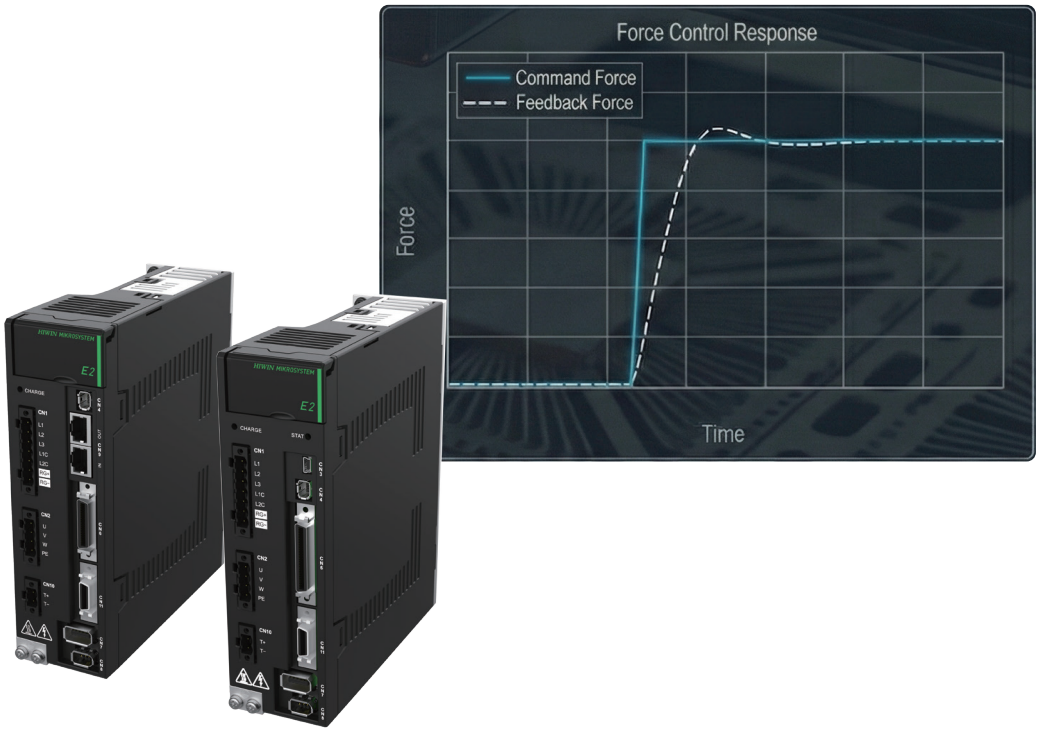
HIWIN® MIKROSYSTEM



E Series Servo Drive

Force Control Function User Manual

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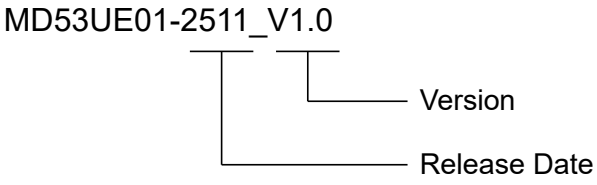
MD53UE01-2511_V1.0

Revision History

The version of the manual is also indicated on the bottom of the front cover.



Release Date	Version	Applicable Product	Revision Contents
Nov. 25th, 2025	1.0	E2 series servo drive	First edition.

Related Documents

Through related documents, users can quickly understand the positioning of this manual and the correlation between manuals and products. Go to HIWIN MIKROSYSTEM's official website → Download → Manual Overview for details (https://www.hiwinmikro.tw/Downloads/ManualOverview_EN.htm).

Firmware Change History

Refer to “E2 Series Servo Drive User Manual” and “E2-R Series Servo Drive User Manual” for the information of servo drive firmware version.

- E2 series servo drive

Servo Drive Firmware Version	Revision Contents related to Force Control Function
3.14.8	Support force control function.

- E2-R series servo drive

Servo Drive Firmware Version	Revision Contents related to Force Control Function
4.14.8	Support force control function.

Preface

This manual describes the hardware configuration, setting procedure, parameters, and application functions related to E series force control system. Force control function inputs analog feedback signals from force sensors (such as load cells) into the servo drive. Based on the desired force command, it performs high-velocity, high-accuracy closed-loop force control, maintaining stable force even when the load changes. This function is suitable for equipment requiring precise force control, such as pressing equipment and bonding machines.

Table of Contents

1. Servo drive specification

The models supporting force control function are listed as follows:

- E1 series servo drive

  Force control function is not supported.

- E2 series servo drive

Table 1.1

Type	Function	Model
Standard	AC	ED2S-V0-□□□-□-A-□□
	Advanced	ED2S-V0-□□□-□-C-□□
	GT	ED2S-V0-□□□-□-T-□□
Fieldbus	AC	ED2F-E0-□□□-□-A-□□
	Advanced	ED2F-E0-□□□-□-C-□□
	GT	ED2F-E0-□□□-□-T-□□

- E2-R series servo drive

Table 1.2

Type	Function	Model
Fieldbus	Rich	ED2F-E0-□□□-□-R-□□

Note:

For Fieldbus servo drives, only EtherCAT models support force control function.

