AC servo systems

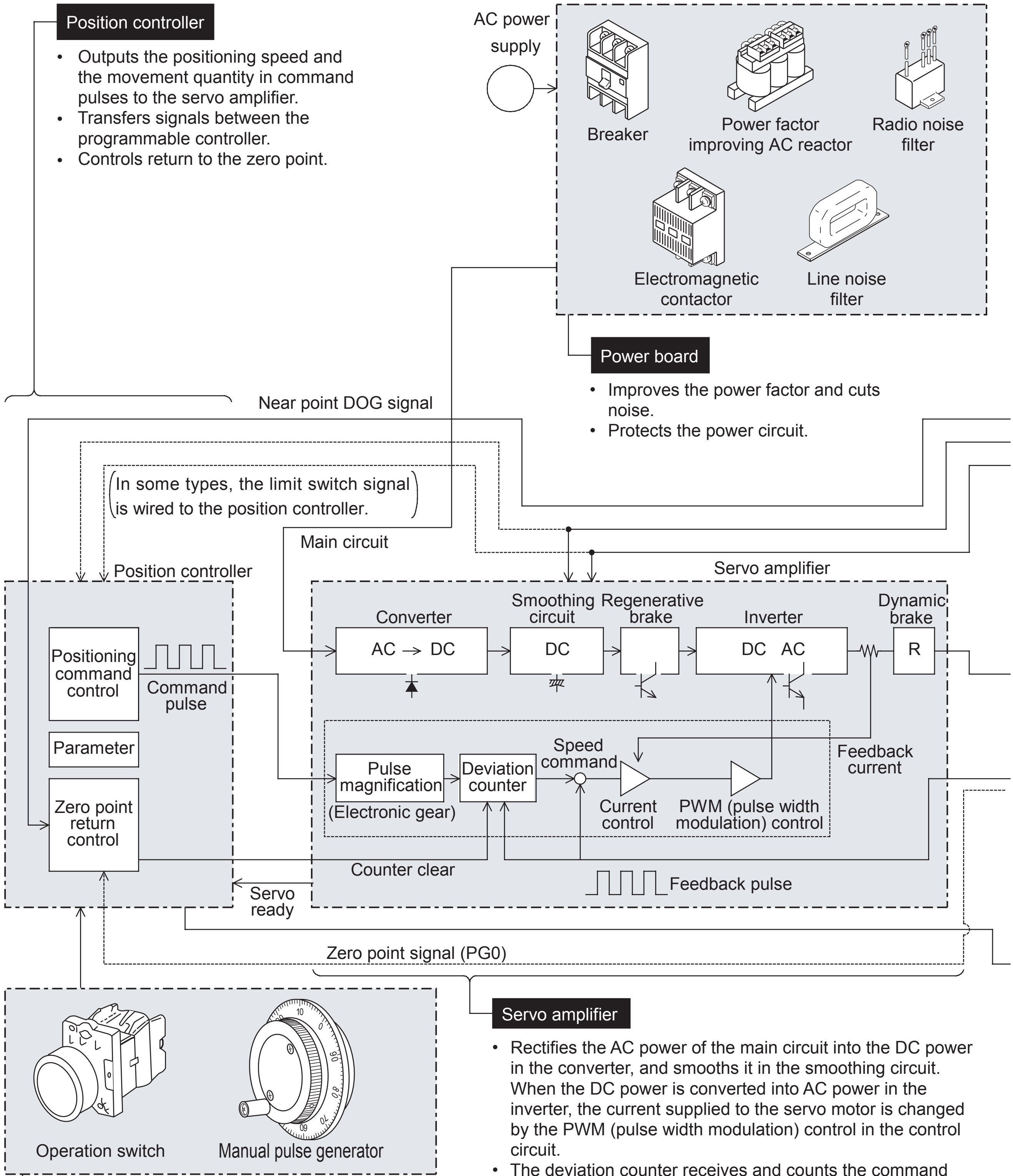
Positioning indicates the operation to move an object, such as a workpiece or tool (drill or cutter), from one point to another point and to stop it with efficiency and precision.
In other words, the principle of positioning is the control of speed in accordance with the position, performed to promptly eliminate the remaining distance to the target position. The flexibility to change the target position electrically and easily is an important requirement.
Several cases of positioning using an AC servo motor are systematically shown below.

Type of machine	Description	Schematic drawing
Constant feed	In the press/shear process for cutting, punching, etc., the processed material is positioned with high precision to produce a constant sized product.	
Tapping	In order to tap a workpiece, “1. Quick feed”, “2. Cutting feed” and “3. Quick return” are performed repeatedly.	
Drilling in steel sheet	In order to perform processing on a flat face, positioning with high precision is performed by two motors (X axis feed motor and Y axis feed motor).	
Index table	The position of the circular table is indexed. The index position is set on the outside (digital switch) or the inside (program). Shortcut drive is performed depending on the index position.	

Type of machine	Description	Schematic drawing
Lifter moving-up/down	As negative load is applied on the servo motor in positioning of the lifter in the vertical direction, a regenerative option is also used. In order to hold the lifter stationary and prevent drop of the lifter by power interruption, a servo motor with an electromagnetic brake is used.	
Cart travel control	A servo motor is mounted in the travel cart as the drive source. A mechanism such as rack and pinion is adopted to prevent slippage between the wheels and rails.	
Carrier robot	After the conveyor stops, the 2-axis servo system and the arm lifting mechanism transfer workpieces to a palette. The workpiece input positions on the palette can be set to many points so that setup change can be easily performed, even if the palette position and the palette shape change.	

3. Components of Positioning Control and Their Roles

Positioning control requires a number of components such as a positioning controller, servo amplifier, servo motor and drive mechanism. This section describes the role of each component.
To begin, the following two-page spread illustrates how the seven key elements function together to perform positioning.



Position controller

- Outputs the positioning speed and the movement quantity in command pulses to the servo amplifier.
- Transfers signals between the programmable controller.
- Controls return to the zero point.

Power board

- Improves the power factor and cuts noise.
- Protects the power circuit.

Servo amplifier

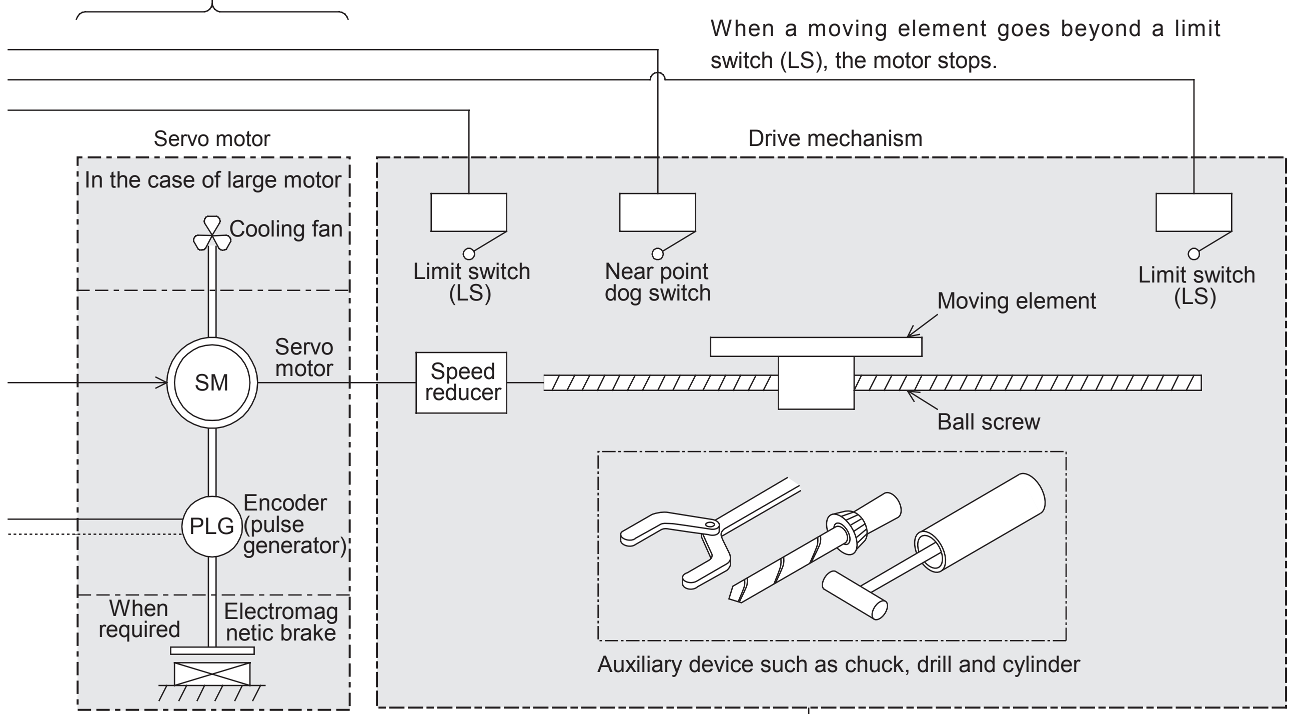
- Rectifies the AC power of the main circuit into the DC power in the converter, and smooths it in the smoothing circuit. When the DC power is converted into AC power in the inverter, the current supplied to the servo motor is changed by the PWM (pulse width modulation) control in the control circuit.
- The deviation counter receives and counts the command pulses from the positioning controller, subtracts the feedback pulses from them, then drives the servo motor until the accumulated pulse number becomes 0.

Operation equipment

- Gives inputs for manual/automatic mode, start/stop, zero point return command, manual forward rotation/reverse rotation and manual pulse generator to the positioning controller.

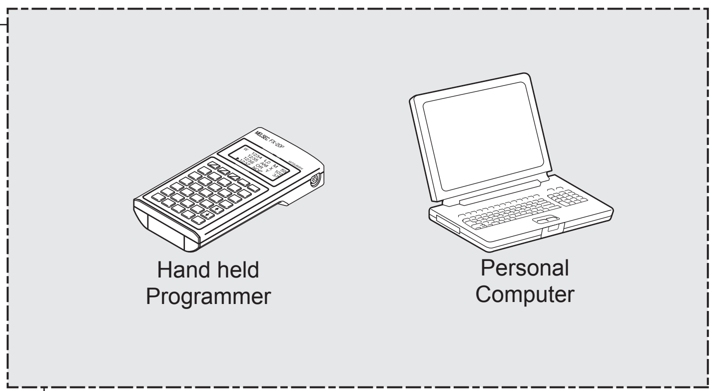
Servo motor

- Dedicated to high speed response optimal to positioning control, has large start torque, large maximum torque and wide variable speed range 1/1 or more (1/1,000 to 1/5,000).



Sensor, actuator, auxiliary device

- The actuator (moving part drive mechanism) is equipped with speed reducer, timing belt, ball screw and limit switch.
- Diversified auxiliary devices are also controlled in accordance with positioning.
- The PLC or the positioning controller also controls auxiliary devices.
- The auxiliary device operation completed signal is output to the PLC or the position controller.



Setting / display unit

- Used to write programs to the position controller, allows setting and display of the data.

3.1 Positioning controller

Positioning controllers use programs and parameters to send positioning commands to the servo amplifier. Contents related to programs and parameters are described below.

3.1.1 Command pulse control method

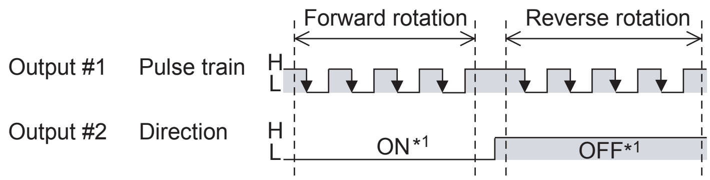
There are two types of control formats used for outputting command pulses from an FX Series positioning controller:

- PLS/DIR (Pulse/Direction) method
- FP/RP (Forward Pulse/Reverse Pulse) method

Each method requires two outputs from the controller to control specific signals for direction and pulse control. A third method, known as the A phase/B phase method, uses overlapping pulse signals to specify direction.

1. PLS/DIR method

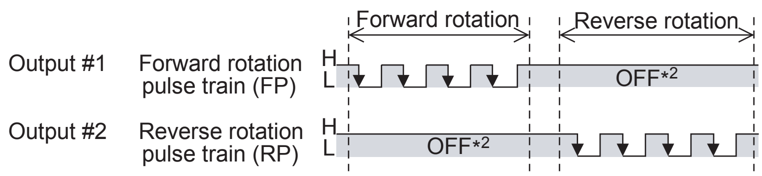
In the PLS/DIR method, one output sends pulses to the drive unit while the other output specifies the direction of travel.



*1. "ON" and "OFF" represent the status of the controller's output.
"H" and "L" respectively represent the HIGH status and the LOW status of the waveform. The command pulse pattern in the figure assumes negative logic.

2. FP/RP method

In the FP/RP method, each output has a different direction and operates individually to send pulses to the drive unit.



*2. "ON" and "OFF" represent the status of the controller's output.
"H" and "L" respectively represent the HIGH status and the LOW status of the waveform. The command pulse pattern in the figure assumes negative logic.

3.1.2 Basic parameter settings

To send a series of pulses (a pulse train) to a servo amplifier, positioning controllers use a specified feed quantity, which is proportional to the number of pulses. A feed speed must also be specified to control the number of pulses output per second.

1. **Feed quantity**

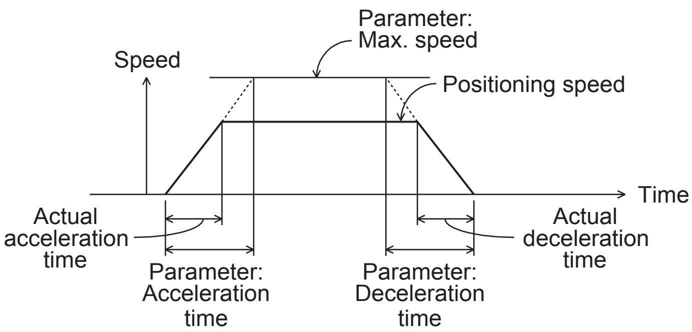
   The feed quantity determined by the target address tells the servo system how far to move the workpiece. So, for example, if a servo motor encoder generates 8,192 pulses for one rotation, the command pulse number "8,192" can be output to rotate the servo motor by 1 rotation.

2. **Feed speed**

   The feed speed defines the amount of travel per unit of time for the workpiece. When a servo motor encoder generates 8,192 pulses for one rotation, the command pulse frequency (speed) "8,192 pulses/s" should be output to rotate the servo motor by 1 rotation per second. Decrease the pulse frequency to rotate the servo motor at a lower speed. Increase the pulse frequency to rotate the servo motor at a higher speed.

3. **Acceleration/deceleration time**

   When the start command is given, acceleration, operation at constant speed, and deceleration are performed for positioning. Set the acceleration time and the deceleration time in the controller's parameters.



3.1.3 Zero point return function

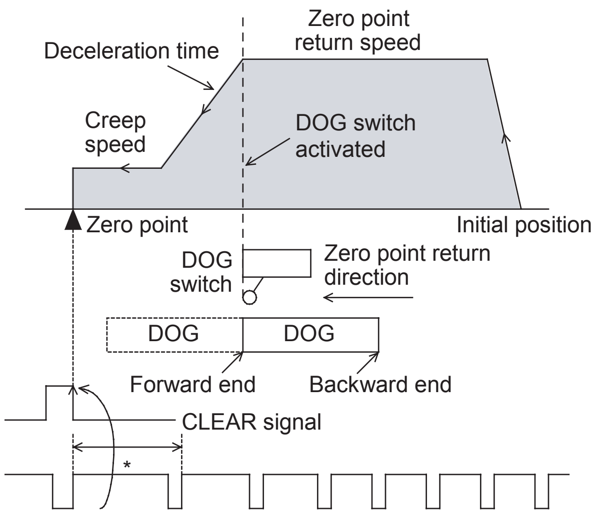
Many positioning systems include a "home position" to where a workpiece may need to return after performing various operations. For this reason, positioning controllers include a built-in function to return a workpiece to a defined position by using a mechanical DOG switch.
To understand how this works, it is necessary to first understand when the function is needed according to the parameter setting of the servo amplifier and the type of servo motor encoder.

1. **Incremental type servo motor encoder (pulse count method)**
When the servo system uses an incremental or relative type encoder, the current value of the address stored in the position controller is not "remembered" or maintained when the power is turned off. This means that the address is set to zero every time the power is cycled, which can be disadvantageous in an application. Accordingly, every time the system is re-powered, it must be calibrated to the correct zero-point location by executing the zero point return function.

2. **Absolute type servo motor encoder (absolute position detection system)**
The absolute position detection system requires an absolute position motor encoder, a backup battery on the servo amplifier, and a parameter specification setting. It is constructed so that the current value stored in the positioning controller is always assured, regardless of power outages or movement while the power is turned off. The advantage to using this method is that after executing the zero point return function once, zero point return it is not needed again.

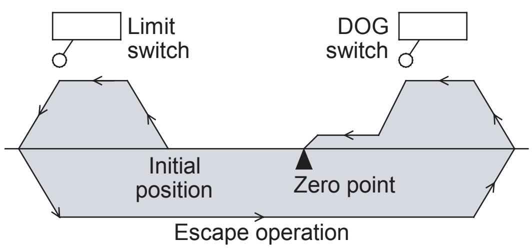
Note

The zero point return function does not actuate movement to a physical zero address. Instead, the zero point return function causes movement in a specified direction (positive or negative) in order to define the physical zero address after contact with a DOG switch.



* The location of the DOG switch should be adjusted so that the backward end of the DOG is released between two consecutive zero point signals (1 pulse per rotation of the motor).
In this example, the DOG length should not be less than the deceleration distance of the machine.

Example of DOG type zero return
In the example to the left, the DOG (which is attached to the workpiece) comes in contact with the DOG switch to turn the DOG signal ON, which then initiates deceleration to creep speed. After the backward end of the DOG passes the DOG switch, turning the DOG signal OFF, the first detected zero point signal stops the motion, turns the CLEAR signal on, and sets the zero point address.
The zero point address (specified in the controller's parameters) is typically zero. When the zero return function finishes, the zero point address is written to the current value register of the positioning controller to overwrite the current address. Since the zero point address is not always zero, the zero return function should be thought of as a homing function instead of a return-to-zero function.
The zero point return direction, zero point address, zero signal count, return speed, deceleration time and creep speed are all set by parameters in the positioning controller.



DOG search function
In some PLC models, if the zero point return function is performed while the workpiece is stopped beyond the DOG switch, the machine moves until the limit switch is actuated, changes direction, then returns to the zero point again (DOG search function, zero point return retry function).

3.2 Servo amplifier and servo motor

The servo amplifier controls the movement quantity and the speed according to the commands given by the positioning controller. The servo motor then transmits rotation to the drive mechanism after receiving signals from the servo amplifier.

3.2.1 Positioning control in accordance with command pulse

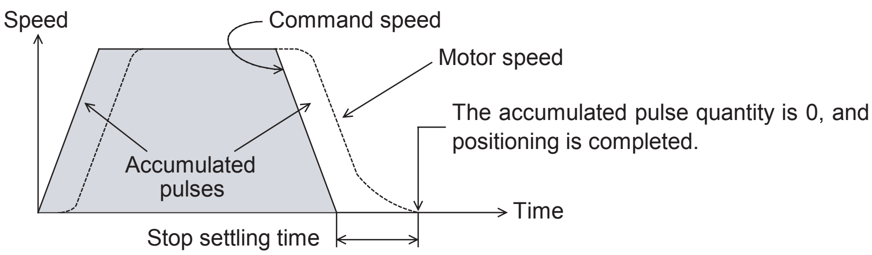
In accordance with speed and position command pulses from the positioning controller, PWM (pulse width modulation) control is performed by the main circuit of the servo amplifier in order to drive the motor. The rotation speed and the rotation quantity are fed back to the amplifier from the encoder attached to the servo motor.

3.2.2 Deviation counter function

The difference between the command pulses and the feedback pulses counted by the deviation counter in the servo amplifier is called accumulated pulses.

While the machine is operating at a constant speed, the accumulated pulse quantity is almost constant. During acceleration and deceleration, the accumulated pulse quantity changes more dramatically.

When the accumulated pulse quantity becomes equivalent to or less than a specified quantity (in-position set value) after command pulses have stopped, the servo amplifier outputs the positioning complete signal.
The servo motor continues operation even after that. Then, when the accumulated pulse quantity becomes 0, the servo motor stops.
The time after the servo motor outputs the positioning complete signal until it stops is called the stop settling time.



3.2.3 Servo lock function

The servo motor is controlled so that the accumulated pulse quantity counted in the deviation counter becomes 0.
For example, if an external force for forward rotation is applied on the servo motor, the servo motor performs the reverse rotation operation to eliminate the accumulated pulses.

Accumulated pulses in deviation counter	Servo motor
Minus pulses	Reverse rotation operation
Plus pulses	Forward rotation operation
0 (zero)	Stop

3.2.4 Regenerative brake function

During deceleration, because the servo motor rotates by the load inertia of the drive mechanism, it functions as a generator and electric power returns to the servo amplifier.
The regenerative resistor absorbs this electric power and functions as a brake (called a regenerative brake.)

A regenerative brake is required to prevent regenerative over voltage in the servo amplifier when the load inertia is large and operations are frequently performed.

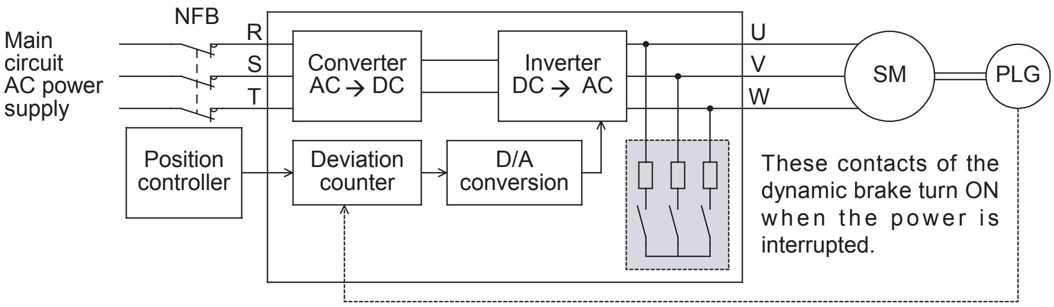
The regenerative resistor is required when the regenerative power generation quantity during deceleration exceeds the allowable regenerative electric power of the servo amplifier.

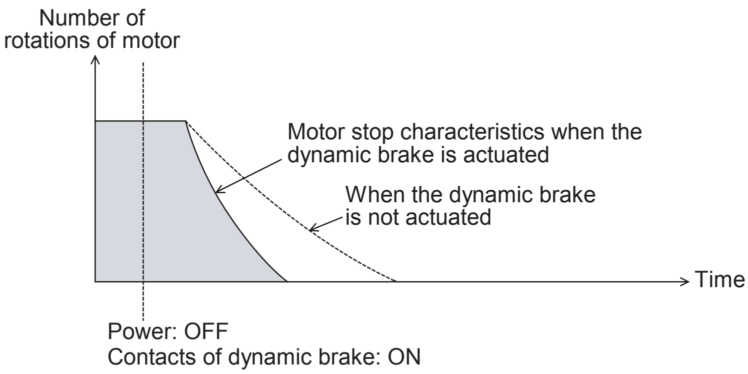
1 The Basics of Positioning Control
2 Positioning by AC Servo System
3 Components of Positioning Control
4 Learning to Use FX Positioning Control

3.2.5 Dynamic brake function

When a circuit inside the servo amplifier is disabled by a power interruption in the AC power of the main circuit or actuation of the protective circuit, the terminals of the servo motor are short-circuited via resistors, the rotation energy is consumed as heat, then the motor immediately stops without free run.

When the motor stops by elimination of the rotation energy, the brake is not effective and the motor runs freely.