2. System architecture

2.1 Control block diagram description

For the control block diagram before entering force control system, refer to “E2 Series Servo Drive User Manual” and “E2-R Series Servo Drive User Manual.” For the control block diagram after entering force control system, it is shown in Figure 2.1.1. Refer to chapter 3 for the relevant setting procedure, and refer to chapter 5 for troubleshooting for alarms.

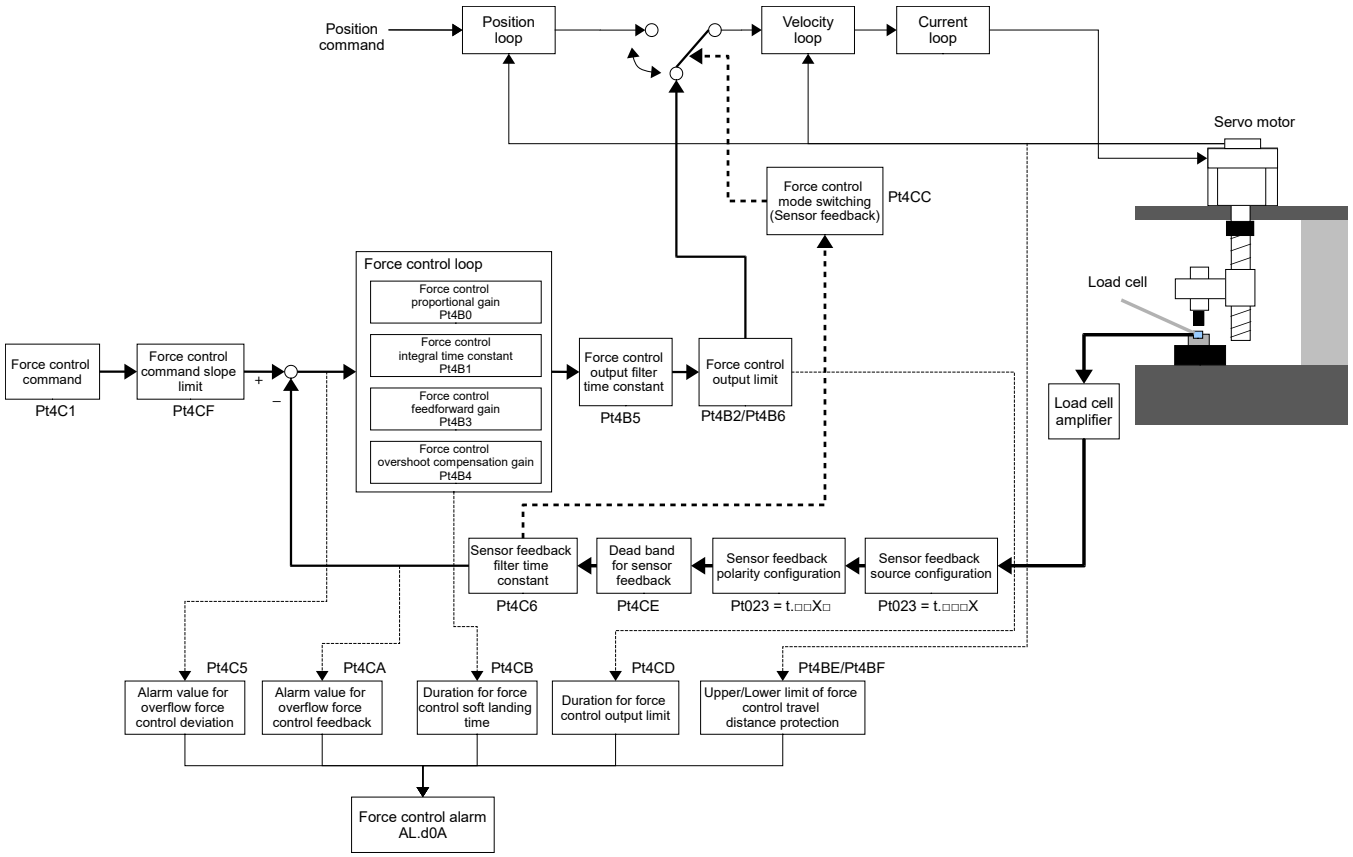


Figure 2.1.1 Control block diagram for force control system

3. Setting procedure

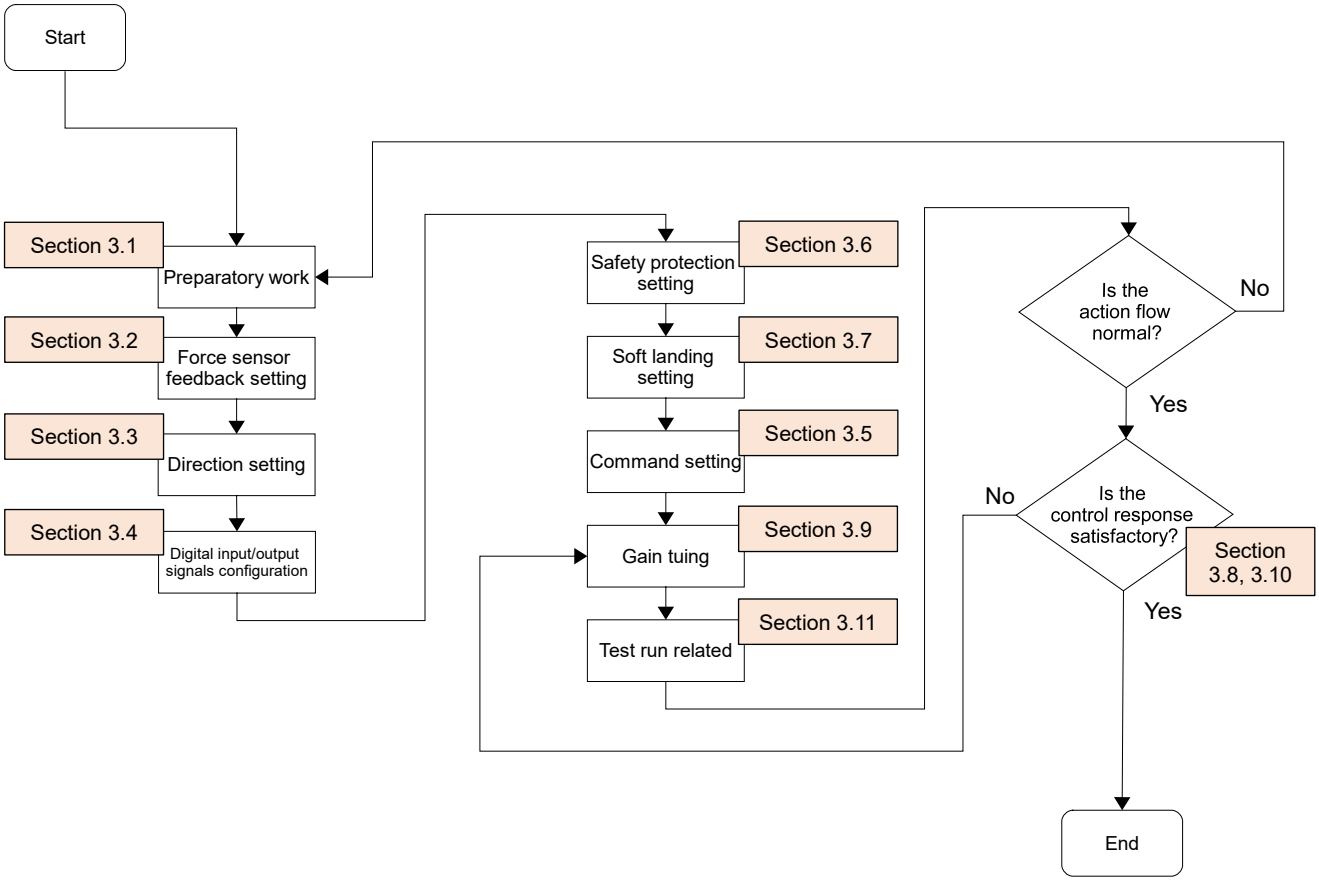


Figure 3.1 Overview of setting procedure

Refer to Figure 3.1 and the corresponding sections for the setting procedure and the description of force control function. Before setting, ensure that the servo drive model supports force control function. Refer to the servo drive specification in chapter 1.

3.1 Preparatory work

Before using force control function, complete the following preparatory work, including the simple evaluation of force sensor selection and the setup steps.

- **Simple evaluation of force sensor selection**

  Generally, the performance of the force sensor (such as the load cell) determines the maximum accuracy that can be achieved by the force control system. Therefore, two core requirements must be considered when selecting a force sensor:

  1. **Target maximum operating force range:**
     It is the maximum force range expected to be applied or measured. It is recommended to select a sensor with a rated capacity slightly larger than (e.g., 1.25~1.5 times) the target maximum operating force range to provide sufficient control margin and protection to avoid sensor overload.
  2. **Target control accuracy:**
     It is the allowable error range of force control which depends on the level of sensor accuracy. Sensor accuracy is typically indicated as a percentage (%) of the full scale (F.S.). A smaller percentage value indicates a smaller maximum measurement error of the sensor, signifying higher accuracy. Therefore, the recommended sensor accuracy is 0.2~0.5 times the desired target force control accuracy to provide sufficient control margin.

  For example, if the maximum target pressing force is 100N and the desired control accuracy at this target force is ±2%, then:

  - **Step 1: Quantify the target force control accuracy**
    - ⇨ 100N * ±2% = ±2N
      Calculation explanation: This indicates that at 100N, force control must remain between 98N and 102N.
  - **Step 2: Select the rated capacity of sensor**
    - ⇨ Recommended: 150N
      Calculation explanation: To maintain a 1.5x margin, the selected rated capacity of sensor is 100N * 1.5 = 150N.
  - **Step 3: Evaluate the accuracy level of sensor**
    - ⇨ Recommended: 0.5% F.S. (refer to the sensor's datasheet for accuracy specifications)
      Calculation explanation: Based on **Step 2**, a sensor with a rated capacity of 150N is selected. Assuming that the sensor accuracy percentage is ±0.5% F.S., the sensor accuracy is 150N * ±0.5% = ±0.75N. This value must be less than the target force control accuracy calculated in **Step 1**.

■ **Complete gain tuning**

Refer to chapter 10 **Tuning** in “E2 Series Servo Drive User Manual” and “E2-R Series Servo Drive User Manual.”