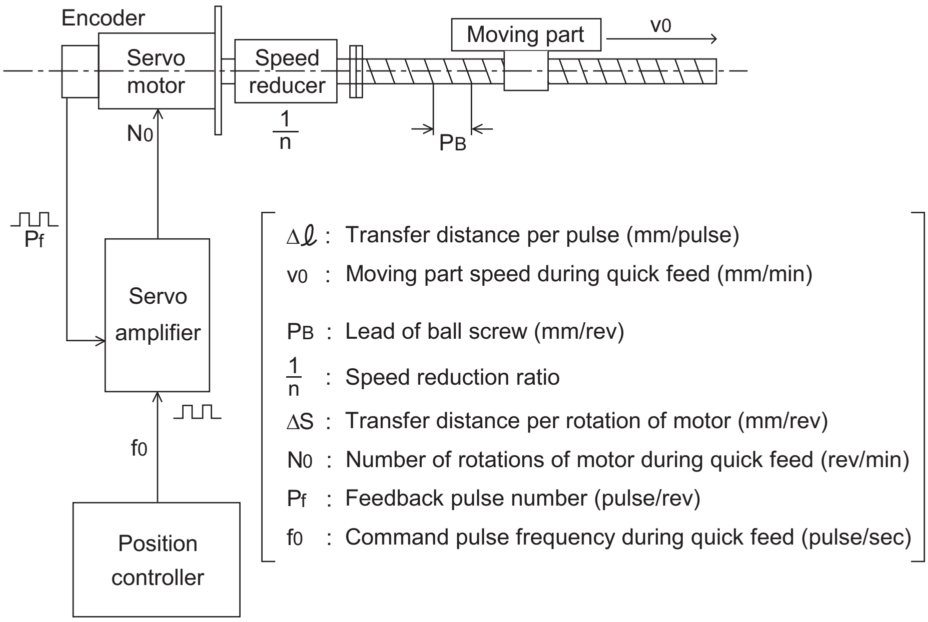


3.3 Drive mechanism

The drive mechanism converts the rotation motion of the servo motor into reciprocating or vertical motion through a speed reducer, timing belt, ball screw, etc. to move the machine.

3.3.1 Concept of drive system movement quantity

The following diagram is a representative AC servo motor positioning system.



- The servo motor stops with the precision $\pm\Delta\ell$, which is within ±1 pulse against the command pulse.
- The movement quantity of the workpiece is:
  [Output pulses from position controller] x [$\Delta\ell$]

  The moving part speed is:
  [f_0] x [$\Delta\ell$]
- Either “mm,” “inch,” degree,” or pulse can be selected for the positioning command unit. Accordingly, when data such as the movement quantity per pulse, positioning speed, or the positioning address in accordance with the positioning command unit are set, pulse trains are output for the target address, and positioning is performed.

Useful equations

To define the system illustrated above, $\Delta\ell$ and v_0 need to be determined using a series of equations. The speed of the moving part (v_0) is constrained by the mechanical gearing system between the servo motor and moving part, the pitch of the ball screw, and the specification of the motor as shown through the following two formulas.

Transfer distance per rotation of motor

$$\Delta S\left(\frac{mm}{rev}\right) = P_B \times \frac{1}{n}$$

Number of rotations of motor during quick feed

$$N_0\left(\frac{rev}{min}\right) = \frac{v_0}{\Delta S} \leqq \text{Rated number of rotations of servo motor}$$

If N_0 does not exceed the rated speed of the motor, this means that the servo system can be used for the application. In order to determine if the positioning controller is applicable, the command pulse frequency during quick feed (f_0) should be checked to verify it does not exceed the maximum allowable frequency setting for the “maximum speed” parameter setting of the controller.

Transfer distance per pulse

$$\Delta\ell\left(\frac{mm}{PLS}\right) = \frac{\Delta S}{P_f} \times \text{(Electronic gear ratio)}$$

Command pulse frequency during quick feed

$$f_0\left(\frac{PLS}{S}\right) = \frac{\Delta S}{\Delta\ell} \times N_0 \times \frac{1}{60}$$

During the above process, the Electronic gear ratio (often “CMX/CDV” for Mitsubishi servos) and Speed reduction ratio can be adjusted to fit the application’s needs.

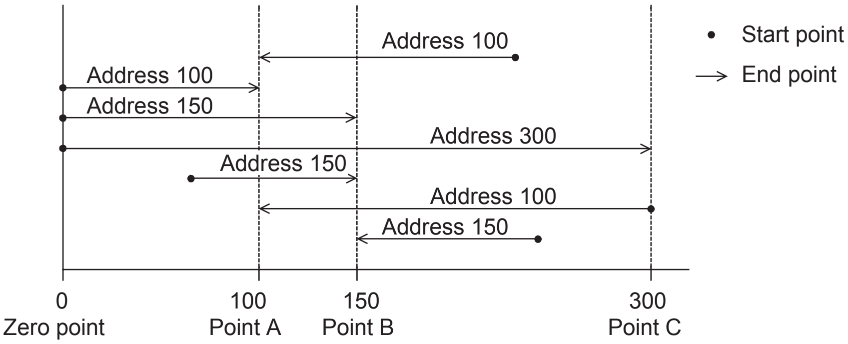
In each of the absolute and incremental positioning methods, the entire movement distance of the machine should not exceed the maximum allowable pulse output number from the positioning controller.

3.3.2 Setting the target position

In positioning control, the target position can be set by the following two methods, specified by the controller's parameter settings.
(Available command units are "mm," "inch", "degree", or "pulse".)

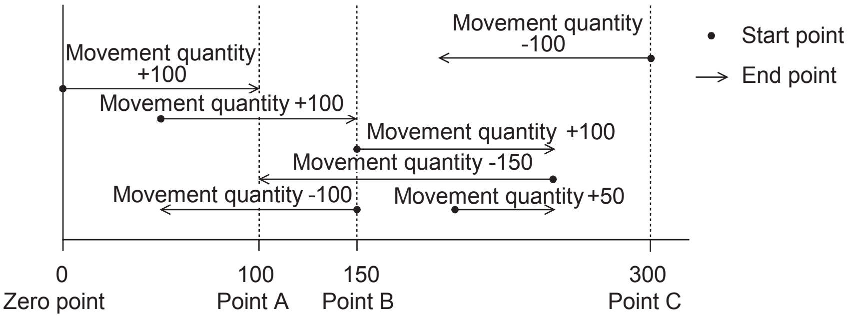
1. Absolute method

In this method, a point (absolute address) is specified for positioning while the zero point is regarded as the reference. The start point is arbitrary.



2. Incremental method

In this method, positioning is performed through specification of the movement direction and the movement quantity while the current stop position is regarded as the start point.



4. Learning to Use the FX Family for Positioning Control

4.1 FX PLC positioning

The FX1S, FX1N and FX3U(C) Series PLC main units include basic positioning instructions to send command pulses to a stepper motor or servo amplifier. While FX PLCs support point-to-point positioning, full control is also available for reading the absolute position from a servo amplifier, performing zero return, and altering the workpiece speed during operation.

Important references for understanding positioning with FX PLCs include:

- FX Series Programming Manual II – (JY992D88101)
- FX3U/FX3UC Series Programming Manual – (JY997D16601)
- FX3U/FX3UC Series User's Manual - Positioning Control Edition – (JY997D16801)

It is assumed that you will have read and understood the above manuals or that you will have them close at hand for reference.

4.1.1 Overview of control

1. **Number of Axes**
The FX1S and FX1N transistor type PLCs support positioning on 2 axes with operation speeds up to 100,000 pulses/second (100 kHz). The FX3U(C) transistor type PLC main units support positioning speeds up to 100 kHz on 3 axes. If two FX3U-2HSY-ADP adapters are connected to the FX3U, 4 axes are available with operation speeds up to 200 kHz. The PLS/DIR pulse output method is used for all PLC main units to output pulses as shown in the following table.

	1st Axis	2nd Axis	3rd Axis	4th Axis
Applicable Model	FX1S, FX1N			
	FX3U(C)			
	FX3U + (2) FX3U-2HSY-ADP*2*3			
Pulse Output	Y0	Y1	Y2	Y3
Direction Output*1	Y4	Y5	Y6	Y7

*1. Output terminals for direction can be specified arbitrarily when the FX3U-2HSY-ADP is not used. Y4, Y5, Y6 and Y7 are used as an example.

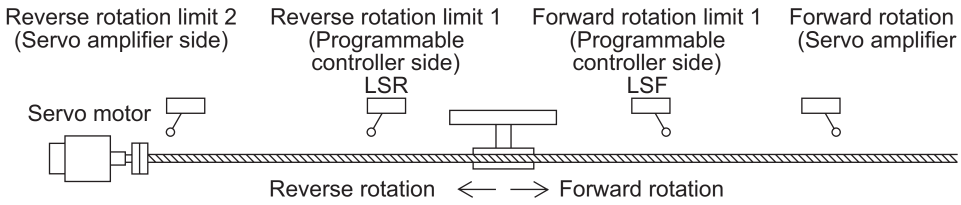
*2. The FP/RP pulse output method is also available with the FX3U-2HSY-ADP.

*3. The FX3UC can not be connected with the FX3U-2HSY-ADP.

2. Limit switches

As with any other positioning system, inputs are needed to detect when the workpiece reaches the outer boundary limits in order to prevent damage to the machine. For the FX3U(C) programmable logic controller, limits are wired to the controller to be used with the DOG search zero return function for reversing the motor's direction of travel in order to hunt for the DOG switch. These limits are called the forward rotation limit (LSF) and the reverse rotation limit (LSR). Hardware limits are used on the servo amplifier side to stop the motor in worst case scenarios.

Example of limit switches for the FX3U(C) PLC:

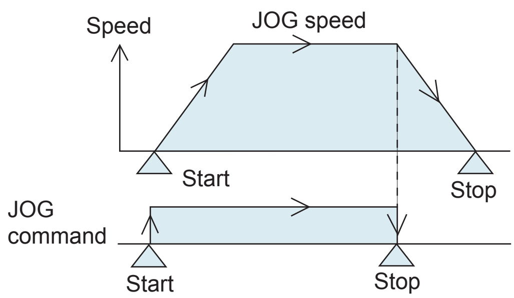
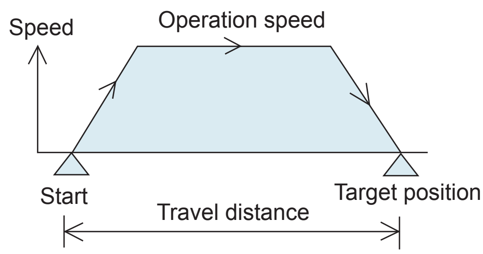


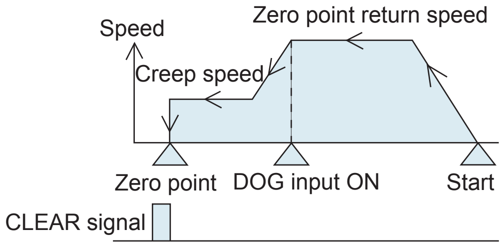
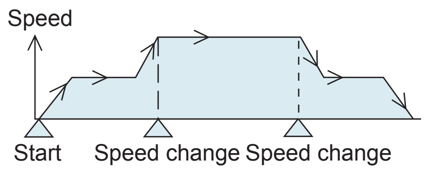
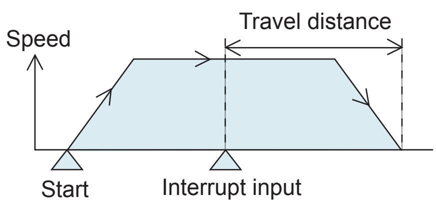
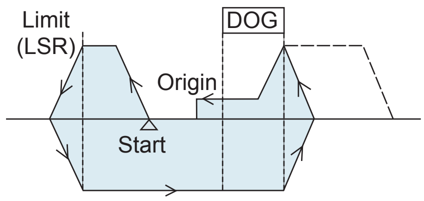
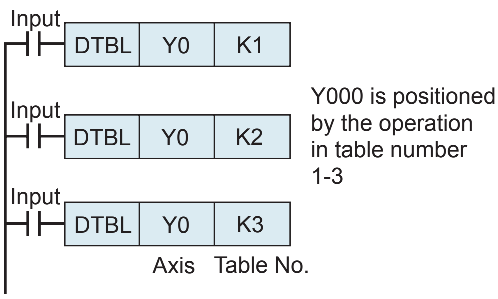
3. Sink vs. Source outputs

In general, MELSERVO Series amplifiers are configured with sink type inputs. To communicate appropriately with sink type inputs, sink type outputs are used on the PLC side. Therefore, when using a Mitsubishi servo control system, a transistor sink output type PLC is used.

4. Options for positioning

Before choosing a PLC for a positioning system, it is important to understand the instructions available for each PLC. The FX1S and FX1N include the same set of positioning instructions. The only disadvantage to choosing an FX1S PLC for positioning is that it does not include as many I/O and that it cannot be expanded with special function blocks for analog or communication control.
The FX3U, combined with high speed positioning adapters, can operate with higher pulse output frequencies and includes 3 additional positioning instructions. The available instructions for FX PLCs are described in the chart below.

Applicable Model	Description	Positioning instruction	Instruction Illustration
FX1S FX1N FX3U(C)	**JOG operation** The motor moves in a specified direction depending on the logic and timing of the drive input signal. (There is no target position.)	DRVI	
FX1S FX1N FX3U(C)	**1-speed positioning** A start command accelerates the motor to a constant speed and moves the workpiece to a specified distance.	DRVI DRVA	

Applicable Model	Description	Positioning instruction	Instruction Illustration
FX1S FX1N FX3U(C)	**Zero return** The machine moves at a specified speed until the DOG input turns ON. The workpiece then slows to creep speed and stops before the CLEAR signal is output.	ZRN	
FX1S FX1N FX3U(C)	**Variable speed operation** After starting with a specified speed, the motor can change its speed depending on commands from the PLC. (For the FX1S and FX1N, acceleration to different speeds is approximated with the RAMP instruction)	PLSV (RAMP)	
FX3U(C)	**Interrupt 1-speed positioning** When an interrupt signal turns ON, the workpiece travels a specific distance at the same speed before decelerating to stop.	DVIT	
FX3U(C)	**DOG search zero return** The machine operates similar to the zero return instruction except for features to hunt for the DOG switch and to use the zero-phase signal.	DSZR	
FX3U(C)	**Table operation** For programming simplicity, position and speed data can be organized in table format for the DRVI, DRVA, DVIT and PLSV instructions.	DTBL	

4.1.2 Important memory locations

For FX PLC programs using positioning instructions, there are several built-in memory addresses to define control parameters and facilitate system operation. These addresses consist of 1-bit, 16-bit, and 32-bit address locations and are briefly outlined below according to their use in the example programs in the following section. Use this table as a reference to understand the example programs. For details on other memory addresses (for example, operation information for control on Y001 or Y002), refer to the FX3U/FX3UC Series User's Manual - Positioning Control Edition (JY997D16801).

Function name	Address	Length	Description	Applicable PLC
RUN monitor	M8000	1-bit	ON when PLC is in RUN.	FX1S, FX1N, FX3U(C)
Initial pulse	M8002	1-bit	ON for the first scan only.	FX1S, FX1N, FX3U(C)
Instruction execution complete flag	M8029	1-bit	Programmed immediately after a positioning instruction. Turns ON when the preceding instruction finishes its operation and stays ON until the instruction stops being driven.	FX1S, FX1N, FX3U(C)
CLEAR signal output enable	M8140	1-bit	Enables a CLEAR signal to be output to the servo.	FX1S, FX1N
Pulse output stop command	M8145	1-bit	Stop outputting Y000 pulses. (Immediate stop)	FX1S, FX1N
	M8349			FX3U(C)
Pulse output monitor flag	M8147	1-bit	OFF when Y000 is READY ON when Y000 is BUSY	FX1S, FX1N
	M8340			FX3U(C)
Instruction execution abnormally complete flag	M8329	1-bit	Programmed immediately after a positioning instruction. Turns ON when an instruction fails to complete correctly and stays ON until the instruction stops being driven.	FX3U(C)
CLEAR signal output function enable	M8341	1-bit	Enables an output to be used for the CLEAR signal for Y000.	FX3U(C)
(Y000) Zero return direction specification	M8342	1-bit	OFF → Reverse rotation ON → Forward rotation	FX3U(C)
Forward rotation limit	M8343	1-bit	Forward pulses on Y000 stop when this relay turns ON.	FX3U(C)
Reverse rotation limit	M8344	1-bit	Reverse pulses on Y000 stop when this relay turns ON.	FX3U(C)
(Y000) Positioning instruction activation	M8348	1-bit	OFF when a positioning instruction is not active. ON when a positioning instruction is active.	FX3U(C)
CLEAR signal device specification function enable	M8464	1-bit	Enables the output terminal for the CLEAR signal to be changed for Y000.	FX3U(C)
Bias speed [Hz]	D8145	16-bit	Sets the bias speed for Y000.	FX1S, FX1N
	D8342			FX3U(C)
Maximum speed [Hz]	D8146	32-bit	Sets the maximum speed for positioning instructions on Y000.	FX1S, FX1N
	D8343			FX3U(C)
Acceleration/ deceleration time [ms]	D8148	16-bit	Sets the acceleration and deceleration time.	FX1S, FX1N
Acceleration time [ms]	D8348	16-bit	Sets the acceleration time for Y000.	FX3U(C)
Deceleration time [ms]	D8349	16-bit	Sets the deceleration time for Y000.	FX3U(C)
CLEAR signal device specification	D8464	16-bit	Sets the output terminal for the CLEAR signal for Y000.	FX3U(C)

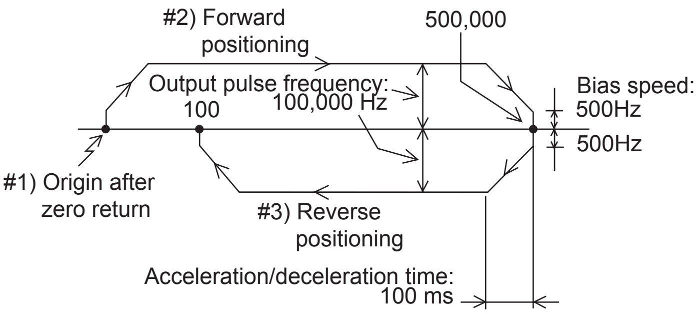
4.1.3 Program examples

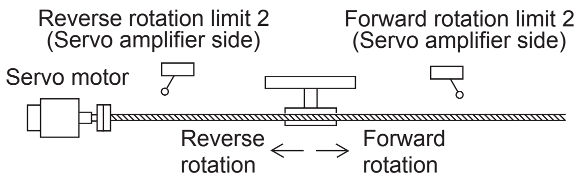
Two positioning examples are included as a reference to get started with PLC programming.

1. Hybrid programming example for FX1S, FX1N, FX3U(C) PLCs

The first example below illustrates zero return and absolute positioning control on 1 axis with an FX1S, FX1N or FX3U(C) PLC. Since the memory addresses for utilizing positioning instructions is different depending on the PLC, please note that the following program is a hybrid program and that memory addresses must be changed according to the type of PLC.

A general understanding of step ladder and ladder logic is necessary to use the program.