■ **Setting of “Electronic gear ratio setting” window**

Force control is typically used in vertical axis systems, where the motor type is ball screw or linear motor. Refer to section 4.3.6.3 **Electronic gear ratio setting** in “E Series Servo Drive Thunder Software Operation Manual” to complete the setting in “Electronic gear ratio setting” window  in Thunder’s Configuration Wizard, as shown in Figure 3.1.1. When using rotary motor with ball screw, the feed constant must be set.

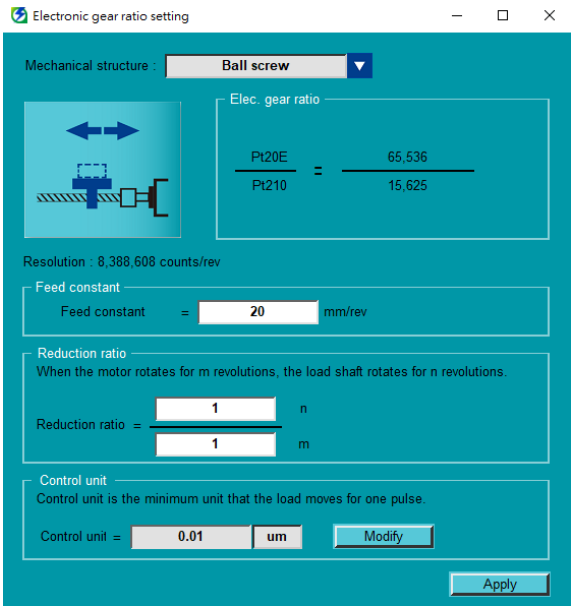


Figure 3.1.1 “Electronic gear ratio setting” window

■ Configuration of force sensor feedback

The servo drive's force control function uses the channel of either the velocity command input signal (V-REF) or the torque command input signal (T-REF) as the source for force sensor feedback. Only one channel can be selected and connected.

For CN6 pin assignment of V-REF or T-REF, refer to "E2 Series Servo Drive User Manual" and "E2-R Series Servo Drive User Manual" for wiring. Set the sensor feedback source Pt023 = t.□□□X based on the actual wiring (refer to section 3.2).

After completing the connection and setting, use Scope in Thunder to observe physical quantity 34 - Force feedback to ensure that the force sensor is providing normal feedback.

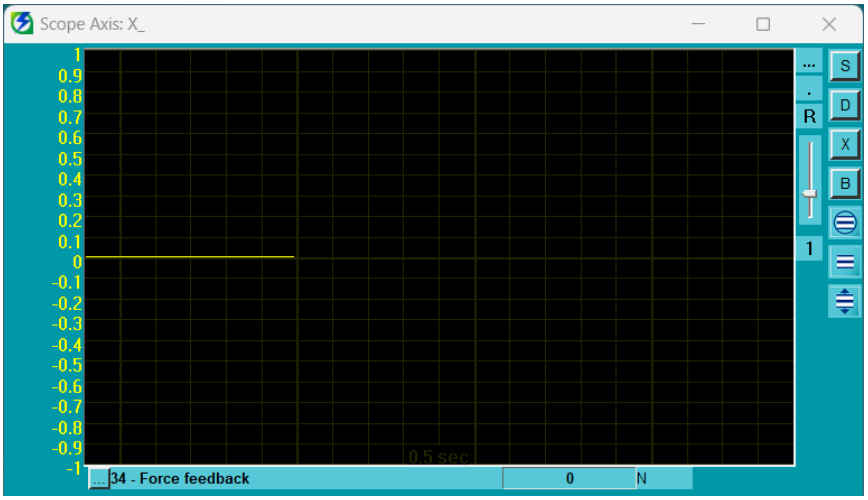


Figure 3.1.2

3.2 Force sensor feedback setting

■ Configuration of force control sensor feedback source

The servo drive's force control function uses the channel of either the velocity command input signal (V-REF) or the torque command input signal (T-REF) as the source for force sensor feedback. Set Pt023 = t.□□□X based on the actual wiring to enable force control function.

Parameter		Description	Effective	Category
Pt023	t.□□□0 (Default)	Disable sensor feedback control function.	After power on	Setup
	t.□□□1	Enable force control function and use V-REF signal as the force sensor feedback source.		
	t.□□□2	Enable force control function and use T-REF signal as the force sensor feedback source.		

⚠CAUTION

◆ When sensor feedback control function is enabled, the following filter-related functions will be disabled:

1. Velocity command filter time constant (Pt307)
2. Average velocity feedforward movement time (Pt30C)
3. T-REF filter time constant (Pt415)
4. Average torque feedforward movement time (Pt426)

In addition, some functions will be restricted based on the setting of Pt023 = t.□□□X:

■ When Pt023 = t.□□□1 is set to use velocity command input signal (V-REF) as the force sensor feedback source, the following functions are unavailable:

1. Velocity command input gain (Pt300)
2. Functions related to V-REF allocation (Pt207 = t.□□X□, Pt002 = t.□□X□)

■ When Pt023 = t.□□□2 is set to use torque command input signal (T-REF) as the force sensor feedback source, the following functions are unavailable:

1. Torque command input gain (Pt400)
2. Functions related to T-REF allocation (Pt002 = t.□□□X)

■ Force control feedback unit gain

It is the conversion ratio between the voltage signal (V) output by the force sensor and the actual physical force unit (N). Set Pt4C2 with the following formula. For example, 10V = 50N, then Pt4C2 = 50 * 1000 / 10 = 5000.

$$\text{Pt4C2} = \frac{\text{Actual force (N)}}{\text{Force sensor output voltage (V)}} \times 1000$$

Parameter	Pt4C2	Range	0~2^{30}	Control Mode	Force control mode
Default	1000	Effective	Immediately	Unit	1 mN/V
Description					
Force control feedback unit gain					

Note:

Ensure that force control feedback unit gain is correctly set. Otherwise, unit display will be abnormal and force control function cannot be normally executed.

■ Sensor feedback filter time constant

In force control system, the output voltage of force sensor feedback (such as load cells) is typically an analog signal, susceptible to noise, vibration, and high-frequency interference. To ensure accurate force status judgment, sensor feedback filter time constant Pt4C6 is provided to smooth the signal and enhance force control stability. A larger value of Pt4C6 indicates a smoother feedback signal; however, an excessive setting may reduce feedback response.

Parameter	Pt4C6	Range	0~65535	Control Mode	Force control mode
Default	100	Effective	Immediately	Unit	0.01 ms
Description					
Sensor feedback filter time constant					

■ Sensor feedback offset adjustment

If the sensor amplifier lacks offset correction, select **Analog offset** from **Tools** in Thunder main window. Click **Set zero** button in “Analog offset” window to automatically adjust the offset.

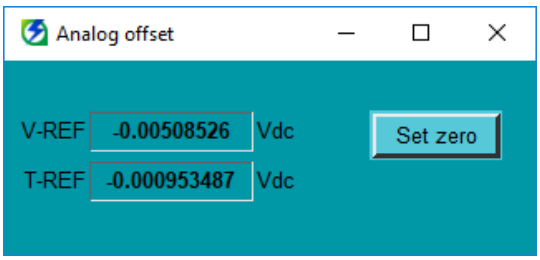


Figure 3.2.1

■ Dead band for sensor feedback

After performing automatic offset adjustment, the analog voltage may still fluctuate slightly. Dead band for sensor feedback can be set to ignore analog feedback signals within this range.

Parameter	Pt4CE	Range	0~65535	Control Mode	Force control mode
Default	0	Effective	Immediately	Unit	1 mV
Description					
Dead band for sensor feedback					

3.3 Force control direction setting

Follow the steps below to confirm and set the direction:

1. Ensure that the motor and the load mechanism operate safely, and that the force sensor is properly installed with normal signal feedback.

2. Force sensor reading value direction setting:
   When the force sensor is pushed (with the force applied toward the sensor body), use Scope in Thunder to observe physical quantity 34 - Force feedback to ensure that the force sensor reading value is “positive accumulation.” If it is not positive accumulation, reverse the sensor polarity as follows:

   - If velocity command input signal (V-REF) is used as the force control feedback source (Pt023 = t.□□□1)
     ⇨ Set Pt023 to t.□□1□ (V-REF signal is inverted)
   - If torque command input signal (T-REF) is used as the force control feedback source (Pt023 = t.□□□2)
     ⇨ Set Pt023 to t.□□2□ (T-REF signal is inverted)

   Note:
   Force control command (Pt4C1) does not support negative values. Therefore, ensure that its output voltage reading value is positive when the force sensor is pushed.

Parameter		Description	Effective	Category
Pt023	t.□□0□ (Default)	The analog input signal is not inverted.	After power on	Setup
	t.□□1□	V-REF signal is inverted.		
	t.□□2□	T-REF signal is inverted.		

3. Force control output direction setting:
   When the motor moves toward the force sensor or the workpiece, there are two possibilities:

■ If the encoder feedback is “accumulating”

⇨ Set Pt4C0 to t.□□□0 (the force control output direction is the same as the encoder direction)

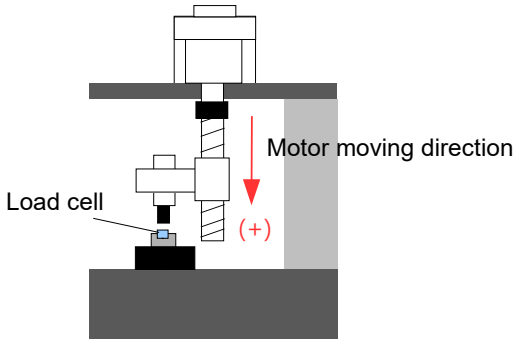


Figure 3.3.1

■ If the encoder feedback is “decrementing”

⇨ Set Pt4C0 to t.□□□1 (the force control output direction is opposite to the encoder direction)

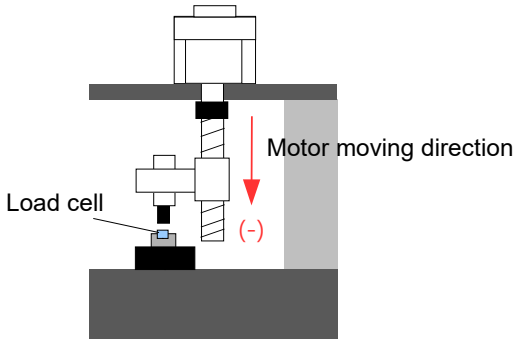


Figure 3.3.2

Note:

If the motor rotation direction (Pt000 = t.□□□X) is changed, reconfirm the setting of the force control direction.