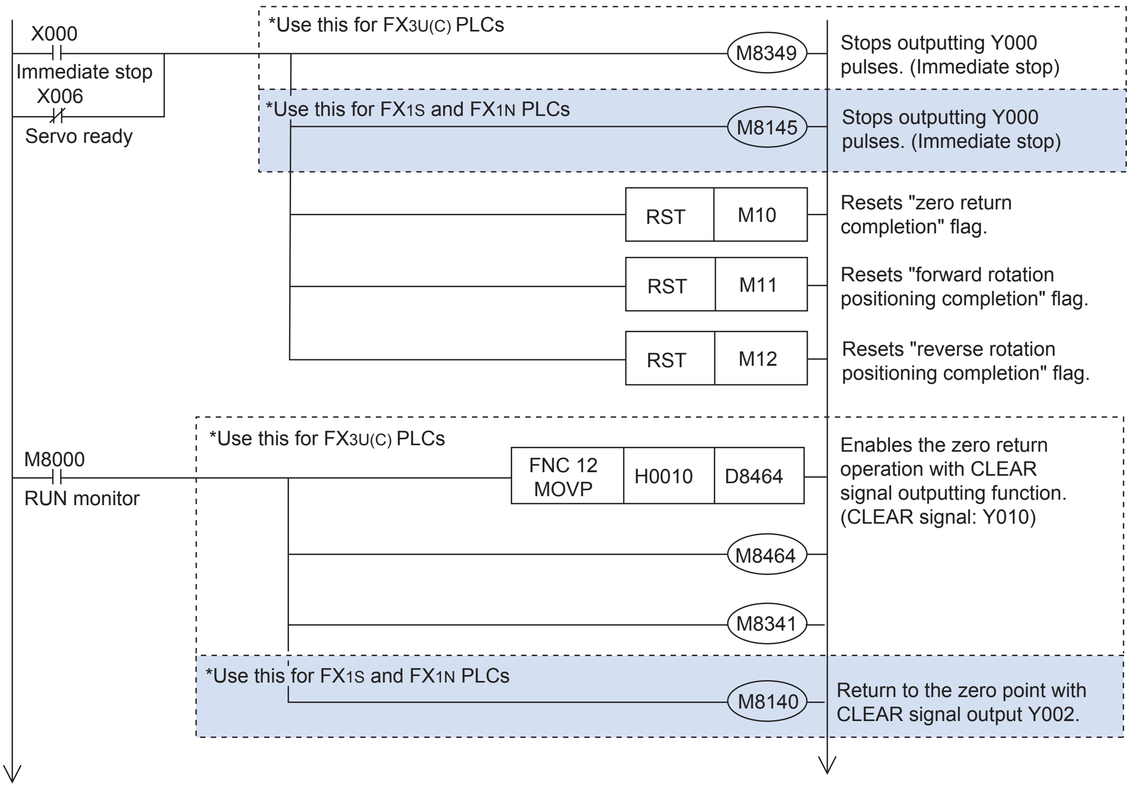


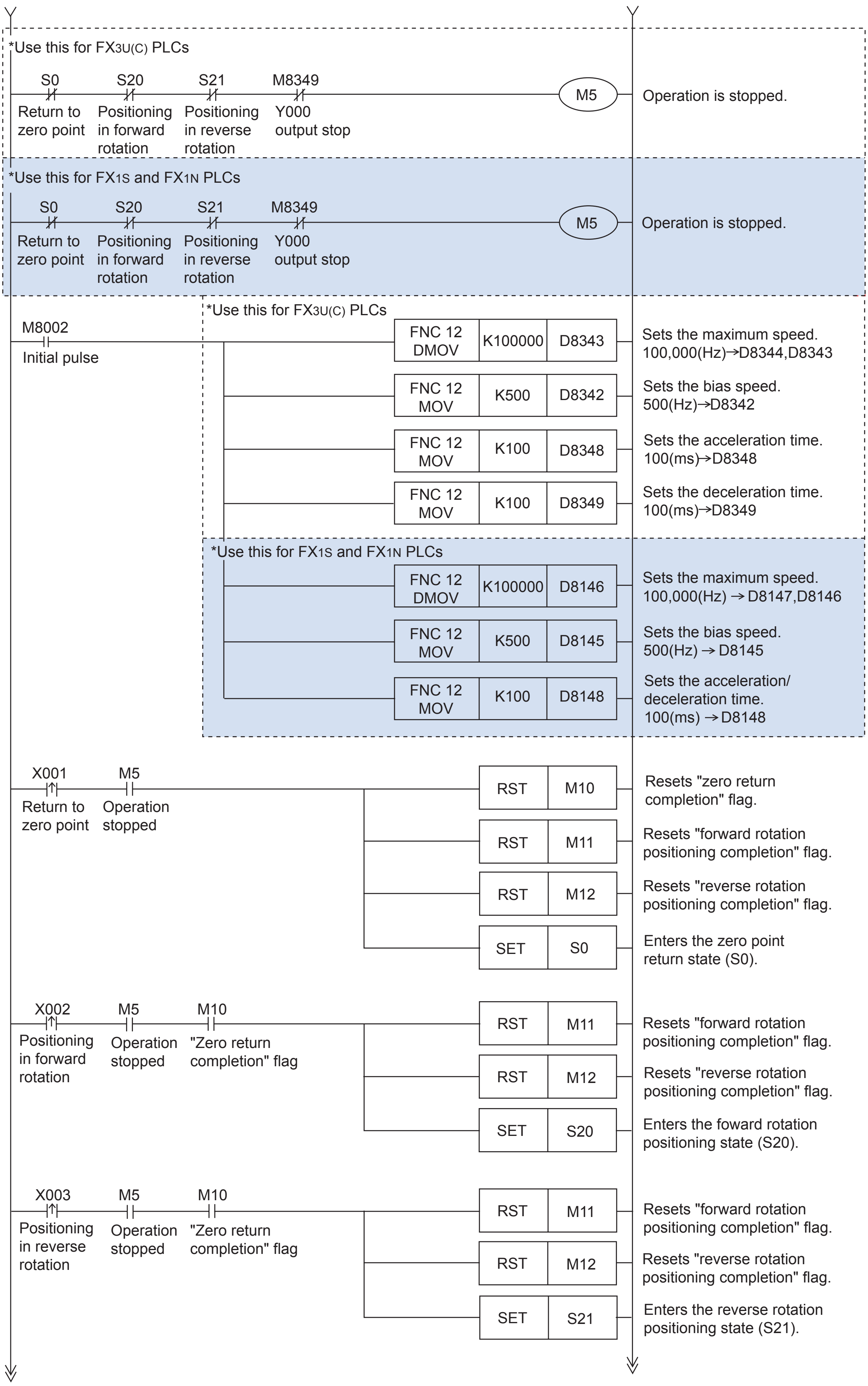


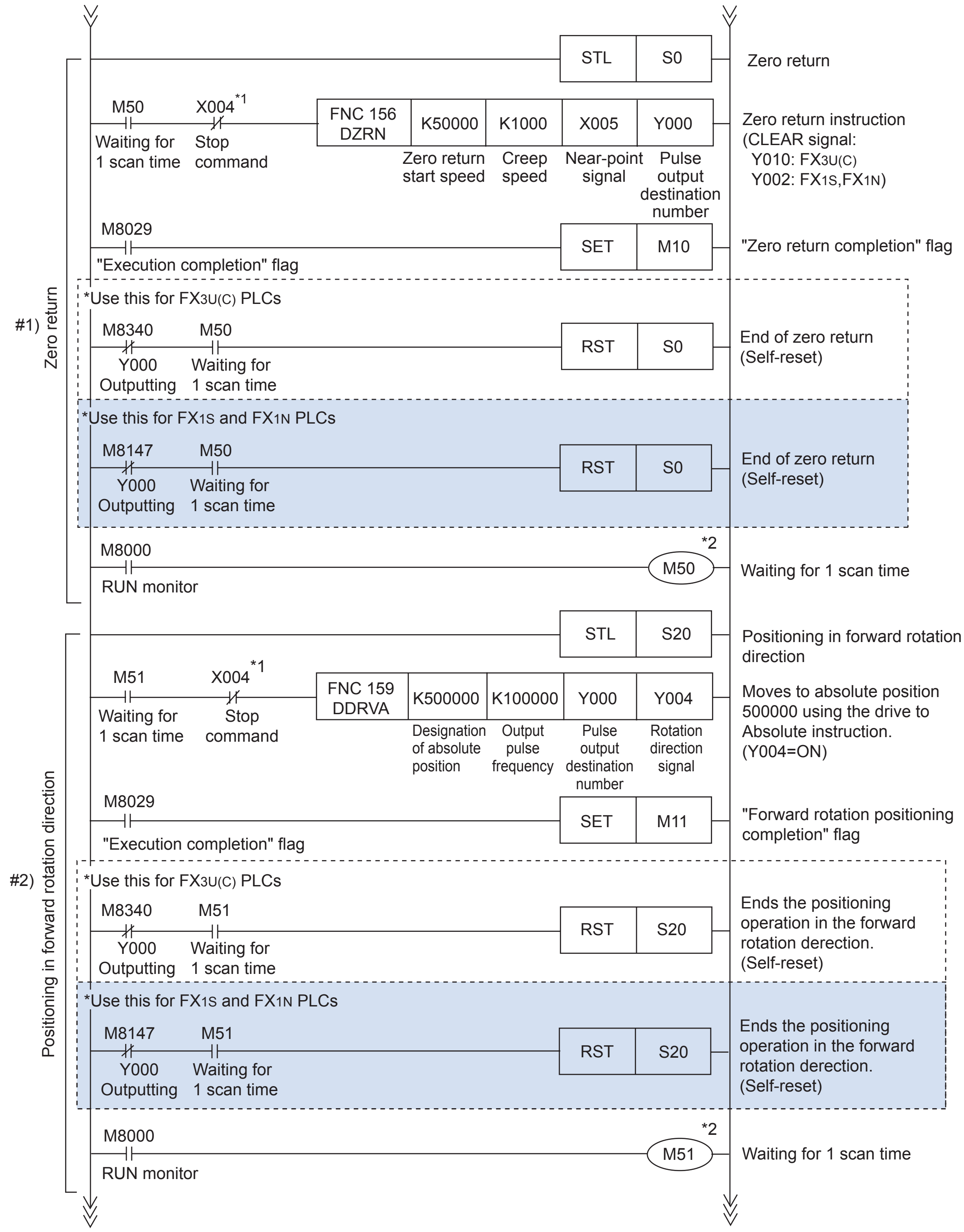
The following inputs and outputs are used:

Input	
X000	Immediate stop
X001	Zero return command
X002	Forward rotation positioning command
X003	Reverse rotation positioning command
X004	Stop command
X005	Near-point signal (DOG)
X006	Servo ready

Output	
Y000	Pulse train output
Y004	Rotation direction signal
Y010/Y002	CLEAR signal

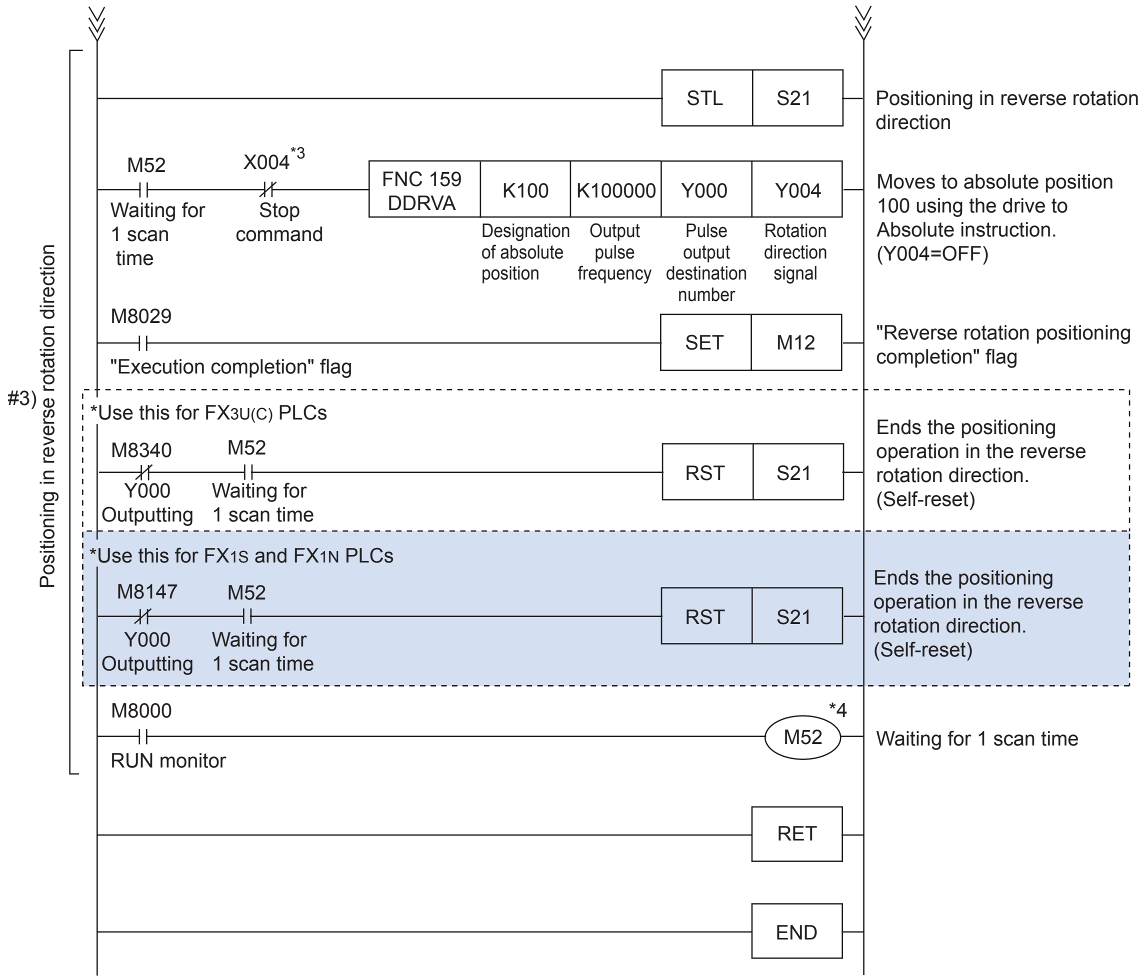



*Use this for FX3U(C) PLCs
S0
S20
S21
M8349
Return to zero point
Positioning in forward rotation
Positioning in reverse rotation
Y000 output stop
M5
Operation is stopped.
*Use this for FX1S and FX1N PLCs
S0
S20
S21
M8349
Return to zero point
Positioning in forward rotation
Positioning in reverse rotation
Y000 output stop
M5
Operation is stopped.
M8002
Initial pulse
*Use this for FX3U(C) PLCs
FNC 12 DMOV K100000 D8343
Sets the maximum speed. 100,000(Hz)→D8344,D8343
FNC 12 MOV K500 D8342
Sets the bias speed. 500(Hz)→D8342
FNC 12 MOV K100 D8348
Sets the acceleration time. 100(ms)→D8348
FNC 12 MOV K100 D8349
Sets the deceleration time. 100(ms)→D8349
*Use this for FX1S and FX1N PLCs
FNC 12 DMOV K100000 D8146
Sets the maximum speed. 100,000(Hz) → D8147,D8146
FNC 12 MOV K500 D8145
Sets the bias speed. 500(Hz) → D8145
FNC 12 MOV K100 D8148
Sets the acceleration/ deceleration time. 100(ms) → D8148
X001
M5
Return to zero point
Operation stopped
RST M10
Resets "zero return completion" flag.
RST M11
Resets "forward rotation positioning completion" flag.
RST M12
Resets "reverse rotation positioning completion" flag.
SET S0
Enters the zero point return state (S0).
X002
M5
M10
Positioning in forward rotation
Operation stopped
"Zero return completion" flag
RST M11
Resets "forward rotation positioning completion" flag.
RST M12
Resets "reverse rotation positioning completion" flag.
SET S20
Enters the foward rotation positioning state (S20).
X003
M5
M10
Positioning in reverse rotation
Operation stopped
"Zero return completion" flag
RST M11
Resets "forward rotation positioning completion" flag.
RST M12
Resets "reverse rotation positioning completion" flag.
SET S21
Enters the reverse rotation positioning state (S21).



*1. To stop the positioning operation, be sure to insert the stop contact before the positioning instruction so that STL instruction cannot be turned off (reset) until "pulse output monitor" flag (M8340 or M8147 (for Y000)) is turned off.

*2. To prevent simultaneous activation of positioning instructions, the instruction activation timing should be delayed by 1 scan time.



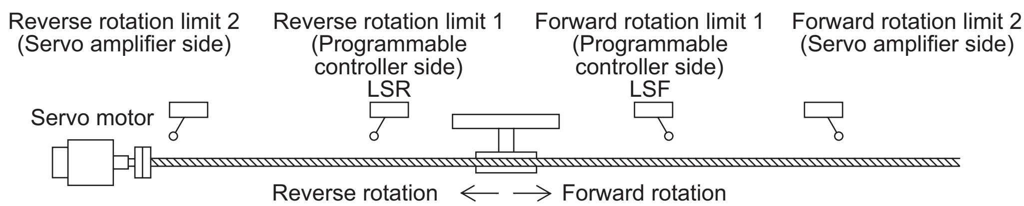
*3. To stop the positioning operation, be sure to insert the stop contact before the positioning instruction so that STL instruction cannot be turned off (reset) until "pulse output monitor" flag (M8340 or M8147 (for Y000)) is turned off.

*4. To prevent simultaneous activation of positioning instructions, the instruction activation timing should be delayed by 1 scan time.

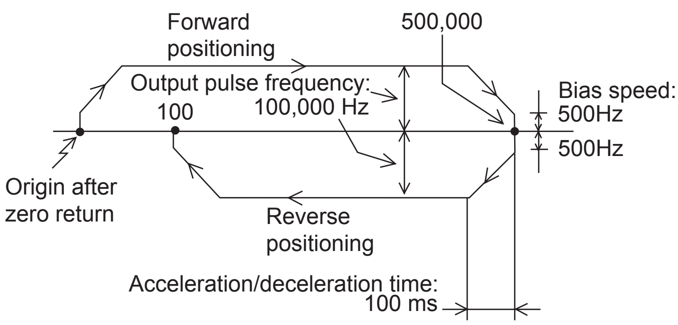
2. Programming example for the FX3U(C) PLC

The following program is similar to the previous one except that it is programmed only in ladder logic and does not follow a specific sequence of step ladder states. Additionally, it includes control for relative positioning with JOG(+) and JOG(-) commands, a DOG search zero return function, and utilization of the DTBL instruction.

When using an FX3U(C) PLC, the DOG search zero return function can be programmed with limit switches wired to the PLC as follows.



The DTBL instruction helps to simplify the programming code and is set up beforehand (along with positioning parameters such as the bias speed, acceleration/deceleration, etc.) with GX Developer.



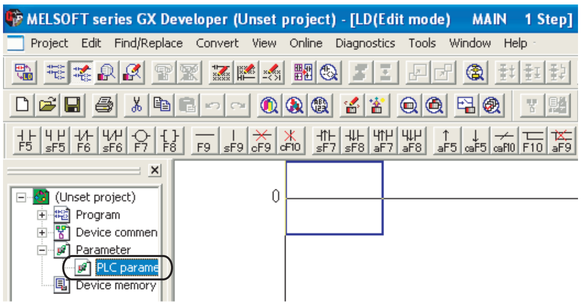
In this example, positioning may be performed arbitrarily along the path to the left.

Using the JOG command, the workpiece is moved to any relative position. This is not illustrated to the left.

Required hardware and software are as follows:

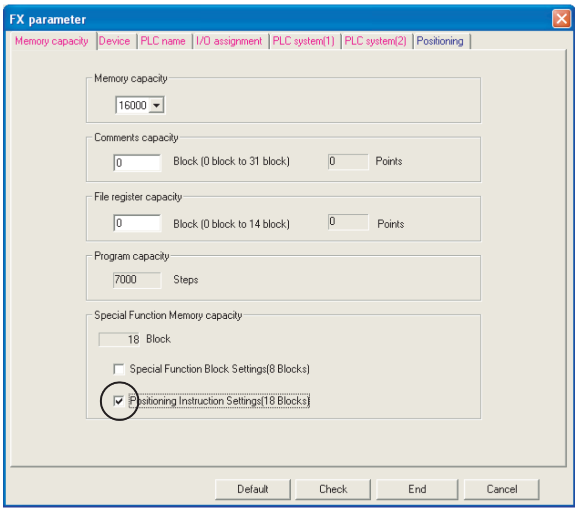
1) FX3U(C) PLC version 2.20 or later
2) GX Developer 8.23Z or later

Parameters for the DTBL instruction are set in GX Developer as shown below.



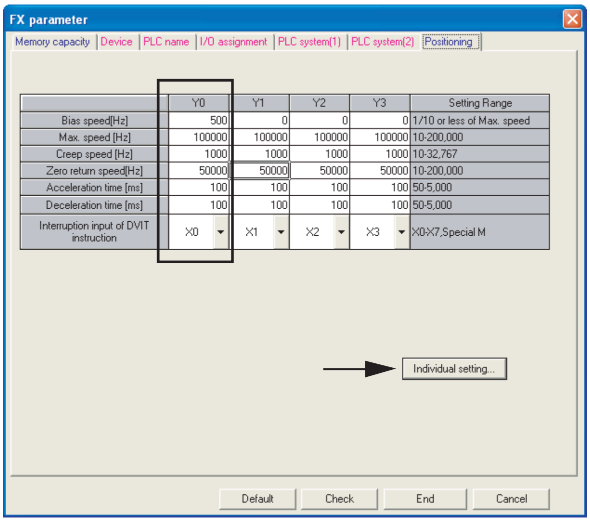
a) Double-click [Parameter] and then [PLC parameter] from the project tree on the left side of the screen.

If the project tree is not displayed on the screen, click [View] on the menu bar, and then click [Project Data List].



b) Click on the [Memory capacity] tab and then enter a check in the [Positioning Instruction Settings] check box.

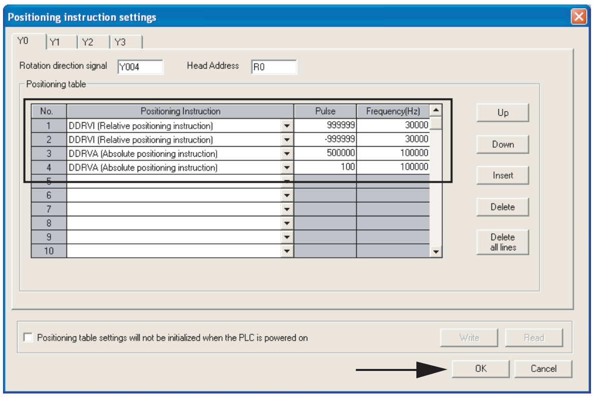
Take note that 9,000 steps are needed to set the positioning data. Therefore, it is necessary to specify a [Memory capacity] of 16,000 steps or more.



c) Click on the [Positioning] tab and then set Y000 (pulse output destination) as follows:

Setting item	Setting value
Bias speed (Hz)	500
Maximum speed (Hz)	100,000
Creep speed (Hz)	1000
Zero return speed (Hz)	50,000
Acceleration time (ms)	100
Deceleration time (ms)	100
Interrupt input for DVIT instruction	X000

d) Click the [Individual setting] button. The “Positioning instruction settings” window will appear. In this window, click on the [Y0] tab to display the positioning table for Y000 (pulse output destination). Set the data in the positioning table as follows:



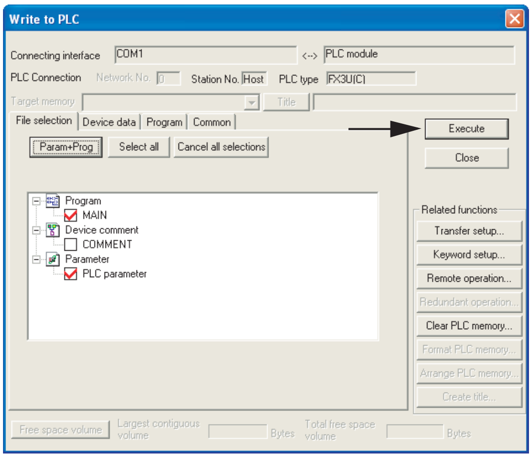
Be sure to change the [Rotation direction signal] to “Y004”.

e) Click the [OK] button and then the [End] button to close the parameters.

f) Create the ladder program as shown below.

Setting item		Setting value
Rotation direction signal		Y004
First device		R0
No. 1	Positioning type	DDRVI (Drive to increment)
	Number of pulses (PLS)	999,999
	Frequency (Hz)	30,000
No. 2	Positioning type	DDRVI (Drive to increment)
	Number of pulses (PLS)	-999,999
	Frequency (Hz)	30,000
No. 3	Positioning type	DDRVA (Drive to absolute)
	Number of pulses (PLS)	500,000
	Frequency (Hz)	100,000
No. 4	Positioning type	DDRVA (Drive to absolute)
	Number of pulses (PLS)	100
	Frequency (Hz)	100,000

g) Once the ladder program is complete, click on [Online] from the top menu bar in GX Developer and select [Write to PLC]. The “Write to PLC” window will appear.

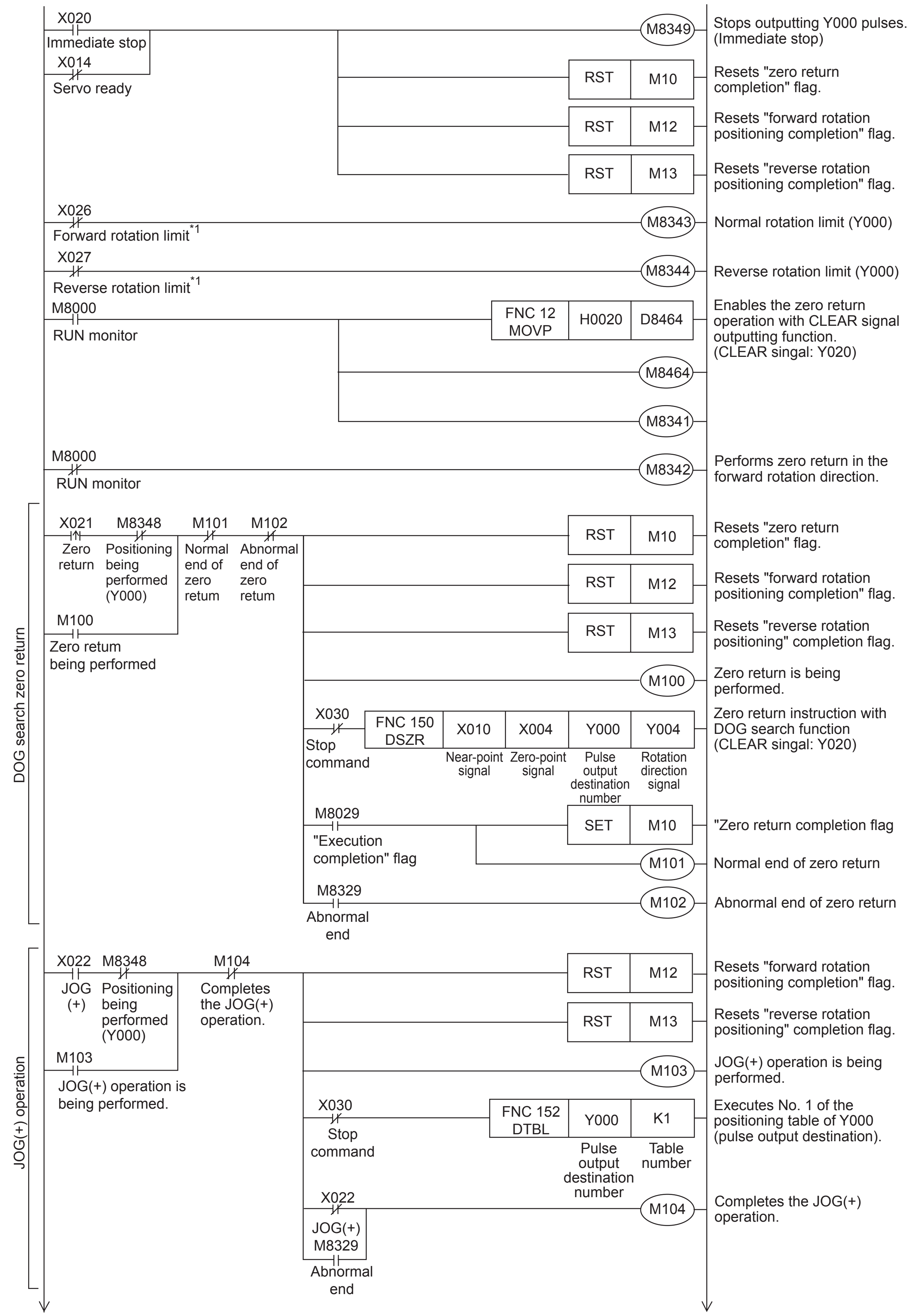


h) Click the [Param + Prog] button and then click the [Execute] button. The parameters and the created program will be transferred to the PLC. To enable the transferred parameters, stop the PLC and then restart it.

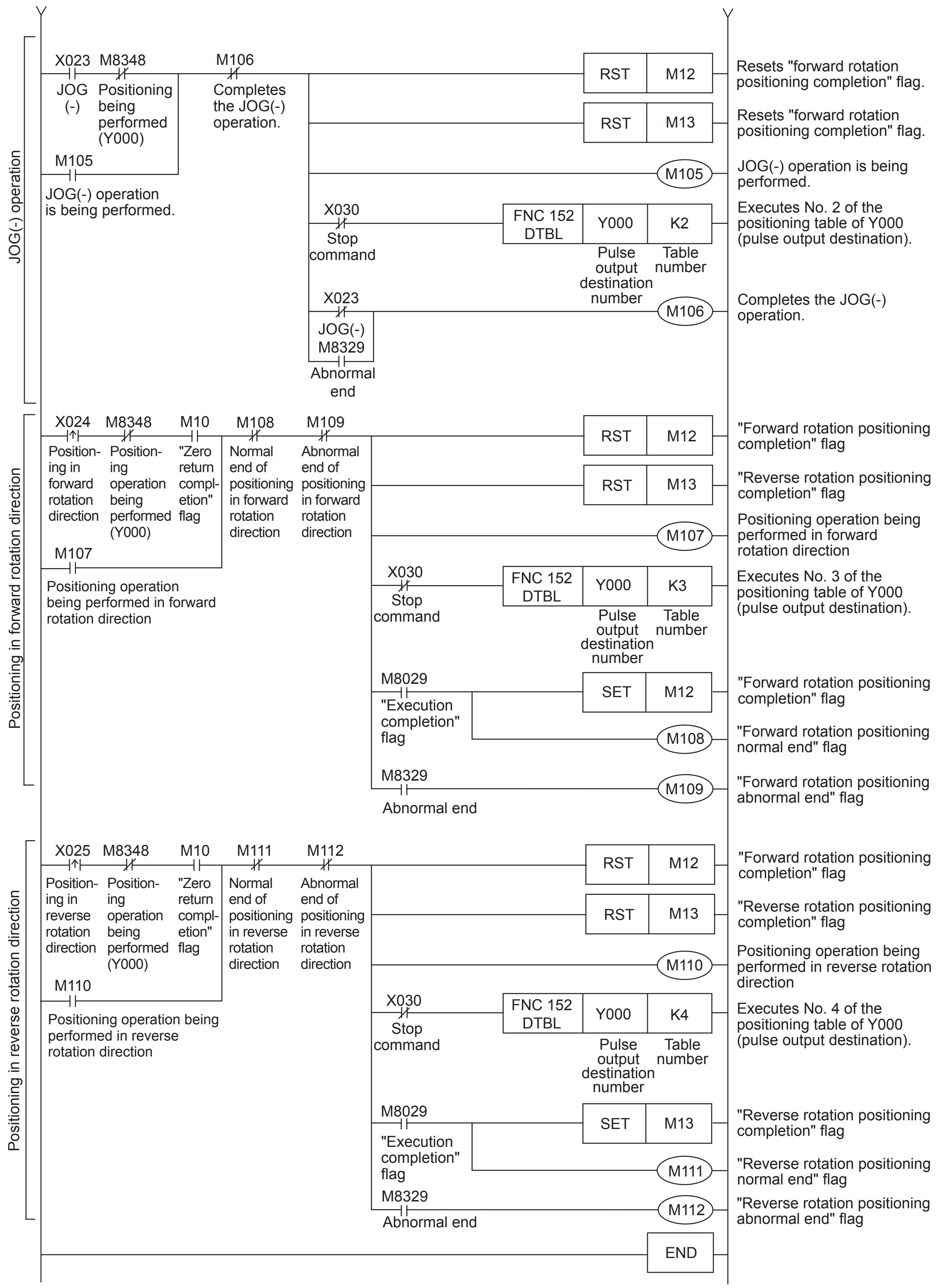
The following inputs and outputs are used:

Inputs	
X004	Zero-point signal
X010	Near-point signal (DOG)
X014	Servo ready
X020	Immediate stop
X021	Zero return command
X022	JOG(+) command
X023	JOG(-) command
X024	Forward rotation positioning command
X025	Reverse rotation positioning command
X026	Forward rotation limit (LSF)
X027	Reverse rotation limit (LSR)
X030	Stop command

Outputs	
Y000	Pulse train output
Y004	Rotation direction signal
Y020	CLEAR signal



*1. The forward and reverse rotation limit switches must be wired so that they are turned ON by default. When these limit switches turn OFF (due to the workpiece going out-of-bounds), M8343 or M8344 will turn ON and cause the pulse operation to stop.


JOG(-) operation
X023
M8348
M106
JOG (-)
Positioning being performed (Y000)
Completes the JOG(-) operation.
M105
JOG(-) operation is being performed.
RST M12
Resets "forward rotation positioning completion" flag.
RST M13
Resets "forward rotation positioning completion" flag.
M105
JOG(-) operation is being performed.
X030
Stop command
FNC 152 DTBL
Y000
K2
Pulse output destination number
Table number
Executes No. 2 of the positioning table of Y000 (pulse output destination).
X023
JOG(-)
M8329
Abnormal end
M106
Completes the JOG(-) operation.
Positioning in forward rotation direction
X024
M8348
M10
M108
M109
Positioning in forward rotation direction
Positioning operation being performed (Y000)
"Zero return completion" flag
Normal end of positioning in forward rotation direction
Abnormal end of positioning in forward rotation direction
M107
Positioning operation being performed in forward rotation direction
RST M12
"Forward rotation positioning completion" flag
RST M13
"Reverse rotation positioning completion" flag
M107
Positioning operation being performed in forward rotation direction
X030
Stop command
FNC 152 DTBL
Y000
K3
Pulse output destination number
Table number
Executes No. 3 of the positioning table of Y000 (pulse output destination).
M8029
"Execution completion" flag
SET M12
"Forward rotation positioning completion" flag
M108
"Forward rotation positioning normal end" flag
M8329
Abnormal end
M109
"Forward rotation positioning abnormal end" flag
Positioning in reverse rotation direction
X025
M8348
M10
M111
M112
Positioning in reverse rotation direction
Positioning operation being performed (Y000)
"Zero return completion" flag
Normal end of positioning in reverse rotation direction
Abnormal end of positioning in reverse rotation direction
M110
Positioning operation being performed in reverse rotation direction
RST M12
"Forward rotation positioning completion" flag
RST M13
"Reverse rotation positioning completion" flag
M110
Positioning operation being performed in reverse rotation direction
X030
Stop command
FNC 152 DTBL
Y000
K4
Pulse output destination number
Table number
Executes No. 4 of the positioning table of Y000 (pulse output destination).
M8029
"Execution completion" flag
SET M13
"Reverse rotation positioning completion" flag
M111
"Reverse rotation positioning normal end" flag
M8329
Abnormal end
M112
"Reverse rotation positioning abnormal end" flag
END

4.2 Inverter drive control

Inverters are essentially the opposite of electrical rectifiers since they are used to convert direct current (DC) into alternating current (AC). In factory automation, inverters (sometimes known as variable frequency drives) are used to efficiently control large current loads through voltage regulation to drive oversized fans, pumps or AC motors. Drive control with inverters can lead to great reductions in energy consumption for a factory.

With a Mitsubishi general-purpose inverter connected to an FX2N(C) or FX3U(C) PLC, a motor can be controlled to move at a specific speed. Through monitoring feedback or by using limit switches, a basic positioning functionality is achieved. However, as described in Chapter 1, Section 1.3, the disadvantage to using an inverter to move a workpiece to a specific location is a loss in the stop precision. Therefore, inverters should not be thought of as positioning controllers.

Important references for understanding inverter drive control for this section include:

- FX Series User's Manual - Data Communication Edition – (JY997D16901)
- F700 Inverter Instruction Manual (Applied) – (IB(NA)-0600177ENG)

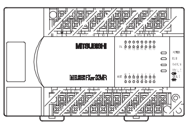
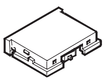
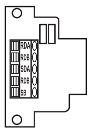
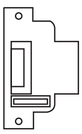
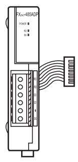
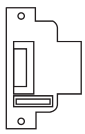
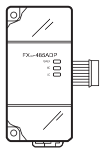
It is assumed that you will have read and understood the above manuals or that you will have them close at hand for reference.

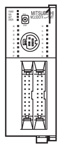
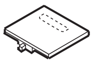
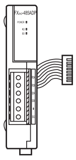
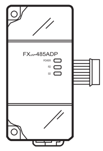
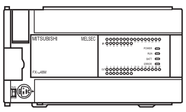
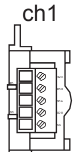
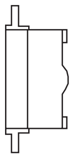
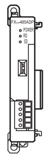
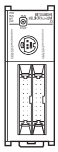
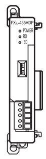
4.2.1 Overview of control

Programmable logic controllers and inverters communicate with each other through passing parameter data and control operation data back and forth. Inverters, when used for variable frequency drive, require a frequency command and a start command to operate.
Mitsubishi's FREQROL Series inverters communicate with FX2N(C) and FX3U(C) PLCs via the Mitsubishi inverter computer link protocol to asynchronously control operations.

4.2.2 Using the FX2N(C), FX3U(C) and FREQROL Inverter

In order to enable RS485 serial communication to a MELCO inverter(s), a special BD board or adapter (ADP) is connected to the main unit FX2N(C) or FX3U(C). The following table describes connection options for using one channel of communication.

FX Series	Communication equipment (option)	Total extension distance
 FX2N +  FX2N-ROM-E1 (Function extension memory cassette)	 FX2N-485-BD (Terminal board)	50 m
	( FX2N-CNV-BD +  FX2NC-485ADP (Terminal block)) or ( FX2N-CNV-BD +  FX0N-485ADP (Terminal block))	500 m

FX Series	Communication equipment (option)	Total extension distance
 FX2NC +  FX2NC-ROM-CE1 (Function extension memory board)	 FX2NC-485ADP (Terminal block) or  FX0N-485ADP (Terminal block)	500 m
 FX3U	ch1  FX3U-485-BD (Terminal block)	50 m
	 FX3U-CNV-BD + ch1  FX3U-485ADP(-MB) (Terminal block)	500 m
 FX3UC	ch1  FX3U-485ADP(-MB) (Terminal block)	500 m

To use the special inverter communication instructions from the PLC, inverter and PLC communication parameters must be set. The FX2N(C) and FX3U(C) PLCs include the following special instructions to communicate with an inverter(s).

FX2N(C)		FX3U(C)	Function/Description
EXTR	K10	IVCK	Monitors operations of an inverter.
	K11	IVDR	Controls operations of an inverter.
	K12	IVRD	Reads a parameter from an inverter.
	K13	IVWR	Writes a parameter to an inverter.
		IVBWR*1	Writes a block of parameters to an inverter.

*1. This instruction is only available for FX3U(C) PLCs.

The programmable controller special auxiliary relays and inverter instruction codes listed in the table below are used in Section 4.2.3. For information on memory addresses that contain error codes and inverter communication operation statuses, refer to the FX Series User's Manual - Data Communication Edition (JY997D16901).

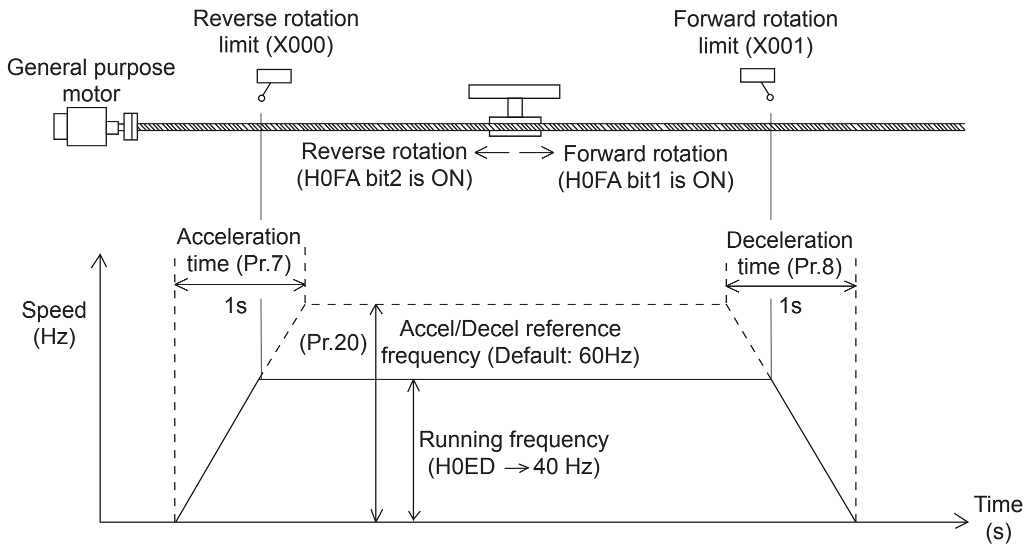
Function name	Address	Length	Description	Applicable PLC
RUN monitor	M8000	1-bit	ON when PLC is in RUN.	FX2N(C), FX3U(C)
Initial pulse	M8002	1-bit	ON for the first scan only.	FX2N(C), FX3U(C)
Instruction execution complete flag	M8029	1-bit	Programmed immediately after an inverter communication instruction. Turns ON when the preceding instruction finishes its operation and stays ON until the instruction stops being driven.	FX2N(C), FX3U(C)

Function name	Instruction Code	No. of Data Digits	Description	Applicable Inverter
Inverter reset	H0FD	4-digits	Resets the inverter and does not request a response. Inverter reset takes about 2.2 seconds to complete.	*2
Operation mode	H0FB	4-digits	Sets the communication operation for the inverter.	*2
Running frequency write	H0ED	4-digits	Changes the drive frequency by writing directly to the inverter RAM.	*2
Run command	H0FA	2-digits	Sets forward rotation (STF) or reverse rotation (STR).	*2
Inverter status monitor	H07A	2-digits	Monitors operation bits of the inverter.	*2
Output frequency [speed]	H06F	4-digits	Monitors the frequency of the inverter.	*2

*2. Applicable for all Mitsubishi FREQROL inverters.

4.2.3 Program example

The following programming example is a hybrid program for FX2N(C) and FX3U(C) controllers to be used with an E500 Series inverter. The travel path and operation pattern are shown below. In the program below, the section "Controlling the inverter to move in the forward or reverse rotation direction" drives the inverter in the forward or reverse direction. When the forward rotation limit (X001) or reverse rotation limit (X000) is reached, the operation stops. For details on connecting the hardware for testing, refer to the appropriate product manual.



Before programming, there are several parameter settings that must be set to the inverter and PLC.

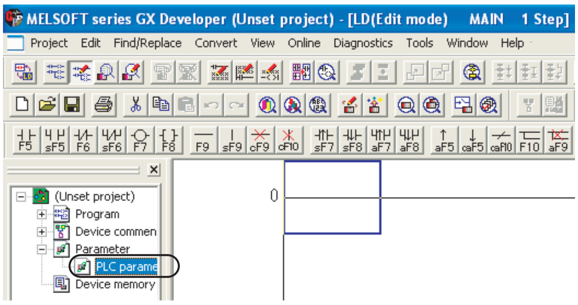
1. Setting communication parameters for the E500 Series inverter

While all operations are stopped (i.e. - the RUN indicator on the E500 is OFF), use the MODE key [MODE], UP/DOWN keys [▲] [▼] and the SET key [SET] to change and/or confirm the following parameters:

Parameter No.	Parameter item	Set value	Setting contents
Pr.79	Operation mode selection	0	External operation mode is selected when power is turned ON.
Pr.117	Communication station number	00 to 31	Up to eight inverters can be connected.
Pr.118	Communication speed	96	9600 bps (default)
Pr.119	Stop bit / Data length	10	Data length: 7-bit Stop bit: 1-bit
Pr.120	Parity check presence/absence selection	2	Even parity present
Pr.122	Communication check time interval	9999	Communication check suspension
Pr.123	Waiting time setting	9999	Set with communication data
Pr.124	CRLF presence/absence selection	1	With CR, without LF

2. Setting communication parameters for the FX2N(C)/FX3U(C) PLC

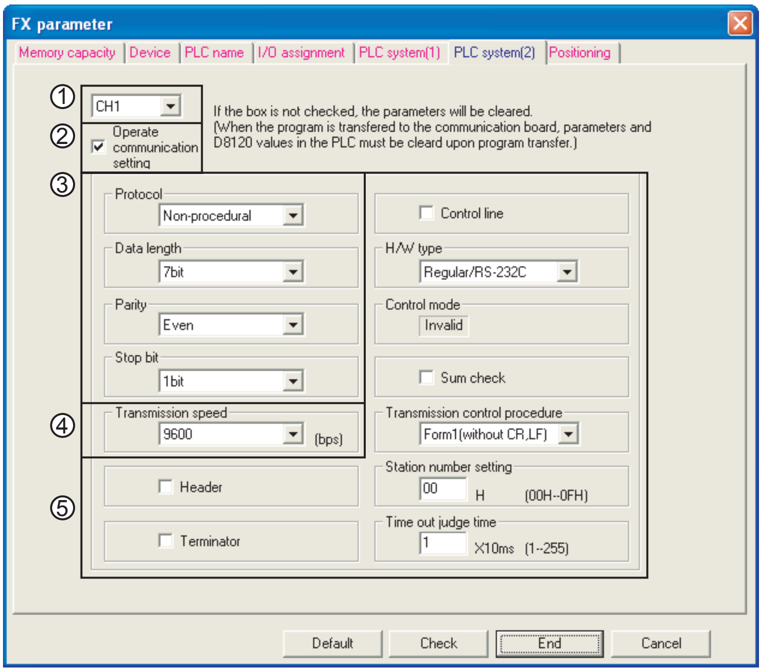
Parameters are set in GX Developer as shown below.



a) Double-click [Parameter] and then [PLC parameter] from the project tree on the left side of the screen.

If the project tree is not displayed on the screen, click [View] on the menu bar, and then click [Project Data List].

b) Click on the [PLC system(2)] tab in the “FX parameter” window and set the parameters as shown below:



① Set CH1 as the channel to be used.

② Put a checkmark in the [Operate communication setting] checkbox to activate the communication settings.

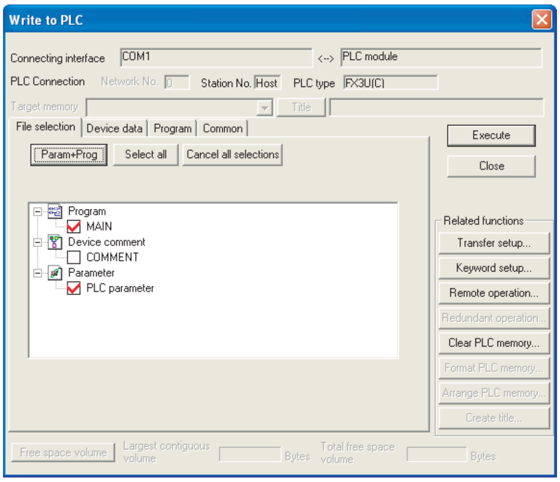
③ Set [Protocol] to "Non-procedural", [Data length] to "7bit", [Parity] to "Even", and [Stop bit] to "1bit".

④ Set [Transmission speed] to "9600" to match the speed setting in the inverter.

⑤ Ignore these items.

c) Click the [End] button.

d) Create the ladder program as shown below.



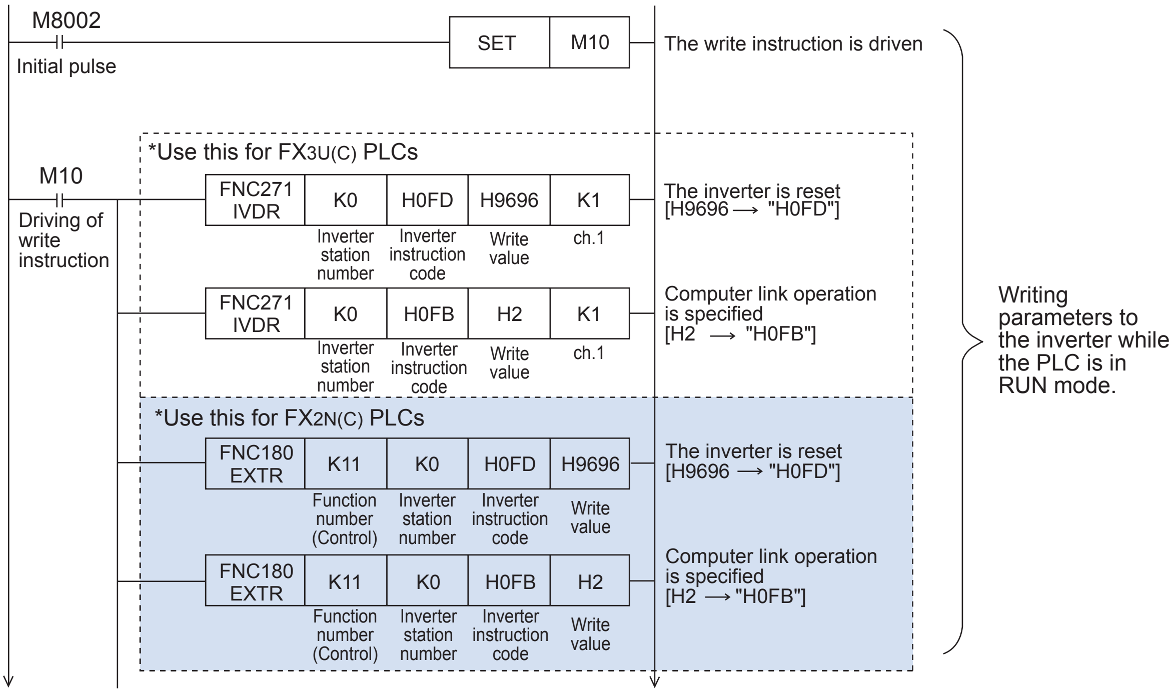
e) Once the ladder program is complete, click on [Online] from the top menu bar in GX Developer and select [Write to PLC]. The "Write to PLC" window will appear.

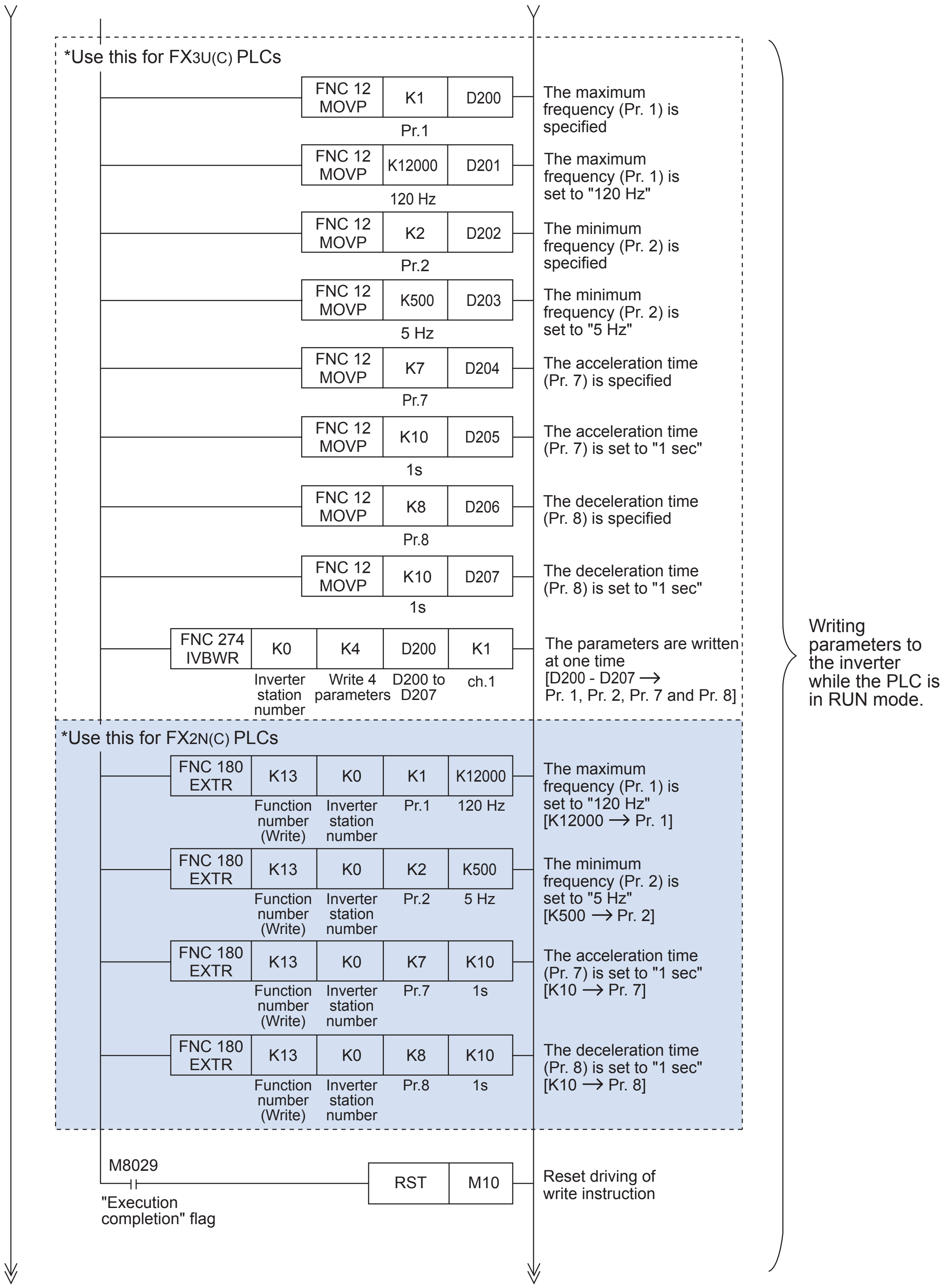
f) Click the [Param+Prog] button and then click the [Execute] button. The parameters and the created program will be transferred to the PLC. To enable the transferred parameters, stop the PLC and then restart it.