Parameter		Description	Effective	Category
Pt4C0	t.□□□0 (Default)	The force control output direction is the same as the encoder direction.	After power on	Setup
	t.□□□1	The force control output direction is opposite to the encoder direction.		

⚠CAUTION

◆ Incorrect force control output direction setting may cause abnormal situations such as loss of control or reverse motion. If an abnormality occurs, immediately stop the equipment and check if the motor rotation direction and the force sensor feedback direction are correctly set.

3.4 Digital input/output signals configuration

Force control function can be activated and monitored via the configuration of digital input/output signals.

Digital input signal configuration:

- Force control function enable input (FC-ENABLE) signal

  To activate force control function via an external trigger signal, set parameter Pt540 = t.□□□X to assign FC-ENABLE signal to the desired pin. For the settings of digital input signal allocation, please refer to section 8.1.1 **Digital input signal allocation** in "E2 Series Servo Drive User Manual" and "E2-R Series Servo Drive User Manual."

Type	Signal Name	Hardware Pin	Signal Status	Description
Input	FC-ENABLE	User-defined	Rising edge trigger	Activate force control.
			Falling edge trigger	Deactivate force control.

*Not supported by Fieldbus models

Digital output signal configuration:

- Force control positioning completion output (FC-IN) signal

  When the force control deviation is less than the force control positioning width (Pt4C7) and remains the debounce time (Pt4C8), digital output signal "FC-IN" will be output, indicating that force feedback has reached the target status. Set parameter Pt518 = t.□□X□ to assign FC-IN signal to the desired pin. For the settings of digital output signal allocation, please refer to section 8.1.2 **Digital output signal allocation** in "E2 Series Servo Drive User Manual" and "E2-R Series Servo Drive User Manual."

Type	Signal Name	Hardware Pin	Signal Status	Description
Output	FC-IN	User-defined	ON	Force control positioning is completed.
			OFF	Force control positioning is not completed.

- Force control ready output (FC-RDY) signal

  When the servo drive enters force control, digital output signal "FC-RDY" will be output. Set parameter Pt518 = t.□X□□ to assign FC-RDY signal to the desired pin. For the settings of digital output signal allocation, please refer to section 8.1.2 **Digital output signal allocation** in "E2 Series Servo Drive User Manual" and "E2-R Series Servo Drive User Manual."

Type	Signal Name	Hardware Pin	Signal Status	Description
Output	FC-RDY	User-defined	ON	Force control is ready.
			OFF	Force control is off.

3.5 Force command setting

■ Force command

Force command is the target force value for force control function. Please set Pt4C1.

Parameter	Pt4C1	Range	0~10000	Control Mode	Force control mode
Default	1000	Effective	Immediately	Unit	1 mV
Description					
Force control command					

■ Force command slope limit

In force control applications, step commands may excite high-frequency vibrations in the system. To suppress mechanical resonance caused by sudden command changes, force command slope limit Pt4CF can be set to adjust the smoothness of command changes.

Parameter	Pt4CF	Range	0~65535	Control Mode	Force control mode
Default	1000	Effective	Immediately	Unit	1 mV/0.1 s
Description					
Force control command slope limit					

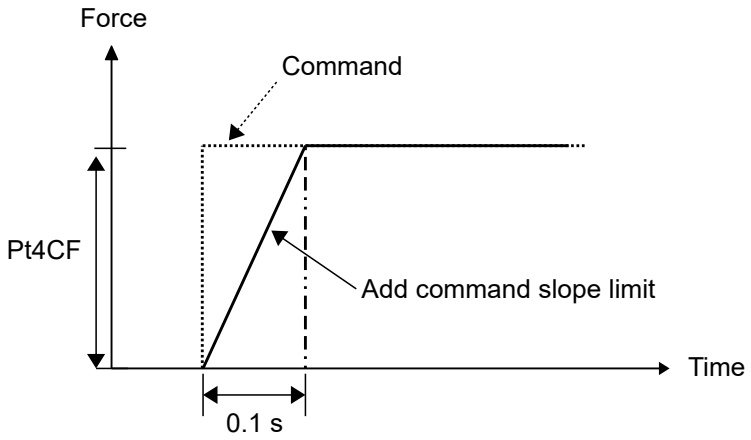


Figure 3.5.1

3.6 Force control safety protection setting

- Alarm value for overflow force control deviation

  During force control, the servo drive continuously compares the difference between the force command and the force feedback to ensure force control accuracy. If the deviation exceeds the setting value of Pt4C5, force control alarm AL.d0A will occur. It is recommended to set a reasonable safety margin slightly larger than the maximum force fluctuation during normal force control.

Parameter	Pt4C5	Range	0~65535	Control Mode	Force control mode
Default	1000	Effective	Immediately	Unit	1 mV
Description					
Alarm value for overflow force control deviation					

- Alarm value for overflow force control feedback

  During force control, the servo drive continuously monitors the force feedback value to ensure it does not exceed the force range that the equipment or workpiece can withstand. This prevents abnormal increases in the force feedback value that could potentially damage the workpiece or overload the sensor. To prevent overpressure, set an appropriate value for Pt4CA based on the maximum force required for the actual application. The setting value should be above the normal pressure range but below the maximum value that the mechanism or sensor can withstand.