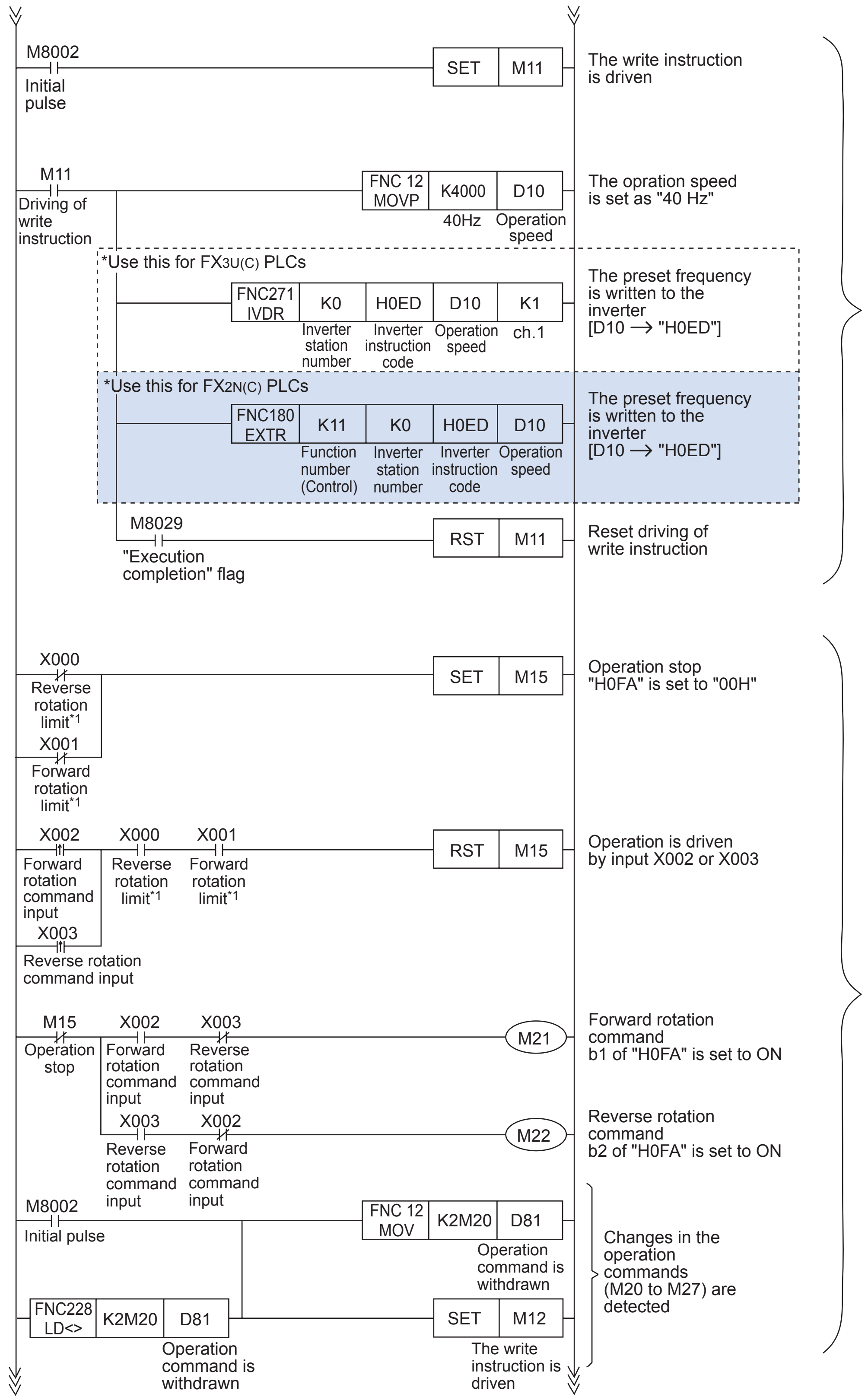
The following inputs and outputs are used:

Inputs	
X000	Reverse rotation limit
X001	Forward rotation limit
X002	Forward rotation command input
X003	Reverse rotation command input

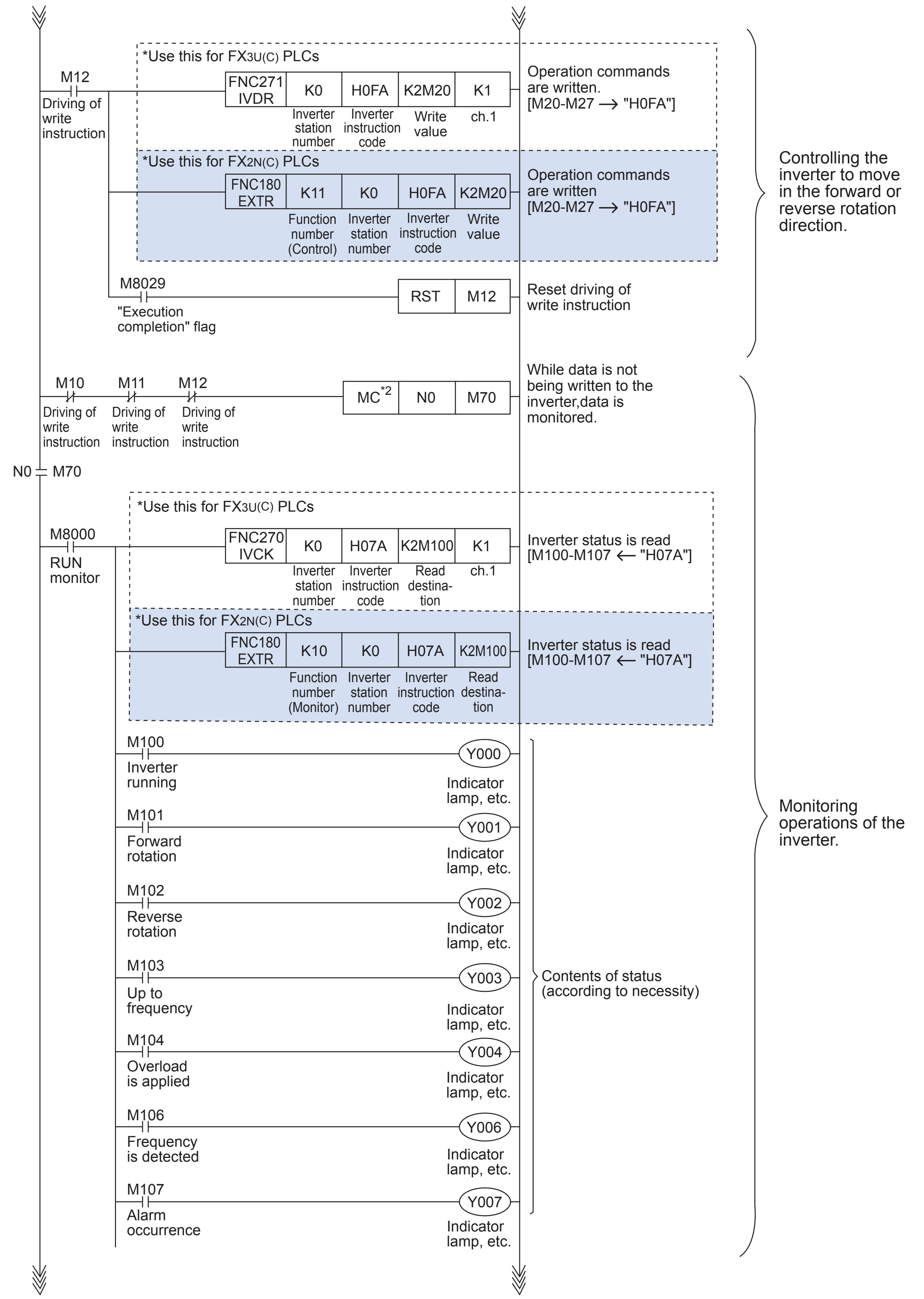
Outputs	
Y000	Inverter running (RUN)
Y001	Forward rotation
Y002	Reverse rotation
Y003	Up to frequency (SU)
Y004	Overload is applied (OL)
Y006	Frequency detection (FU)
Y007	Alarm occurrence



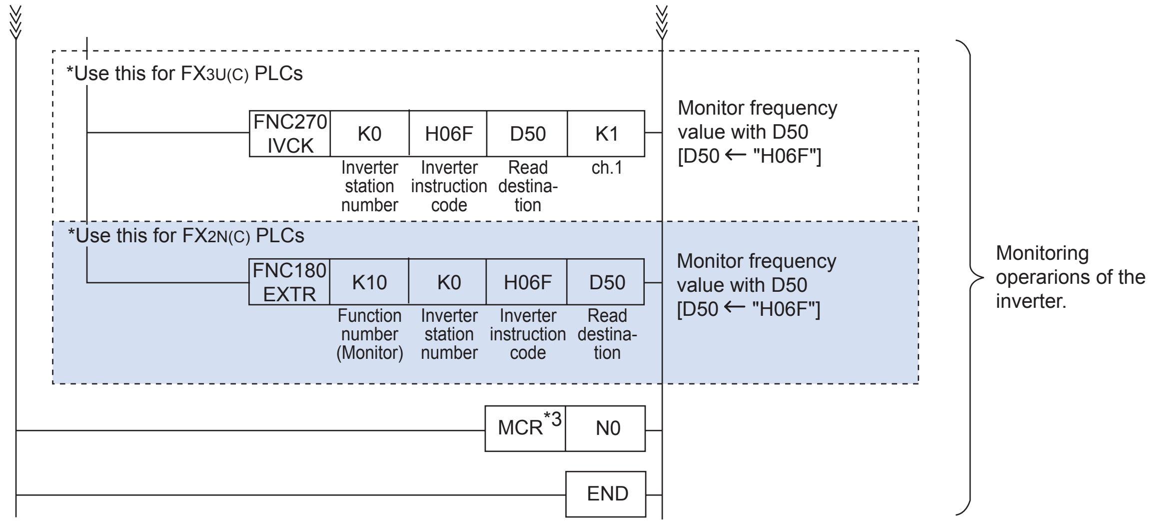

*Use this for FX3U(C) PLCs
FNC 12 MOVP
K1
D200
Pr.1
The maximum frequency (Pr. 1) is specified
FNC 12 MOVP
K12000
D201
120 Hz
The maximum frequency (Pr. 1) is set to "120 Hz"
FNC 12 MOVP
K2
D202
Pr.2
The minimum frequency (Pr. 2) is specified
FNC 12 MOVP
K500
D203
5 Hz
The minimum frequency (Pr. 2) is set to "5 Hz"
FNC 12 MOVP
K7
D204
Pr.7
The acceleration time (Pr. 7) is specified
FNC 12 MOVP
K10
D205
1s
The acceleration time (Pr. 7) is set to "1 sec"
FNC 12 MOVP
K8
D206
Pr.8
The deceleration time (Pr. 8) is specified
FNC 12 MOVP
K10
D207
1s
The deceleration time (Pr. 8) is set to "1 sec"
FNC 274 IVBWR
K0
K4
D200
K1
Inverter station number
Write 4 parameters
D200 to D207
ch.1
The parameters are written at one time
[D200 - D207 → Pr. 1, Pr. 2, Pr. 7 and Pr. 8]
*Use this for FX2N(C) PLCs
FNC 180 EXTR
K13
K0
K1
K12000
Function number (Write)
Inverter station number
Pr.1
120 Hz
The maximum frequency (Pr. 1) is set to "120 Hz"
[K12000 → Pr. 1]
FNC 180 EXTR
K13
K0
K2
K500
Function number (Write)
Inverter station number
Pr.2
5 Hz
The minimum frequency (Pr. 2) is set to "5 Hz"
[K500 → Pr. 2]
FNC 180 EXTR
K13
K0
K7
K10
Function number (Write)
Inverter station number
Pr.7
1s
The acceleration time (Pr. 7) is set to "1 sec"
[K10 → Pr. 7]
FNC 180 EXTR
K13
K0
K8
K10
Function number (Write)
Inverter station number
Pr.8
1s
The deceleration time (Pr. 8) is set to "1 sec"
[K10 → Pr. 8]
M8029
"Execution completion" flag
RST
M10
Reset driving of write instruction
Writing parameters to the inverter while the PLC is in RUN mode.



*1. The forward and reverse rotation limit switches must be wired so that they are turned ON by default. When either of these limit switches turns OFF (due to the workpiece going out-of-bounds), the inverter operation will be stopped.



*2. MC denotes the start of a master control block.
In this example, the master control block "N0" is only executed when data is not being written to the inverter.



*3. MCR denotes the end of a master control block.
In this example, the master control block "N0" is only executed when data is not being written to the inverter.

4.3 FX2N-1PG-E positioning

The FX2N(C) and FX3U(C) PLCs support connection with the FX2N-1PG-E special function block. Special function blocks are separate pieces of hardware that can be connected to PLCs to enhance control. Since special function blocks process information separately from the PLC, the scan time of the PLC is not adversely affected during operations controlled by special function blocks. This provides an advantage for programming. Additionally, special function blocks such as the FX2N-1PG-E offer separate, more advanced control through the use of their own inputs and outputs.
An important reference for understanding positioning with the FX2N-1PG-E is:

- FX2N-1PG/FX-1PG User's Manual – (JY992D65301)

It is assumed that you will have read the above manual or that you will have it nearby for reference.

4.3.1 Overview of control

The FX2N-1PG-E is a popular unit for performing general point-to-point positioning operations on 1 axis up to 100,000 pulses/second (100 kHz). A stepper motor or servo motor can be used with the FX2N-1PG-E to perform positioning operations.
Some of the main advantages to using the FX2N-1PG-E for positioning as opposed to the FX1S, FX1N or FX3U(C) include: the flexible use of the zero point signal PG0, two speed positioning operations with or without interrupt, and the option to choose the FP/RP pulse output method.

4.3.2 Important buffer memory locations

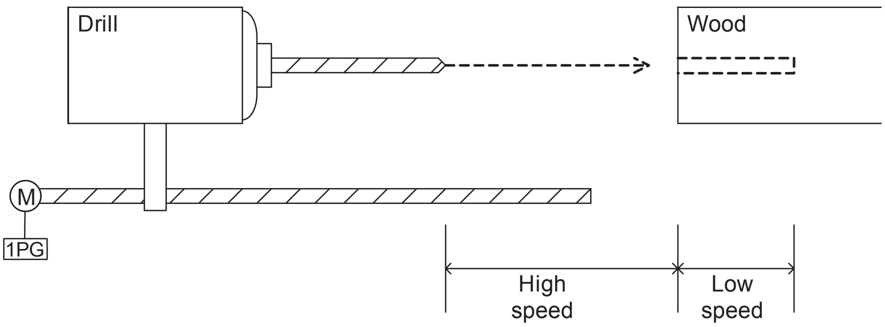
The FX2N-1PG-E contains 32 buffer memory (BFM) addresses, which are 16-bit (1 word) areas of memory that contain information relevant to the control of positioning operations. The FX2N(C) or FX3U(C) PLC that is connected to the FX2N-1PG-E can send and receive data to the buffer memory addresses to change and/or update information. This exchange of information takes place through dedicated PLC instructions known as the FROM/TO instructions. (For FX3U(C) PLCs, the MOV instruction can also be used to transfer data to/from special function blocks.)
The following buffer memory addresses are used in the ladder program example below. For details on other BFM addresses, refer to the FX-1PG/FX2N-1PG User's Manual (JY992D65301).

BFM #	Item		Set value	Note
#0	Pulse rate		4,000	PLS/rev
#2, #1	Feed rate		1,000	μm/rev
#3	Parameters			
	b1, b0	System of units	b1:1, b0:0	Combined system
	b5, b4	Multiplication factor*1	b5:1, b4:1	10^3
#5, #4	Maximum speed		40,000	Hz
#6	Bias speed		0	Hz
#15	Acceleration/ Deceleration time		100	ms
#18, #17	Target address 1		100	mm
#20, #19	Operating speed 1		40,000	Hz
#22, #21	Target address 2		150	mm
#24, #23	Operating speed 2		10,000	Hz
#25	Operation command			
	b0	Error reset	M0	X000
	b1	STOP command	M1	X001
	b2	Forward rotation limit	M2	X002
	b3	Reverse rotation limit	M3	X003
	b7	Relative/Absolute positioning	M7 (b7=0)	Absolute positioning
	b10	Two speed positioning START command	M10	X007
#27, #26	Current address		D11, D10	mm
#28	Status information		M20 – M31	
#29	Error code		D20	

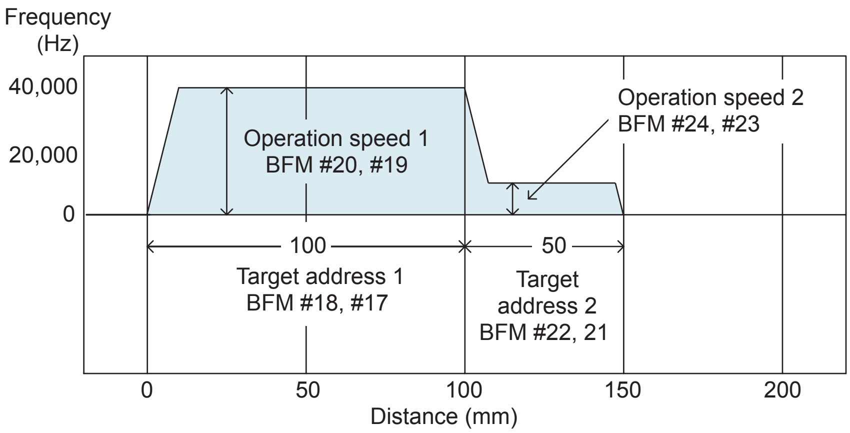
*1. Using a multiplication factor of 10^3 changes the units from μm to mm.

4.3.3 Program example

In the example that follows, a two speed positioning instruction is used to move a drill 100 mm toward a block of wood with a high speed pulse frequency of 40 kHz. When the drill reaches the wood, the speed decreases to 10 kHz. The drill is then driven for 50 mm into the wood before decelerating to stop.



The two speed positioning operation is illustrated in the following graph. Neither the zero point return nor the JOG instructions are used in the ladder program.

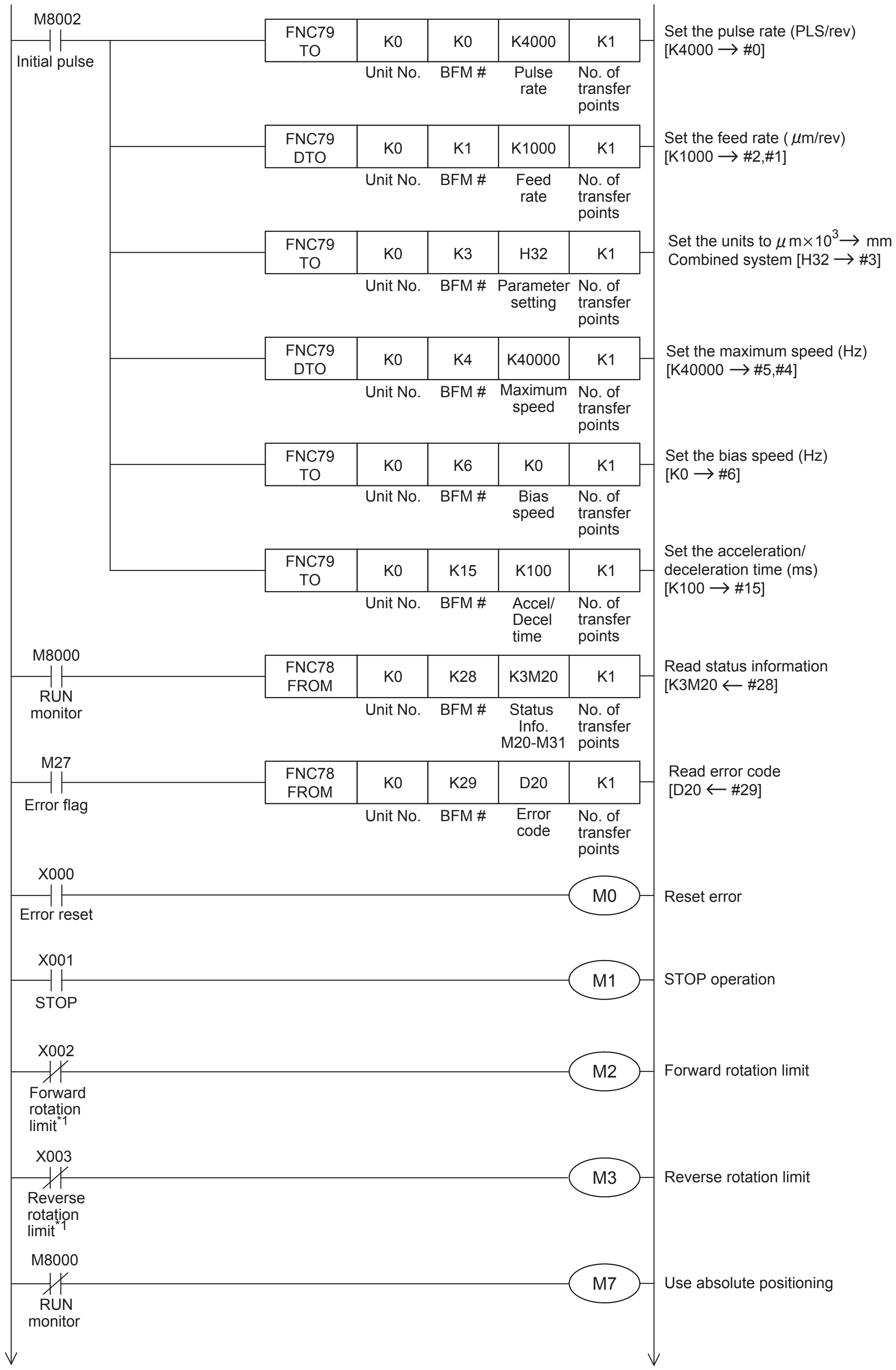


Although the following ladder program is not very complicated, it is important to establish good programming practice by paying attention to the order with which the PLC writes and reads to the buffer memory of the FX2N-1PG-E. Before writing the Operation command (START command) to the module's BFM from the PLC, several settings must be established such as Target addresses 1 & 2, Operation speeds 1 & 2, and various settings such as the bias speed, maximum speed, and the acceleration/deceleration time.

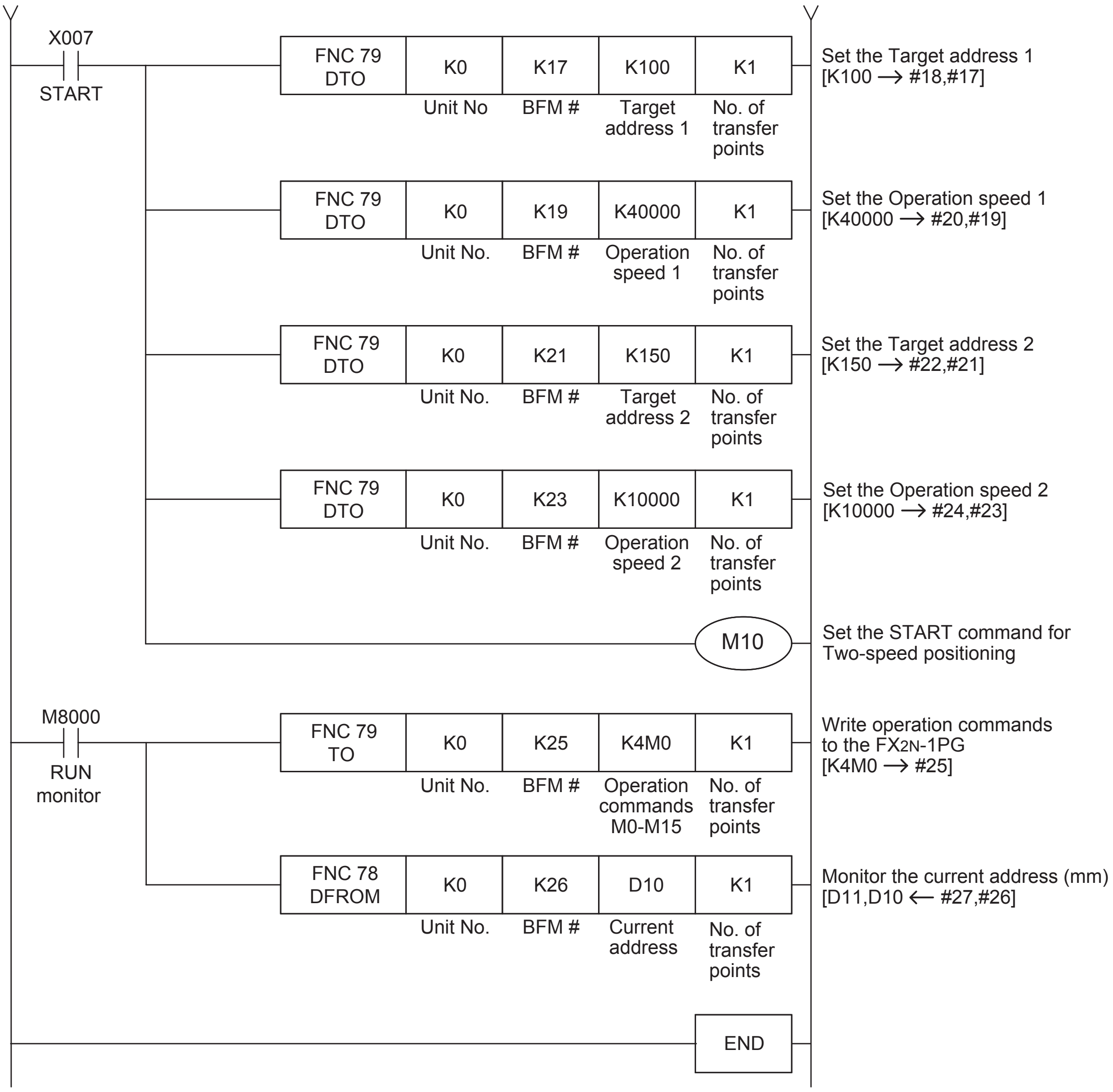
The most critical part of the program is the section where the operation commands are enabled by writing bits M0 to M15 to BFM#25. When the positioning START command turns ON, the operation begins with the specified settings.

The ladder program example on the following page can be programmed with an FX2N(C) or FX3U(C) PLC and does not require an actuator (i.e., servo system) for testing. The following inputs are used in the program:

Inputs	
X000	Error reset
X001	STOP command
X002	Forward rotation limit
X003	Reverse rotation limit
X007	2-speed positioning START command



*1. The forward and reverse rotation limit switches must be wired so that they are turned ON by default. When these limit switches turn OFF(due the workpiece going out-of-bounds), M2 or M3 will turn ON and cause the pulse operation to stop.


X007
START
FNC 79 DTO | K0 | K17 | K100 | K1
Unit No | BFM # | Target address 1 | No. of transfer points
Set the Target address 1 [K100 → #18,#17]
FNC 79 DTO | K0 | K19 | K40000 | K1
Unit No. | BFM # | Operation speed 1 | No. of transfer points
Set the Operation speed 1 [K40000 → #20,#19]
FNC 79 DTO | K0 | K21 | K150 | K1
Unit No. | BFM # | Target address 2 | No. of transfer points
Set the Target address 2 [K150 → #22,#21]
FNC 79 DTO | K0 | K23 | K10000 | K1
Unit No. | BFM # | Operation speed 2 | No. of transfer points
Set the Operation speed 2 [K10000 → #24,#23]
M10
Set the START command for Two-speed positioning
M8000
RUN monitor
FNC 79 TO | K0 | K25 | K4M0 | K1
Unit No. | BFM # | Operation commands M0-M15 | No. of transfer points
Write operation commands to the FX2N-1PG [K4M0 → #25]
FNC 78 DFROM | K0 | K26 | D10 | K1
Unit No. | BFM # | Current address | No. of transfer points
Monitor the current address (mm) [D11,D10 ← #27,#26]
END

4.4 FX2N-10PG positioning

The FX2N(C) and FX3U(C) PLCs support connection with the FX2N-10PG special function block. As described in Section 4.3, special function blocks are separate pieces of hardware that can be connected to a PLC to enhance control. Due to the separate processing sequence that takes place in special function blocks through the use of buffer memory data, special function blocks provide a distinct advantage to PLC programming through individualized control that expands and improves PLC operations. Additionally, special function blocks such as the FX2N-10PG include extra input points and output points.

An important reference for understanding positioning with the FX2N-10PG is:

- FX2N-10PG User's Manual – (JY992D93401)

It is assumed that you will have read the above manual or that you will have it nearby for reference.

4.4.1 Overview of control

The FX2N-10PG is used to perform point-to-point positioning operations on 1 axis up to 1,000,000 pulses/second (1 MHz). With the FX2N-10PG differential line driver type outputs that provide improved stability and better noise immunity, a stepper motor or servo motor can be controlled to perform a variety of positioning operations including multi-speed positioning and interrupt stop positioning. The controller also supports the connection of a manual pulse generator dial to control individual pulses from a position dial. Another advantage to using the FX2N-10PG is the ability to use a defined set of positioning operations in table format with up to 200 predefined table operations.

4.4.2 Important buffer memory locations

The FX2N-10PG contains 1,300 buffer memory (BFM) addresses, which are 16-bit (1 word) areas of memory that contain information relevant to the control of positioning operations. Most of these addresses are reserved for data to be used in table operations. The FX2N(C) or FX3U(C) PLC that is connected to the FX2N-10PG can send and receive data to the buffer memory addresses to change and/or update information. This exchange of information takes place through dedicated PLC instructions known as the FROM/TO instructions. (For FX3U(C) PLCs, the MOV instruction can also be used to transfer data to/from special function blocks.)

The following buffer memory addresses are used in the ladder program example below. For details on other BFM addresses, refer to the FX2N-10PG User's Manual (JY992D93401).

BFM #	Item		Set value	Note
#1, #0	Maximum speed		50,000	Hz
#2	Bias speed		0	Hz
#11	Acceleration time		100	ms
#12	Deceleration time		100	ms
#14, #13	Target address 1		50	mm
#16, #15	Operation speed 1		50,000	Hz
#25, #24	Current address		D11, D10	mm
#26	Operation command			
	b0	Error reset	M0	X000
	b1	STOP	M1	X001
	b2	Forward rotation limit	M2	X002
	b3	Reverse rotation limit	M3	X003
	b8	Relative/Absolute positioning	M8 (b8 =1)	Relative positioning
	b9	START command	M9	X007
#27	Operation pattern			
	b0	1-speed positioning operation		
#28	Status information		M20 – M31	
#33, #32	Pulse rate		4,000	PLS/rev
#35, #34	Feed rate		1,000	μm/rev

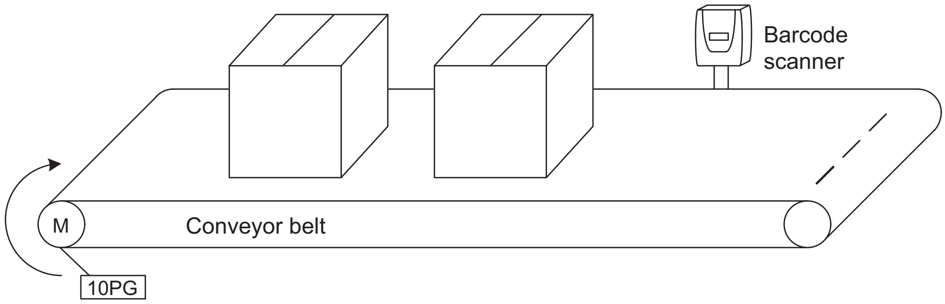
BFM #	Item		Set value	Note
#36	Parameters			
	b1, b0	System of units	b1:1, b0:0	Combined system
	b5, b4	Multiplication factor*1	b5:1, b4:1	10^3
#37	Error code		D20	

*1. Using a multiplication factor of 10^3 changes the units from μm to mm.

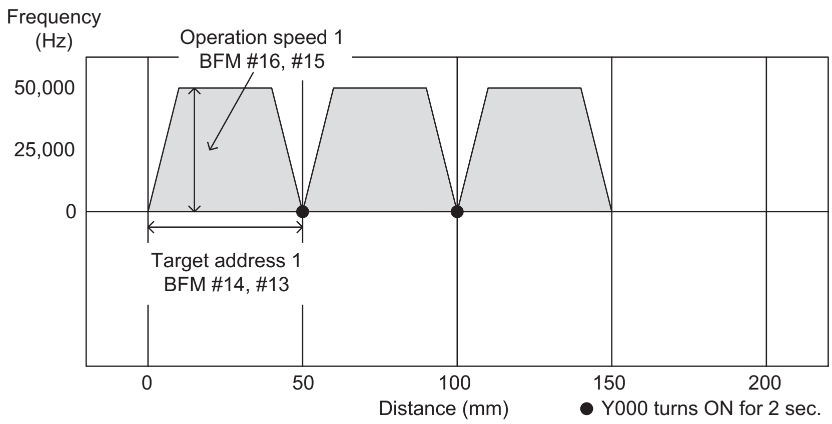
4.4.3 Program example

In the program example that follows, a series of three individual 1-speed positioning operations are controlled from the FX2N-10PG with an output signal from the PLC that turns ON between each operation. An event timing chart is included on the next page to help understand the logic flow of the program.

This example uses a conveyor system to carry boxes from one location to another. Each intermittent positioning operation positions a box in front of a scanner to scan it for 2 seconds. During each 2-second scan, Y000 from the PLC turns ON to illuminate an indicator light. The number of boxes to be scanned can be varied by changing the value of the counter, C100, in the program.



The positioning pattern is shown in the following figure. Neither the zero point return nor the JOG instructions are used in the ladder program example.



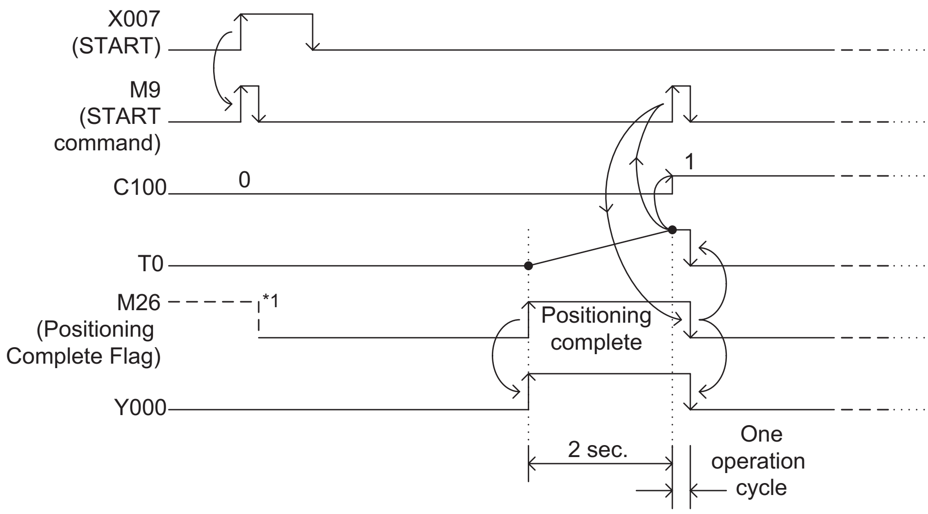
In order for the program to function correctly for the specified number of repetition cycles, the START command input (X007) must not be turned ON again during the positioning operation. If the START command is turned ON again, the counter C100 is reset, which clears the number of repetitions.

The following program can be used with an FX2N(C) or FX3U(C) PLC and does not require an actuator (i.e., servo system) for testing. The input and output points include:

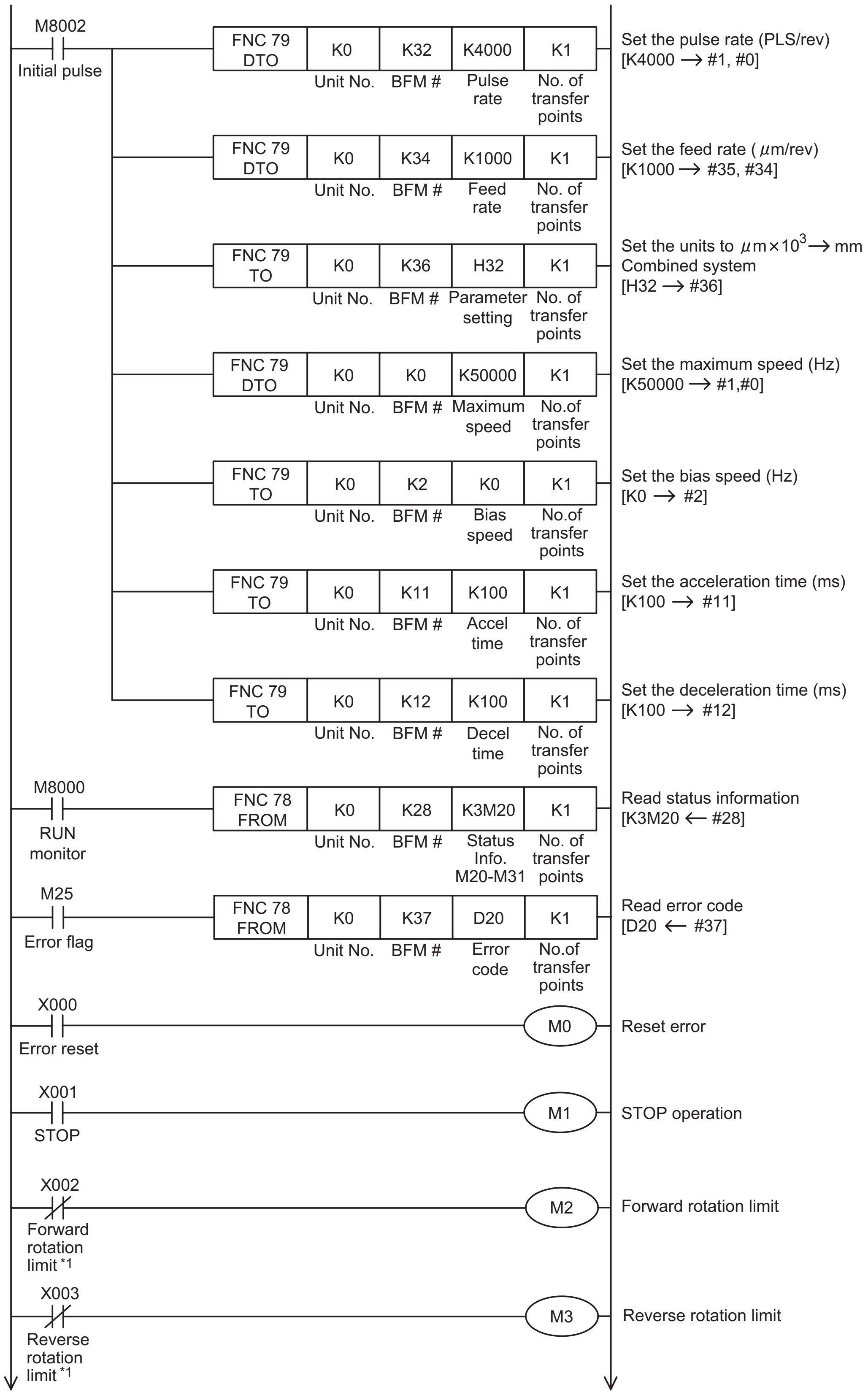
Inputs	
X000	Error reset
X001	STOP command
X002	Forward rotation limit
X003	Reverse rotation limit
X007	START command

Outputs	
Y000	Indicator lamp (ON for 2 sec. intervals)

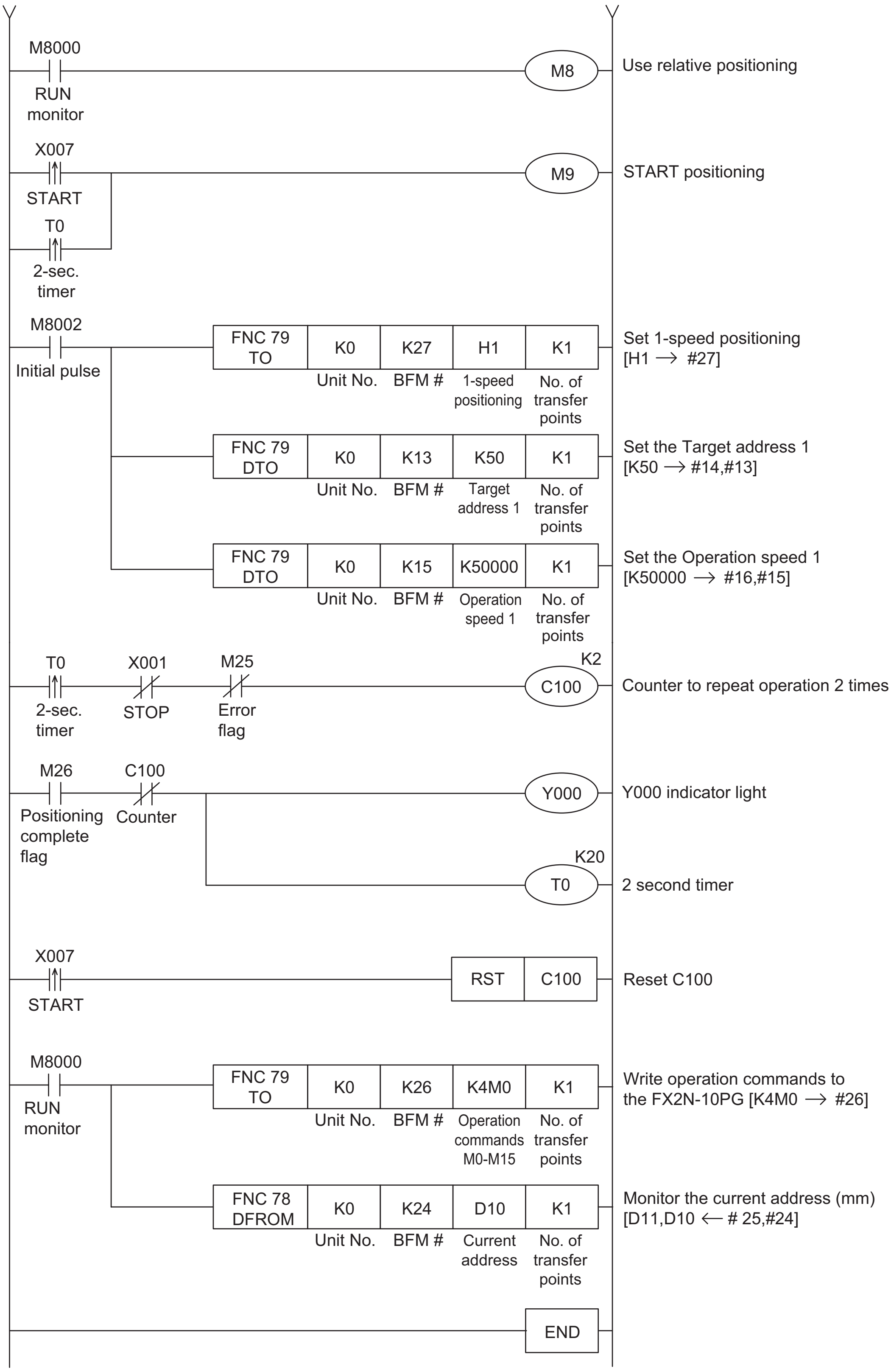
The following figure is an event timing chart for part of the operation in the program below.



*1. The positioning complete flag will only be ON at the very beginning of the program when it is not the first time to operate the equipment and the power has not been recycled.



*1. The forward and reverse rotation limit switches must be wired so that they are turned ON by default. When these limit swiches turn OFF (due to the workpiece going out-of-bounds), M2 or M3 will turn ON and cause the pulse operation to stop.


M8000
RUN monitor
M8
Use relative positioning
X007
START
T0
2-sec. timer
M9
START positioning
M8002
Initial pulse
FNC 79 TO
K0
K27
H1
K1
Unit No.
BFM #
1-speed positioning
No. of transfer points
Set 1-speed positioning [H1 → #27]
FNC 79 DTO
K0
K13
K50
K1
Unit No.
BFM #
Target address 1
No. of transfer points
Set the Target address 1 [K50 → #14,#13]
FNC 79 DTO
K0
K15
K50000
K1
Unit No.
BFM #
Operation speed 1
No. of transfer points
Set the Operation speed 1 [K50000 → #16,#15]
T0
2-sec. timer
X001
STOP
M25
Error flag
K2
C100
Counter to repeat operation 2 times
M26
Positioning complete flag
C100
Counter
Y000
Y000 indicator light
K20
T0
2 second timer
X007
START
RST
C100
Reset C100
M8000
RUN monitor
FNC 79 TO
K0
K26
K4M0
K1
Unit No.
BFM #
Operation commands M0-M15
No. of transfer points
Write operation commands to the FX2N-10PG [K4M0 → #26]
FNC 78 DFROM
K0
K24
D10
K1
Unit No.
BFM #
Current address
No. of transfer points
Monitor the current address (mm) [D11,D10 ← # 25,#24]
END

4.5 FX2N-10GM and FX2N-20GM positioning

The FX2N-10GM and FX2N-20GM controllers (also referred to as the 10GM and 20GM) are unique in that they can operate as individual stand-alone units with their own programming language, power supplies and separate sets of inputs and outputs. This means that the 10GM and 20GM can be used with or without a PLC to control logic instructions and standard positioning operations.

Important references for understanding positioning with the FX2N-10GM and FX2N-20GM are:

- FX2N-10GM/FX2N-20GM Hardware/Programming Manual – (JY992D77801)
- FX-PCS-VPS/WIN-E Software Manual – (JY992D86801)

It is assumed that you will have read and understood the above manuals or that you will have them nearby for reference.

4.5.1 Overview of control

Along with the capability to be used for independent control, the FX2N-10GM (1 axis of control) and FX2N-20GM (2 axes of control) can be used as special function blocks in conjunction with an FX2N(C) or FX3U(C) PLC to transfer data back and forth via dedicated buffer memory addresses. These addresses overlap with and replace the special M and special D registers in the 10GM and 20GM. One particular advantage to using a PLC with the FX2N-10GM is the ability to use the table method where up to 100 positioning operations can be defined and saved for consecutive execution.

The FX2N-10GM and FX2N-20GM output pulse trains to control a stepper/servo motor with a maximum output frequency of 200,000 pulses/second (200 kHz). This offers the same speed as the FX3U high speed positioning adapters, except that the GM controllers use open collector type outputs instead of differential line driver type.

Combined with standard positioning operations such as 1-speed and 2-speed positioning, the 10GM and 20GM include an electrical zero return function to return the motor(s) to a specific user-defined address without the use of a hardware DOG switch. This feature is unique since it is not available with any of the other FX Series controllers.

The main differences between the FX2N-10GM and FX2N-20GM are listed in the following table.

	FX2N-10GM	FX2N-20GM
Inputs/Outputs	4 inputs, 6 outputs	8 inputs, 8 outputs
Expandable I/O	No	Yes (48 additional I/O)
Memory type	EEPROM	Built-in RAM (RAM has battery backup) (EEPROM cassette optional)
Memory size	3.8K steps	7.8K steps
Table method	Yes	No
Connectors	CON1: Control + I/O CON2: Axis1	CON1: I/O CON2: Control CON3: Axis1 CON4: Axis2

4.5.2 Using dedicated software to set positioning for the FX2N-20GM

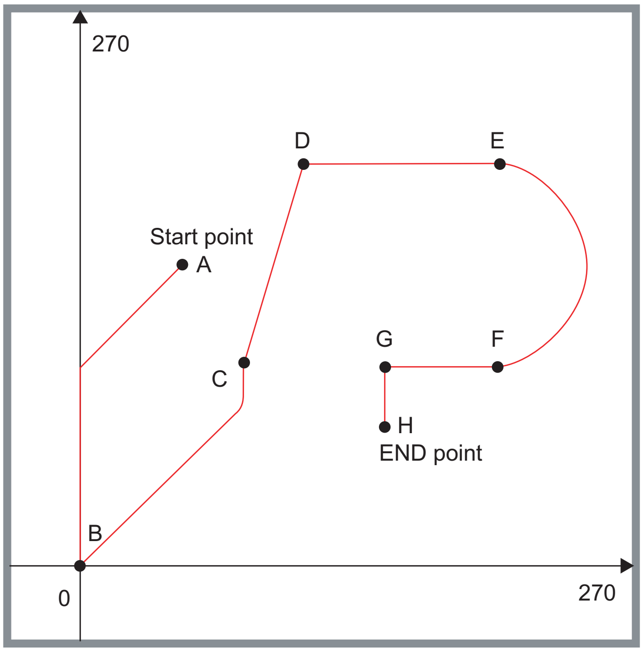
In the example that follows, an FX2N-20GM is used with the FX-PCS-VPS/WIN-E software to perform positioning on two axes. The FX-PCS-VPS/WIN-E software (also referred to as VPS) is beneficial for defining positioning parameters and setting positioning operations. Operations can be visually organized in a flow chart format and a monitoring window can be configured with user-defined objects.

To test operations with an FX2N-20GM, an actuator (i.e., servo system) and PLC are not required. For information on the cables necessary to connect an FX2N-20GM to a personal computer for programming, refer to the FX2N-10GM/FX2N-20GM Hardware/Programming Manual (JY992D77801).

1. Operation objective

The objective of this example is to use the FX2N-20GM to trace a path using 1-speed, linear interpolation, and circular interpolation operations.

Path of travel



Operation Details

Point	Coordinate	Description
A	(X, Y)	This point can be anywhere.
B	(0, 0)	Move to zero point, wait for 2 seconds
C	(80, 100)	Output Y0 turns ON, wait for 2 seconds
D	(110, 200)	–
E	(200, 200)	–
F	(200, 100)	–
G	(150, 100)	Output Y0 turns OFF, wait for 2 seconds
H	(150, 70)	End point

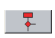
The output Y0 is used to imitate a pen, or other end effector.