Parameter	Pt4CA	Range	0~65535	Control Mode	Force control mode
Default	8000	Effective	Immediately	Unit	1 mV
Description					
Alarm value for overflow force control feedback					

- Force control output limit and duration

  To prevent system oscillation or instability caused by excessive continuous force control output, set the force control output limit (Pt4B2 for rotary motor, Pt4B6 for linear motor) and the protection time for the output limit duration (Pt4CD). Therefore, if the force control output remains at the limit value for a period exceeding the setting value of Pt4CD, force control alarm AL.d0A will occur.

Parameter	Pt4B2	Range	0~3000	Control Mode	Force control mode
Default	20	Effective	Immediately	Unit	1 rpm
Description					
Force control output limit (rotary servo motor)					

Parameter	Pt4B6	Range	0~1000	Control Mode	Force control mode
Default	10	Effective	Immediately	Unit	1 mm/s
Description					
Force control output limit (linear servo motor)					

Parameter	Pt4CD	Range	0~65535	Control Mode	Force control mode
Default	3000	Effective	Immediately	Unit	1 ms
Description					
Duration for force control output limit					

- Force control travel distance protection function

  This prevents unexpected situations during force control that could cause abnormal motor movement, such as continuous movement in the same direction leading to workpiece damage. Set the upper and lower limits of the force control travel distance protection function with a safety margin based on the actual encoder feedback direction and the motor feedback position during normal force control. Enable force control travel distance protection function by setting Pt4C0 = t.□□1□.

  Setting Example:

  Under normal force control during pressing, if the motor position is at 1000 control unit and a safety margin of 200 control unit is applied, set Pt4BE and Pt4BF based on the encoder's movement toward the workpiece.

➢ If the encoder moves toward the workpiece in "accumulating" mode:

Set Pt4BE to 1200 (1000+200) and set Pt4BF to 800 (1000-200).

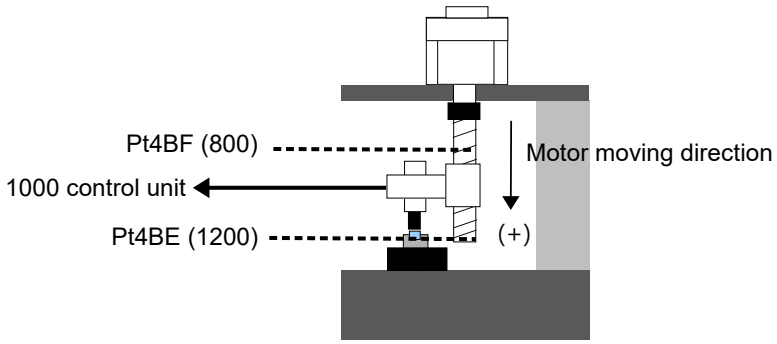


Figure 3.6.1

➢ If the encoder moves toward the workpiece in “decrementing” mode:
Set Pt4BE to 800 (1000-200) and set Pt4BF to 1200 (1000+200).

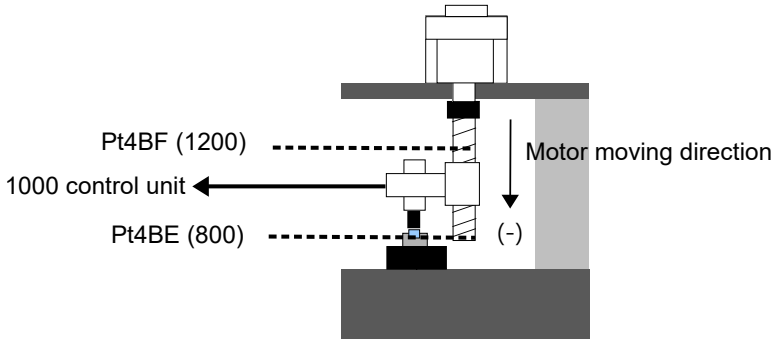


Figure 3.6.2

⚠CAUTION

◆ Correctly set Pt4BE and Pt4BF according to the encoder direction. Incorrect setting will cause the protection function to fail.

Parameter		Description	Effective	Category
Pt4C0	t.□□0□ (Default)	Disable force control travel distance protection function.	Immediately	Setup
	t.□□1□	Enable force control travel distance protection function.		

Parameter	Pt4BE	Range	-1073741823 ~ 1073741823	Control Mode	Force control mode
Default	0	Effective	Immediately	Unit	1 control unit
Description					
Upper limit of force control travel distance protection					

Parameter	Pt4BF	Range	-1073741823 ~ 1073741823	Control Mode	Force control mode
Default	0	Effective	Immediately	Unit	1 control unit
Description					
Lower limit of force control travel distance protection					

3.7 Force control soft landing setting

Soft landing function is a feature in force control to enhance contact stability and safety.
It operates as follows:

1. **Low-velocity approach:** When force control function is enabled, the motor moves according to the set soft landing acceleration/deceleration time (Pt4C4) and soft landing velocity (Pt4C3) and waits for the execution side to contact the workpiece.
2. **Force monitoring:** The servo drive continuously monitors the force feedback signal.
3. **Automatic mode switching:** Once the force feedback is detected to be larger than the setting value of force control effective voltage Pt4CC, it indicates that the workpiece has been contacted. The servo drive will automatically switch from velocity mode to force control mode.