Each point-to-point operation is described as follows:

(A to B) – Return to Electrical Zero
(B to C) – High speed positioning
(C to D) – Linear interpolation
(D to E) – High speed positioning
(E to F) – Clockwise circular interpolation
(F to G) – High speed positioning
(G to H) – High speed positioning

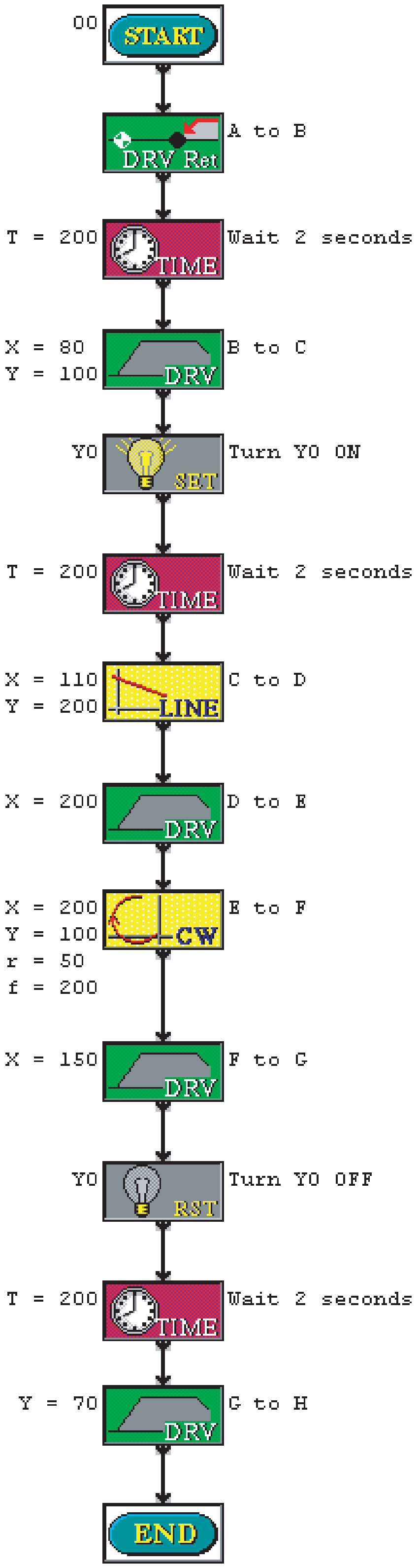
2. Getting started with FX-PCS-VPS/WIN-E

Open a new file with VPS and choose [FX(2N)/E-20GM with simultaneous 2 axis]. This setting allows for linear and circular interpolation operations to be placed on a flow chart for positioning.

Take a minute to familiarize yourself with the layout and menu items of the software. The panel on the left side of the screen is required for selecting the [Flow], [Code], and [Func] components to place into the Flow Chart window. To place an item into the Flow Chart window, click on the item once and then click anywhere within the Flow Chart window. Once an item has been placed in the Flow Chart window, it can be dragged to any position. Items are connected by using the wire tool  to drag a wire between each item.

3. Creating a Flow Chart

The flow chart below demonstrates basic positioning using the FX2N-20GM. Since this program is designed to be used without a mechanical plotter, an electrical zero point is used for reference.
Re-create the diagram below by using the [Code] and [Func] buttons on the left panel of the VPS software to select and place each function block.



Many programs can be stored in a GM controller at one time. This example uses program number 0.

The "DRV Ret" command is used to move from the start point to the electrical zero point.

Here, the program waits for 2 seconds, using a 10ms timer.

This command indicates a high speed positioning command to position C.

Here, Y0 is turned ON to mimic the use of an end effector tool.

This timer allows for a tool to be activated, or for an operation to be executed.

This command is the start of a continuous steady path using linear interpolation to position D.

Only the X-axis is used in this 1-speed positioning instruction to move to position E.

For a smooth arc to position F, circular interpolation is used. This example shows the start and end positions as well as the radius (r) and speed (f).

Only the X-axis is used in this 1-speed positioning instruction to move to position G.

Here, Y0 is turned OFF to mimic the end of use for an end effector.

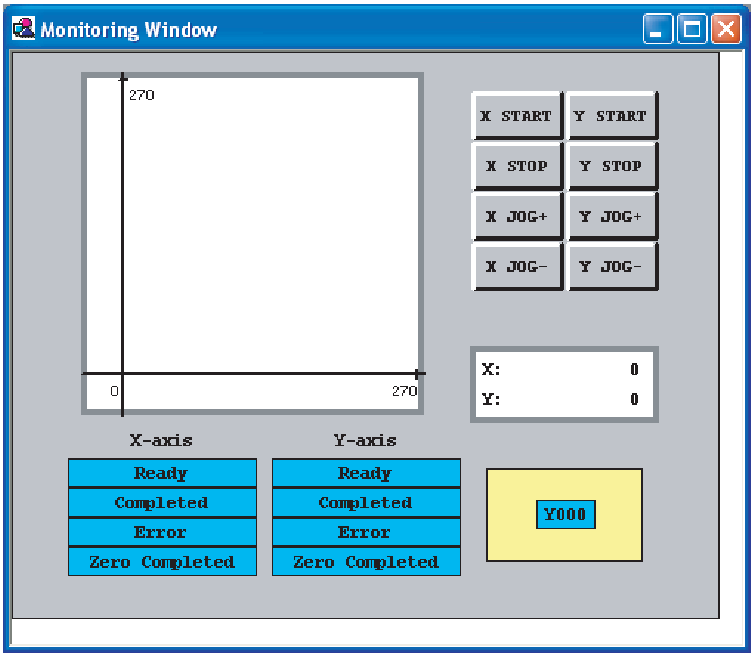
A timer is used to ensure the end effector operation has finished completely.

This command rapidly moves the Y-axis for a short distance so that it can reach position H.

This denotes the end of the program, where the controller waits for the next start command.

4. Creating a Monitor Window

Along with the flow chart, create a monitoring window similar to the one shown below.
All of the items on the monitoring window can be found using the [Insert] menu at the top of the screen.



The following items from the [Insert] menu are used:

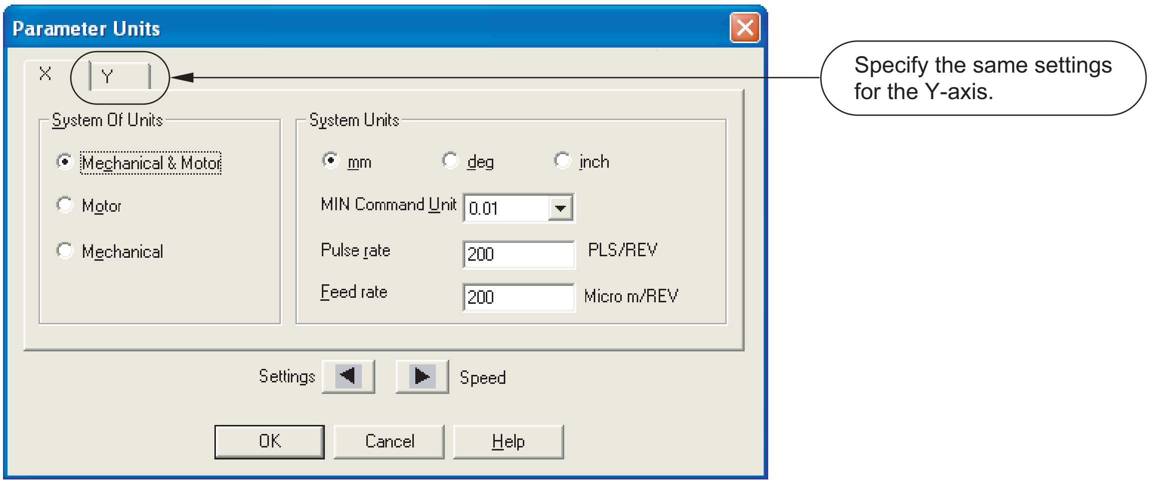
<table>
<tr><th>Item</th><th colspan="2">Description</th></tr>
<tr><td>Current Position</td><td colspan="2">This displays (monitors) the current address during positioning.</td></tr>
<tr><td>Plotting</td><td colspan="2">Double click on the plot area to change the scale.</td></tr>
<tr><td>Device Status</td><td colspan="2">Select Y0, 1 point.</td></tr>
<tr><td>Rectangle</td><td colspan="2">Create a rectangle around Y000 by selecting the rectangle button from the drawing toolbar at the top of the screen. While the rectangle is selected, the background color can be changed by pressing the [B] “Brush Color” button.</td></tr>
<tr><td rowspan="5">Manual Operation</td><td>X-axis</td><td>Y-axis</td></tr>
<tr><td>Start</td><td>Start</td></tr>
<tr><td>Stop</td><td>Stop</td></tr>
<tr><td>+ Jog</td><td>+ Jog</td></tr>
<tr><td>- Jog</td><td>- Jog</td></tr>
<tr><td>FX-GM Status</td><td colspan="2">This is a lamp that automatically monitors positioning operations.</td></tr>
</table>

5. Setting parameters

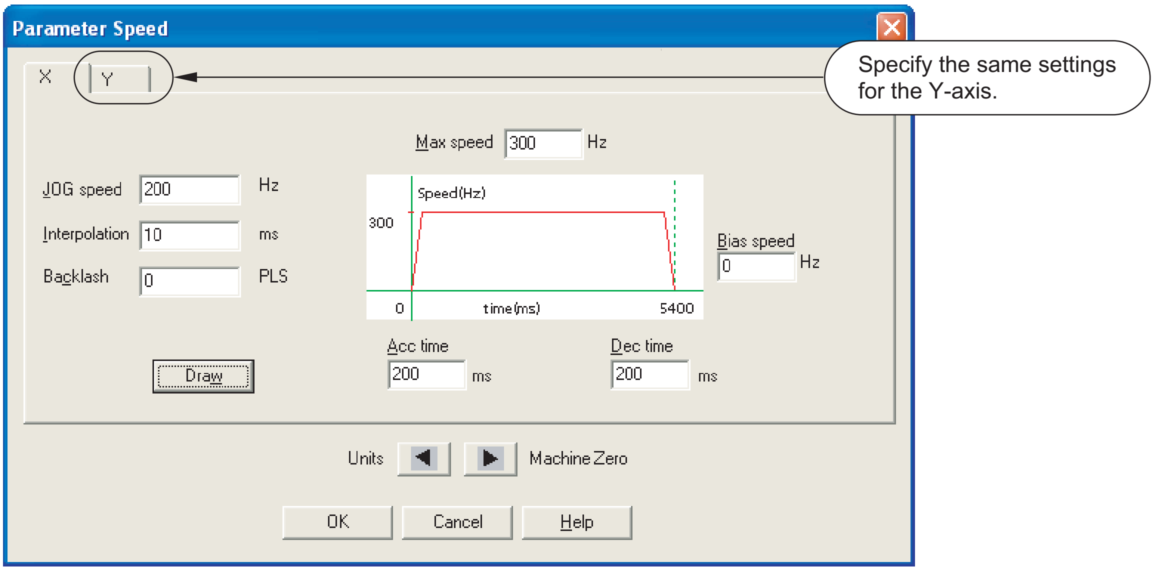
In addition to the preparation of a positioning program, diversified parameters should be set in the FX2N-20GM. In this example, only a few parameters need to be set. (When working with various equipment such as a mechanical plotter that uses an X-Y plotting table, the parameters should be set in accordance with the mechanism being used. These settings depend on the specific plotter type and should be located in the documentation provided with the plotter.)

Below are the four positioning parameter windows from VPS. The settings on these windows should be copied for BOTH the X- and Y- axes before performing positioning.

First, open the “Parameter Units” window by selecting [Parameters] → [Positioning] → [Units] from the main menu bar at the top of the screen.

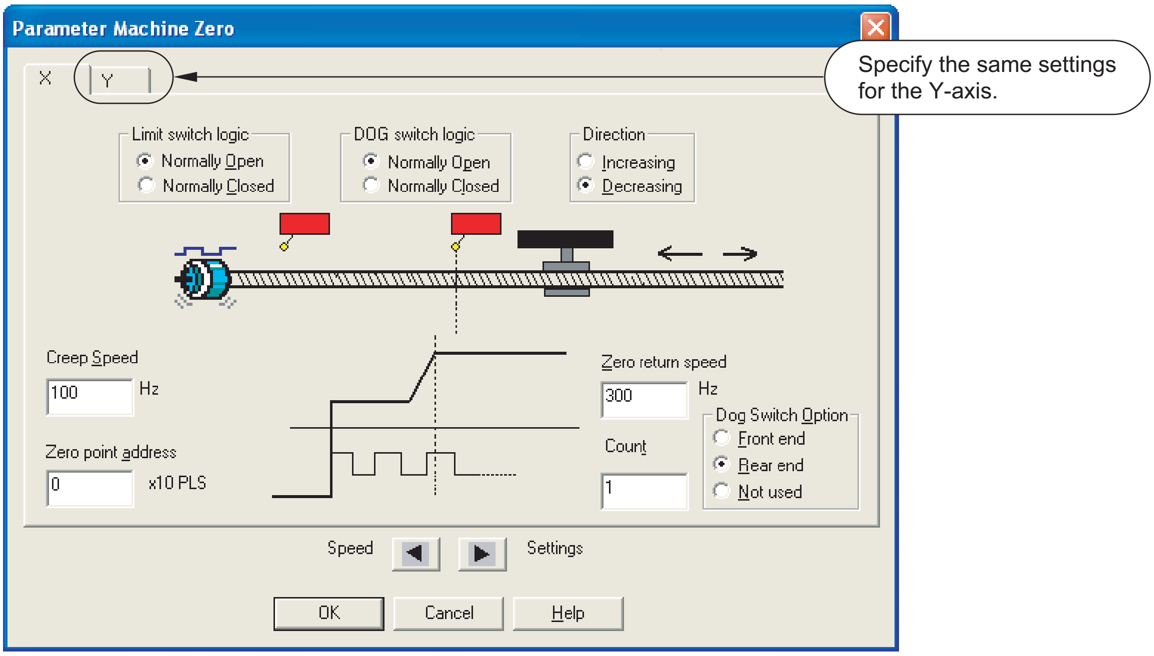


Next, open the “Parameter Speed” window by selecting [Parameters] → [Positioning] → [Speed] from the menu bar at the top of the screen.



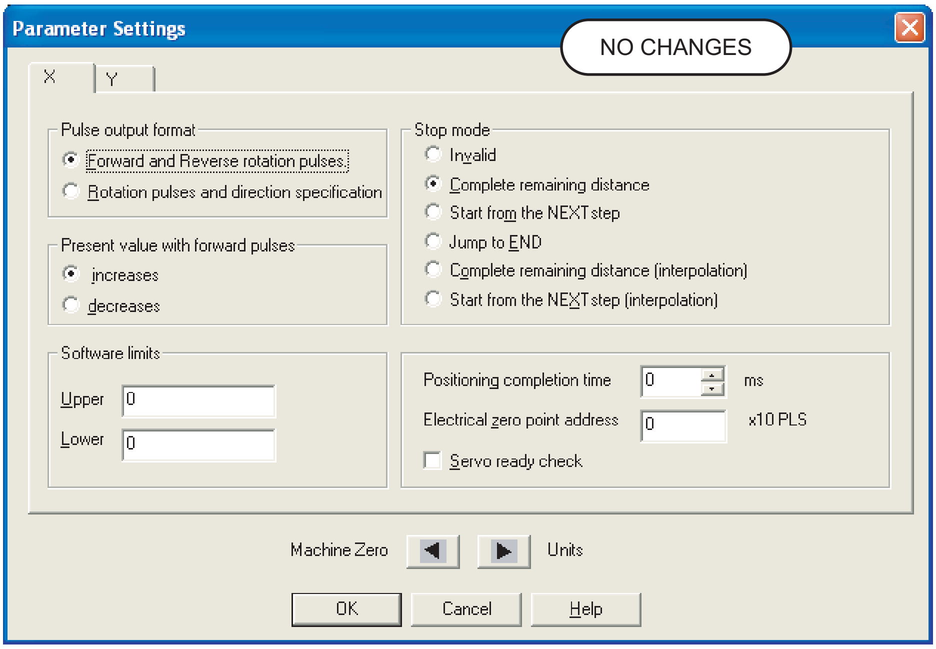
The [Max speed] is set very low in order for the VPS software to trace the path during operation through the “Monitoring Window.” In turn, both the JOG speed and interpolation value must be reduced. (In practice, it is impossible to have the JOG speed set to a value higher than the Max speed setting.)

Next, open the “Parameter Machine Zero” window by selecting [Parameters] → [Positioning] → [Machine Zero] from the menu bar at the top of the screen.



Since mechanical hardware will not be connected to the FX2N-20GM for this example, it is not necessary to configure the limit switch and DOG switch settings in the parameters. It is, however, necessary to reduce the [Creep speed] and the [Zero return speed].

For the last parameter screen, open the “Parameter Settings” window by selecting [Parameters] → [Positioning] → [Settings] from the menu bar at the top of the screen.



None of the parameters in the “Parameter Settings” window need to be changed. When using a mechanical plotter, however, these settings become more important.

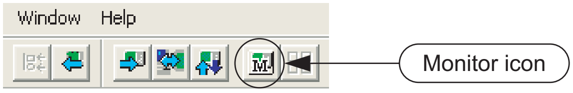
4.5.3 Testing and monitoring operations

After setting the parameters and defining the positioning travel paths described in the previous section, testing can be performed as follows.

Check the communication between the FX2N-20GM and the personal computer by selecting [FX-GM] → [Com Port] and then the [Test] button. Make sure the GM unit is in 'MANU' mode by checking the hardware switch on the unit.

Download the project by selecting [FX-GM] → [Write to FX-GM] from the menu bar at the top of the screen and select the [Write after saving file] button. The program will be downloaded to the 20GM.

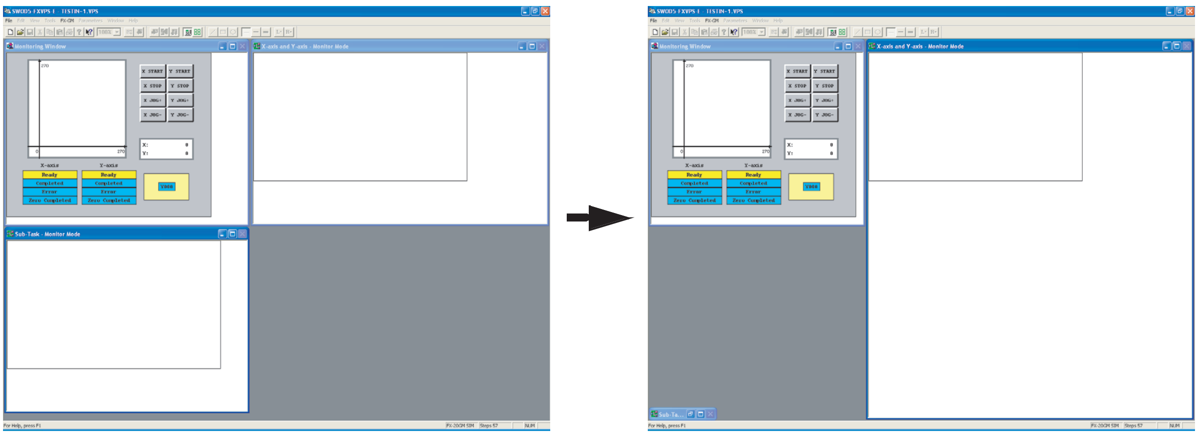
In VPS, start the Monitor mode by clicking the Monitor icon on the tool bar as shown below.



The monitor mode window will appear with three windows:

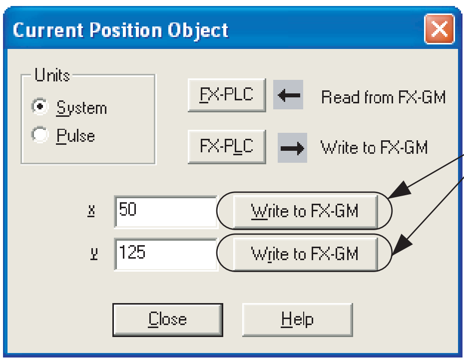
Monitoring window	X-axis and Y-axis – Monitor Mode	Sub-Task – Monitor Mode
This is the window that has already been created where the unit will be controlled and monitored from.	At first, this window will be empty, but as soon as the program is started, the flow chart will appear. Each positioning operation will be highlighted in RED as it is performed.	This window is not needed since there are not any sub-routines being used. This window can be minimized to create more space on the screen.

After minimizing the "Sub-Task – Monitor Mode" window, resize the "Monitoring Window" and "X-axis and Y-axis – Monitor Mode" windows.



Before starting the operation, it is necessary to set the start point. This can be done by using the [X JOG+] and [Y JOG-] buttons or by double clicking on the current position [X: 0 Y: 0] display.

Double click the current position display in the "Monitoring window" to set the start point.



After editing the current address to X: 50 and Y: 125, click on the [Write to FX-GM] button for each axis.

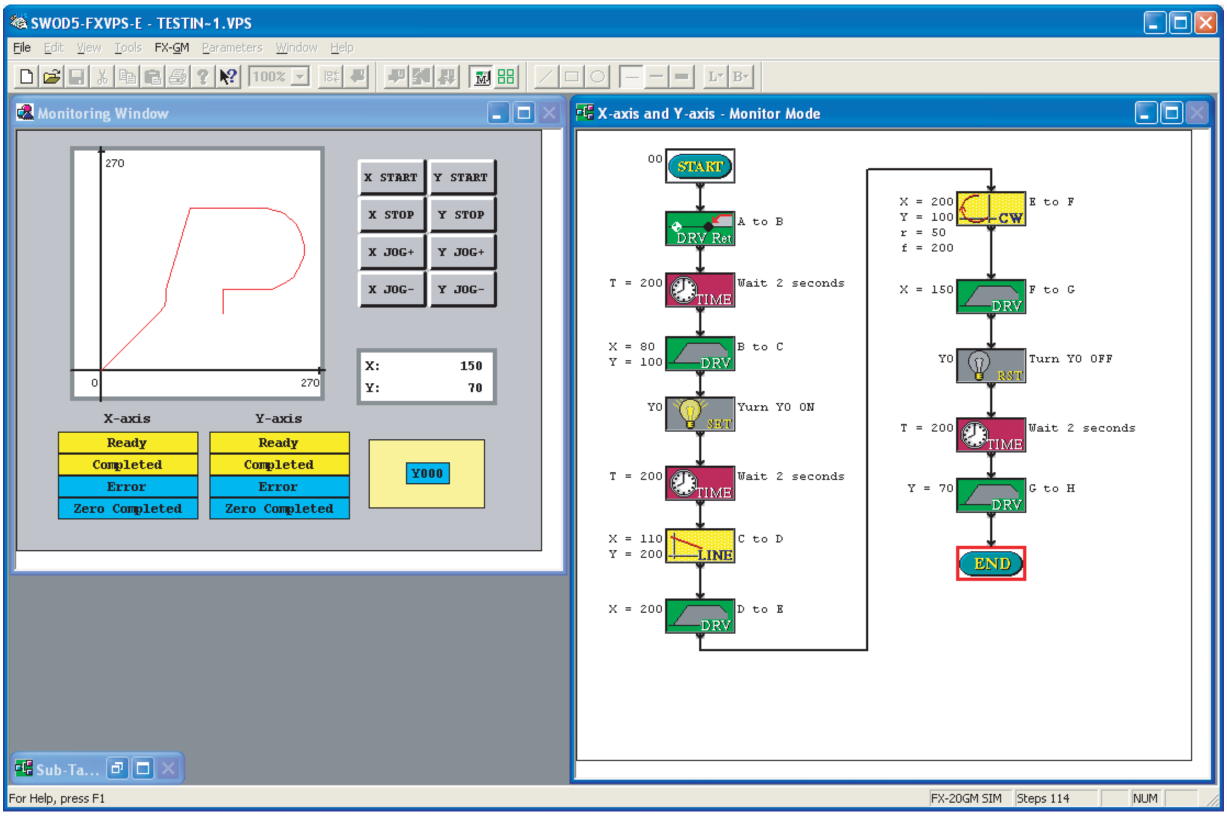
As the address information is changed, red lines will appear on the plotter. This shows the current position.

To clear these red lines before positioning, double click on the plotting area, and then click on the [Clear] button.

The next step is to switch the FX2N-20GM to ‘AUTO’ mode by moving the switch on the unit to ‘AUTO’.

Finally, on the “Monitoring Window” screen, click on either the [X START] or [Y START] buttons.

The positioning operation will be performed and the plot result should look identical to the one shown in the following picture.



To run the program again, set a new start position (or let it start from where it is), clean the plot area, and press the [X START] or [Y START] button again.

If the plot does not look like the one above, check the flow chart program against the program listed in Section 4.5.2 (3).

4.6 FX3U-20SSC-H positioning

The FX3U(C) PLC supports connection with the FX3U-20SSC-H special function block, which is an advanced module to perform positioning operations on two axes using Mitsubishi's fiber optic communication servo network known as SSCNET III (Servo System Controller Network).

Important references for understanding positioning with the FX3U-20SSC-H include:

- FX3U-20SSC-H User's Manual – (JY997D21301)
- FX Configurator-FP Operation Manual – (JY997D21801)

It is assumed that you will have read the above manuals or that you will have them nearby for reference.

4.6.1 Overview of control

Using an FX3U PLC with the FX3U-20SSC-H (20SSC-H) module and two Mitsubishi MR-J3-B servo amplifier systems, high speed positioning with pulse output frequencies up to 50,000,000 pulses/second (50 MHz) is possible on two axes. However, since motors compatible with the MR-J3-B servo amplifier system have a maximum rated speed of 6,000 RPM, the maximum controllable speed from the 20SSC-H becomes:

$$6{,}000\ \frac{\text{rev}}{\text{min}} \times 262{,}144\ \frac{\text{PLS}}{\text{rev}} \times \frac{1}{60} = 26{,}214{,}400\ \frac{\text{PLS}}{\text{sec}}$$

The FX3U-20SSC-H provides several advantages compared to other controllers in the FX family:

FX3U-20SSC-H Feature	Advantage
Bidirectional communication	With SSCNET III, the PLC can communicate with the servo amplifier to monitor torque, servo status flags, servo parameters and absolute position data.
Wiring	Easy to use wiring.
	High immunity to noise from external devices.
	Long distance wiring (50m).
Software	Easy setup of parameters and table data (up to 300 table operations per axis).
	Convenient use of monitoring and testing functions.

With the use of a built-in Flash ROM, the FX3U-20SSC-H can store data permanently via non-volatile storage. Since the flash memory transfers all of its data to the buffer memory of the 20SSC-H each time the power is turned ON, the flash memory provides extra benefit for applications requiring a default set of data to be automatically loaded. This eliminates the need to use a PLC program for setting parameters and table data, which can greatly simplify the length and complexity of a ladder program.

The FX3U-20SSC-H includes an input connector to connect manual pulse generator dials and various switches such as the START, DOG, and interrupt switches. These inputs assist in controlling positioning operations and are necessary to operate instructions such as the interrupt 1-speed constant quantity feed instruction and the DOG type mechanical zero return command.

4.6.2 Using dedicated software to set positioning for the FX3U-20SSC-H

In the example that follows, an FX3U-20SSC-H is used with FX Configurator-FP to perform positioning on two axes with an XY-axis table operation. FX Configurator-FP is convenient for defining servo parameters, positioning parameters and table information. It is also recommended to be used whenever possible since the use of a sequence program for setting parameters and table data requires many steps and devices, resulting in a complex program and increased PLC scan time.

Different from other FX positioning controllers, the FX3U-20SSC-H requires connection to a servo system to perform positioning. For details on connecting an MR-J3-B servo system, refer to the appropriate servo manual.

1. Setting parameters

Prior to setting positioning parameters and servo parameters, check to verify the connection between the PLC and the personal computer is valid. Since ladder logic in the PLC is not used in this example, set the RUN/STOP switch on the PLC to [STOP].

a) Open a new file in FX Configurator-FP by clicking on the [Make new file] button.

b) Expand the tree of folders in the [File data list] panel on the left-hand side of the screen by double clicking on [Unset file / FX3U-20SSC-H], [Edit], and then [Monitor].

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

d) Double click on [Positioning parameters] in the [File data list] panel on the left-hand side of the screen to modify the positioning parameters.
Set items in the [Item] column for both the X- and Y- axes as shown:

Maximum speed	26214400 Hz	26214400 Hz
OPR mode	1:Data set	1:Data set
OPR interlock setting	0:Invalid	0:Invalid

e) Next, double click on [Servo parameters] in the [File data list] panel on the left-hand side of the screen to modify the servo parameters.
Set items from the [Kind] column for both the X- and Y- axes as shown:

Servo amplifier series	Servo amplifier series	1:MR-J3-B	1:MR-J3-B

Basic setting parameters	detection system	position detection system	system	system
	Function selection A-1	Servo forced stop selection	1:Invalid (Do not use the forced stop signal.)	1:Invalid (Do not use the forced stop signal.)
	Auto tuning	Gain adjustment mode ...	1:Auto tuning mode 1	1:Auto tuning mode 1

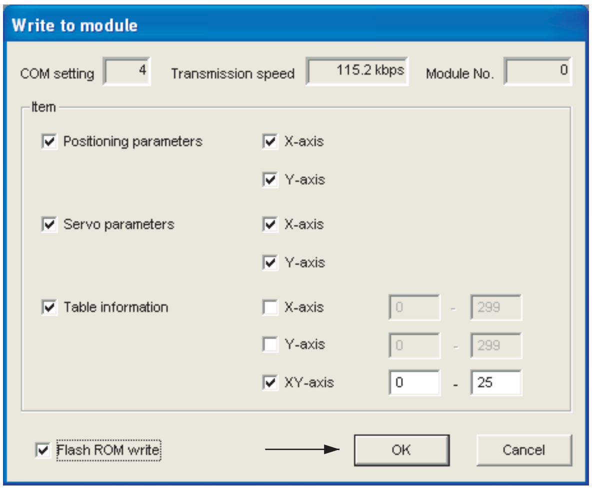
2. Creating XY-axis table operation data

Double click on [XY-axis Table information] in the [File data list] panel on the left-hand side of the screen to open the XY table. Maximize the window to enter the following data:

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	20,000,000	10,000,000				-1
2	Y-axis positioning at 1-step speed						-1
		20,000,000	10,000,000				
3	XY-axis positioning at 1-step speed	5,000,000	2,000,000				-1
		-5,000,000	2,000,000				
4	Circular interpolation (CNT,CW)	0	15,000,000	5,000,000			-1
		0		5,000,000			
5	Dwell				30		-1
6	XY-axis positioning at 2-step speed	10,000,000	10,000,000				-1
		-10,000,000	10,000,000				
7	XY-axis positioning at 2-step speed	-10,000,000	10,000,000				
		10,000,000	10,000,000				
8	Dwell				30		-1
9	XY-axis positioning at 2-step speed	10,000,000	10,000,000				-1
		-10,000,000	10,000,000				
10	XY-axis positioning at 2-step speed	-10,000,000	10,000,000				
		10,000,000	10,000,000				
11	Dwell				30		-1
12	Circular interpolation (CNT,CCW)	0	7,000,000	5,000,000			-1
		0		5,000,000			
13	Dwell				30		-1
14	XY-axis positioning at 2-step speed	10,000,000	15,000,000				-1
		5,000,000	7,500,000				
15	XY-axis positioning at 2-step speed	-5,000,000	7,500,000				
		-10,000,000	15,000,000				
16	Dwell				30		-1
17	Linear interpolation	20,000,000	26,214,400				-1
		-20,000,000					
18	Dwell				150		-1
19	Jump					0	
20	End						

3. Writing data to the FX3U-20SSC-H

Write the servo parameters, positioning parameters and table information to the FX3U-20SSC-H BFM and Flash ROM by pressing the [Write to module] button and placing check marks in the following boxes. Change the range of table data to be written to 0 - 25.



Next, reset the module by pressing the [System reset] button. This is necessary to refresh the servo parameters.

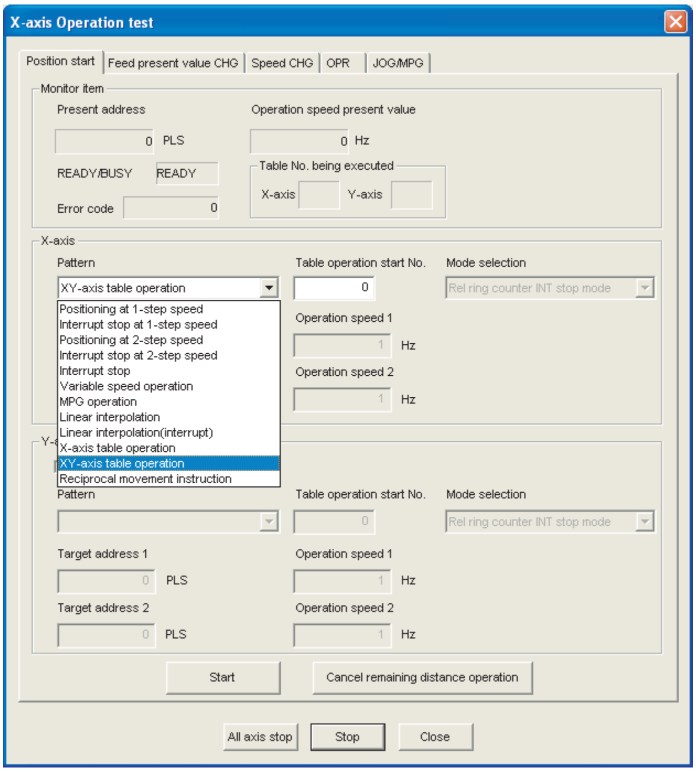
4.6.3 Testing and monitoring operations

With the parameters and table information saved to the FX3U-20SSC-H module from Section 4.6.3 and the PLC in STOP mode, testing is performed by using TEST MODE in FX Configurator-FP.

First, enter TEST MODE by pressing the [Test On/Off] button.

After entering TEST MODE, click on the [Operation Test X-axis] button to display the “X-axis Operation test” window.

Next, select the [XY-axis table operation] from the [X-axis] [Pattern] combination box and click on the [Start] button to begin positioning. Note that because the table operation includes a "Jump" command, the operation will continuously loop from row 0 to row 20.



To stop positioning, click on the [All axis stop] or [Stop] button.

After stopping the table operation, a variety of other positioning operations can be tested from the [X-axis] [Pattern] combination box such as 1-speed positioning, 2-speed positioning, and linear interpolation.
For additional control in TEST MODE, the tabs at the top of the "X-axis Operation test" window can be used according to the following information:

Position start	Feed present value CHG	Speed CHG	OPR	JOG/MPG
Positioning operations can be executed from this window. Target address and operation speed data is defined here.	The value of the current address can be changed using this window.	Two operations for changing the speed of the motor are available from this window.	By clicking on the [REQ. OPR] button, zero return is executed.	JOG operation and manual pulsar operation testing can be performed from this window.

4.6.4 Important buffer memory locations

The FX3U-20SSC-H buffer memory includes five separate data areas for: Monitor data, Control data, Table data, Positioning parameter data, and Servo parameter data. With "read only" or "read/write" access, buffer memory addresses use bit and word information to control positioning operations. Similar to the FX2N-10PG, a large percentage of the BFM is dedicated to the control of table positioning operations.

Monitor data	Control data	Table information	Positioning parameters	Servo parameters
Used to monitor the current position, statuses, etc.	Used to control positioning operations.	Used to store predefined table data.	Used to store parameters such as the max. speed and accel/decel times.	Used to store parameters relevant to the servo(s).

The following buffer memory addresses are used in the ladder program example below. For details on other BFM addresses, refer to the FX3U-20SSC-H User's Manual (JY997D21301).

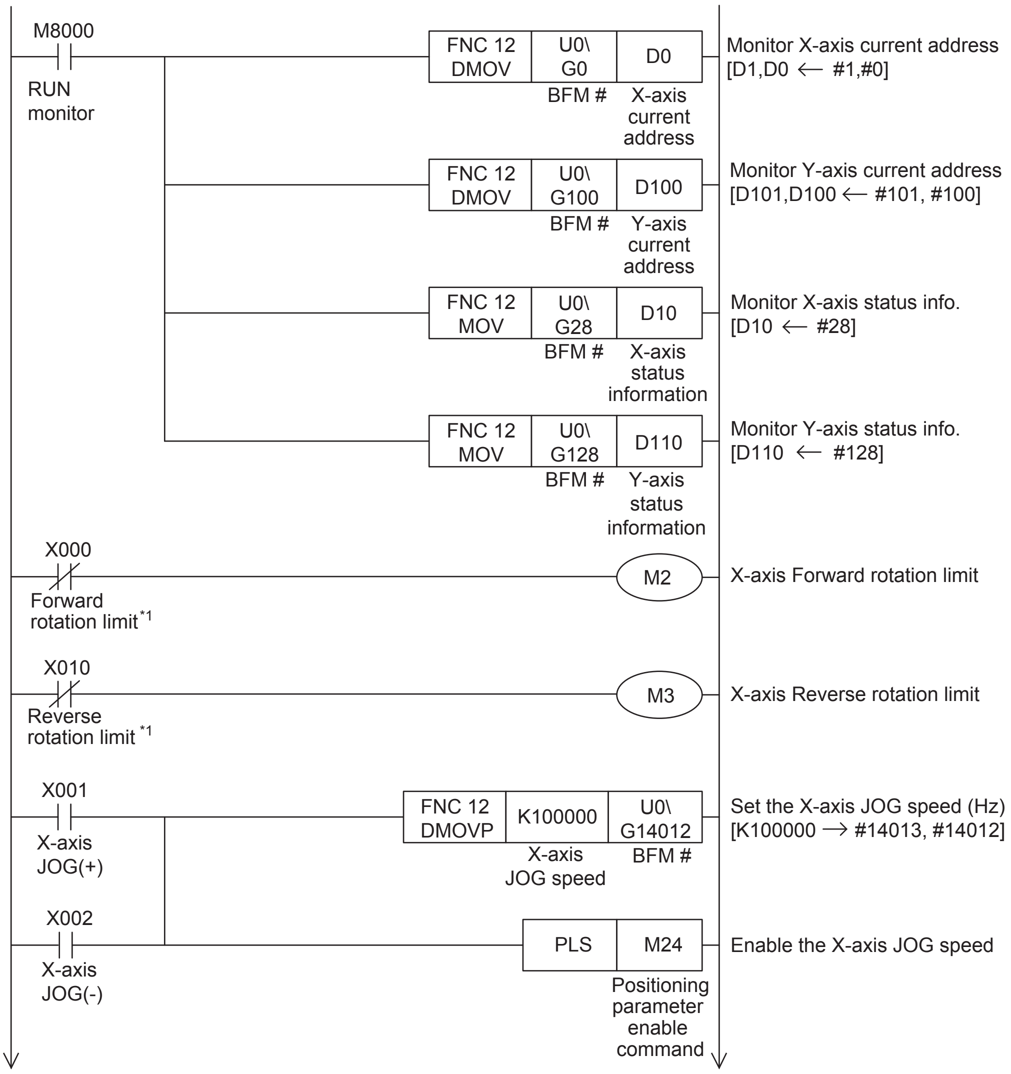
BFM Area	BFM #	Item		Set value	Note
Monitor data	#1, #0	X-axis current address		D1, D0	PLS
	#101, #100	Y-axis current address		D101, D100	PLS
	#28	X-axis status information		D10	
	#128	Y-axis status information		D110	
Control data	#501, #500	X-axis Target address 1		10,000,000	PLS
	#503, #502	X-axis Operation speed 1		2,000,000	Hz (PLS/sec)
	#518	X-axis Operation command 1		M0 - M15	
		b0	Error reset	M0	X007
		b1	STOP	M1	X006
		b2	Forward rotation limit	M2	X000
		b3	Reverse rotation limit	M3	X010
		b4	Forward rotation JOG(+)	M4	X001
		b5	Reverse rotation JOG(-)	M5	X002
		b6	Zero-return	M6	X003
		b8	Relative/Absolute positioning	M8 (b8 =1)	Relative positioning
		b9	START command	M9	X004, X005
	#618	Y-axis Operation command 1		M100 - M115	
		b0	Error reset	M100	X007
		b6	Zero-return	M106	X003
	#519	X-axis Operation command 2		M20 - M35	
		b4	Positioning parameter enable command	M24	X001, X002
	#520	X-axis Operation pattern selection			
		b0	1-speed positioning	H1	X004
		b10	Table operation (simultaneous)	H400	X005
	#521	Table operation start number		0	Table row #0
Positioning parameter data	#14013, #14012	X-axis JOG speed		1,000,000	Hz (PLS/sec)

4.6.5 Program example

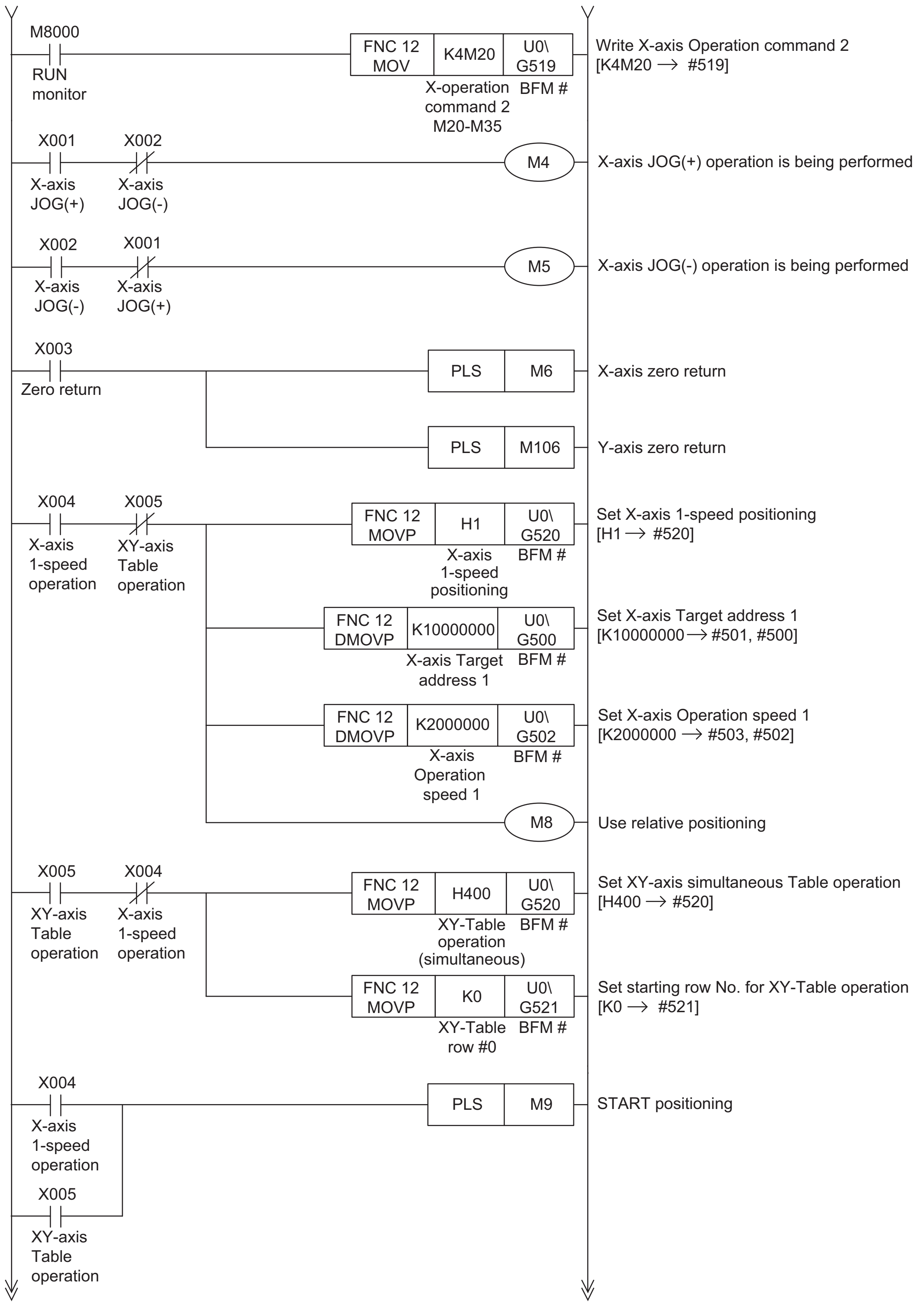
The following program uses buffer memory communication to perform JOG positioning, 1-speed positioning, and table operation control. The XY-table created in the previous section can be used in this example. For this example, FX Configurator-FP should be used to specify the servos, change the maximum speed, and to set the zero return mode as described in Section 4.6.2.

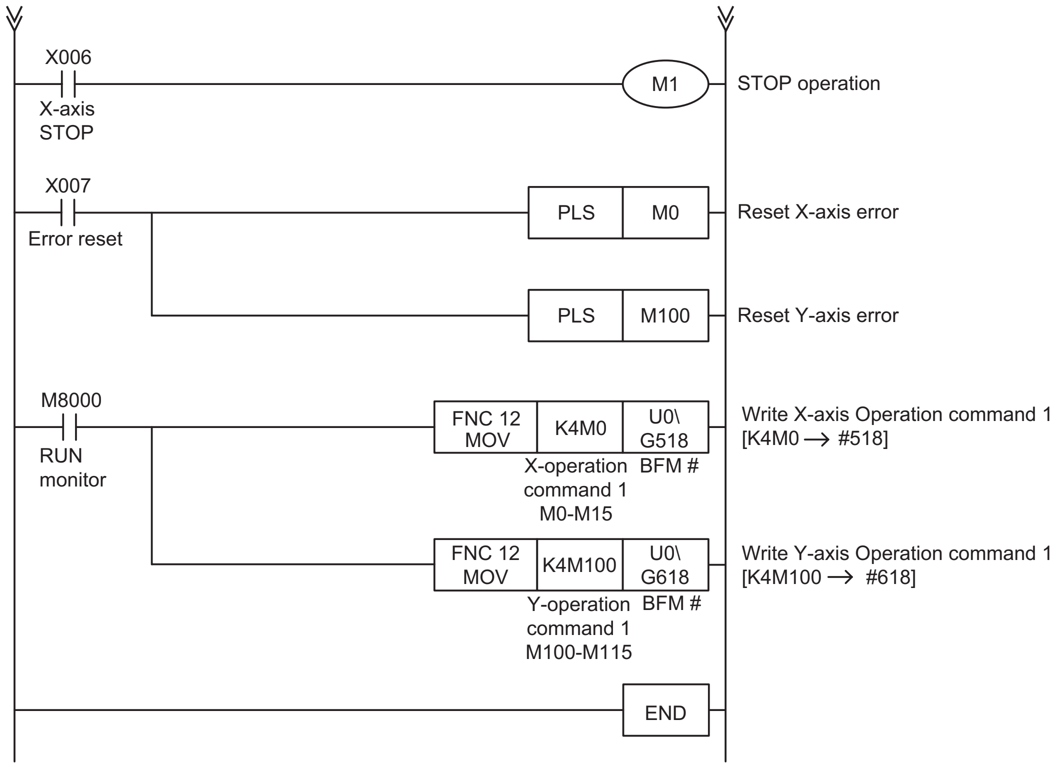
The ladder program is to be used with an FX3U(C) PLC and MR-J3-B servo system. Without these components, the program cannot be tested. Input points from the PLC include:

Inputs	
X000	X-axis Forward rotation limit
X001	X-axis Forward rotation JOG(+)
X002	X-axis Reverse rotation JOG(-)
X003	X- and Y-axis Zero return
X004	START command (X-axis 1-speed operation)
X005	START command (XY-axis Table operation)
X006	STOP command
X007	Error reset
X010	X-axis Reverse rotation limit



*1. The forward and reverse rotation limit switches must be wired so that they are turned ON by default. When these limit switches turn OFF (due to the workpiece going out-of-bounds), M2 or M3 will turn ON and cause the pulse operation to stop.


M8000
RUN monitor
FNC 12 MOV
K4M20
U0\ G519
X-operation command 2 M20-M35
BFM #
Write X-axis Operation command 2
[K4M20 → #519]
X001
X002
X-axis JOG(+)
X-axis JOG(-)
M4
X-axis JOG(+) operation is being performed
X002
X001
X-axis JOG(-)
X-axis JOG(+)
M5
X-axis JOG(-) operation is being performed
X003
Zero return
PLS
M6
X-axis zero return
PLS
M106
Y-axis zero return
X004
X005
X-axis 1-speed operation
XY-axis Table operation
FNC 12 MOVP
H1
U0\ G520
X-axis 1-speed positioning
BFM #
Set X-axis 1-speed positioning
[H1 → #520]
FNC 12 DMOVP
K10000000
U0\ G500
X-axis Target address 1
BFM #
Set X-axis Target address 1
[K10000000 → #501, #500]
FNC 12 DMOVP
K2000000
U0\ G502
X-axis Operation speed 1
BFM #
Set X-axis Operation speed 1
[K2000000 → #503, #502]
M8
Use relative positioning
X005
X004
XY-axis Table operation
X-axis 1-speed operation
FNC 12 MOVP
H400
U0\ G520
XY-Table operation (simultaneous)
BFM #
Set XY-axis simultaneous Table operation
[H400 → #520]
FNC 12 MOVP
K0
U0\ G521
XY-Table row #0
BFM #
Set starting row No. for XY-Table operation
[K0 → #521]
X004
X-axis 1-speed operation
X005
XY-axis Table operation
PLS
M9
START positioning


X006
X-axis STOP
M1
STOP operation
X007
Error reset
PLS
M0
Reset X-axis error
PLS
M100
Reset Y-axis error
M8000
RUN monitor
FNC 12 MOV
K4M0
U0\ G518
X-operation command 1 M0-M15
BFM #
Write X-axis Operation command 1
[K4M0 → #518]
FNC 12 MOV
K4M100
U0\ G618
Y-operation command 1 M100-M115
BFM #
Write Y-axis Operation command 1
[K4M100 → #618]
END

MEMO

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