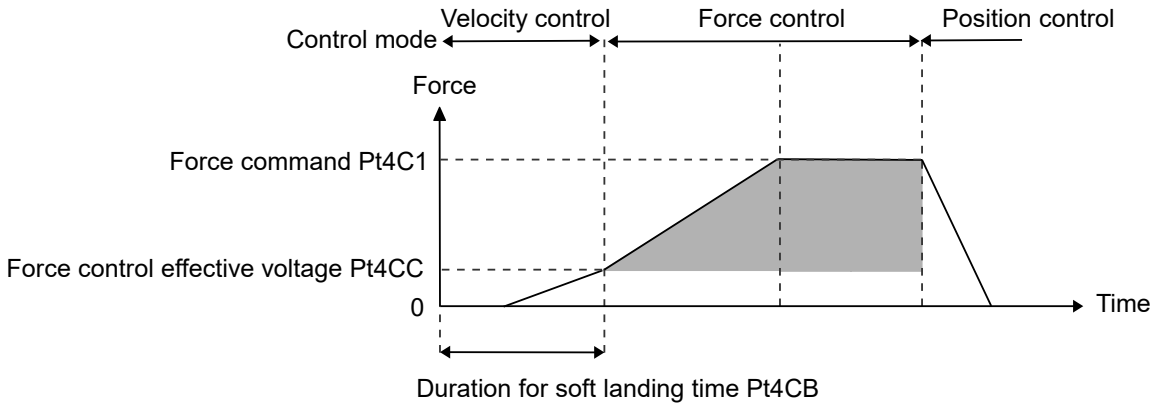


Figure 3.7.1

Note:

(1) The gray area in the figure indicates the effective area of force control.

(2) The lower the force control effective voltage setting, the faster the response to switching to force control mode. However, an excessively low setting may increase the risk of false triggering. Conversely, a higher setting requires the motor to apply greater force to trigger the switching, which may cause a greater impact when contact is made. Therefore, it is usually set slightly higher than the reading value of the force sensor in the unpressurized state.

(3) Note that the setting value of force command (Pt4C1) must be larger than the force control effective voltage (Pt4CC), otherwise there may be unexpected action.

(4) After soft landing function is activated, to prevent damage caused by failure to detect workpiece contact in time due to abnormal situations such as sensor failure, force control alarm AL.d0A will occur if the force feedback signal still does not reach the setting value of Pt4CC within the soft landing duration (Pt4CB).

■ Relevant parameters

Parameter	Pt4CB	Range	0~65535	Control Mode	Force control mode
Default	1000	Effective	Immediately	Unit	1 ms
Description					
Duration for force control soft landing time					

Parameter	Pt4CC	Range	0~10000	Control Mode	Force control mode
Default	100	Effective	Immediately	Unit	1 mV
Description					
Force control effective voltage					

Parameter	Pt4C3	Range	0~3000	Control Mode	Force control mode
Default	20	Effective	Immediately	Unit	1 rpm
Description					
Force control soft landing velocity (rotary servo motor)					

Parameter	Pt4C9	Range	0~1000	Control Mode	Force control mode
Default	10	Effective	Immediately	Unit	1 mm/s
Description					
Force control soft landing velocity (linear servo motor)					

Parameter	Pt4C4	Range	0~65535	Control Mode	Force control mode
Default	100	Effective	Immediately	Unit	1 ms
Description					
Force control soft landing time					

The actual soft landing time is calculated as follows:

$$\text{Actual soft landing time} = \frac{\text{Soft landing velocity}}{\text{Reference velocity}} \times \text{Force control soft landing time (Pt4C4)}$$

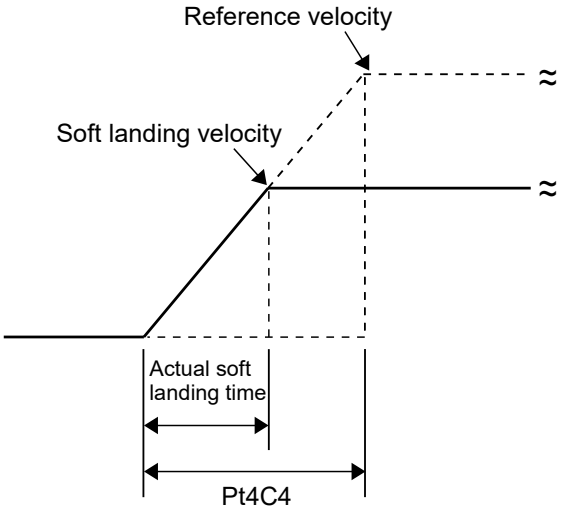


Figure 3.7.2

Note:

The reference velocity for rotary motor is Pt317, and for linear motor is Pt386.

The soft landing velocity for rotary motor is Pt4C3, and for linear motor is Pt4C9.

3.8 Force control positioning setting

When the force feedback reaches the target force, the force deviation is less than the force control positioning width (Pt4C7) and the debounce time (Pt4C8) is maintained, force control positioning completion output signal (FC-IN) will be output, called force positioning. The time from the start of the force command to the completion of the force positioning output is the total time, which is the sum of the force command planning time and the force positioning time, as shown in the figure below. Users can also observe the command planning time, positioning time, and total time via force control function interface in Thunder.

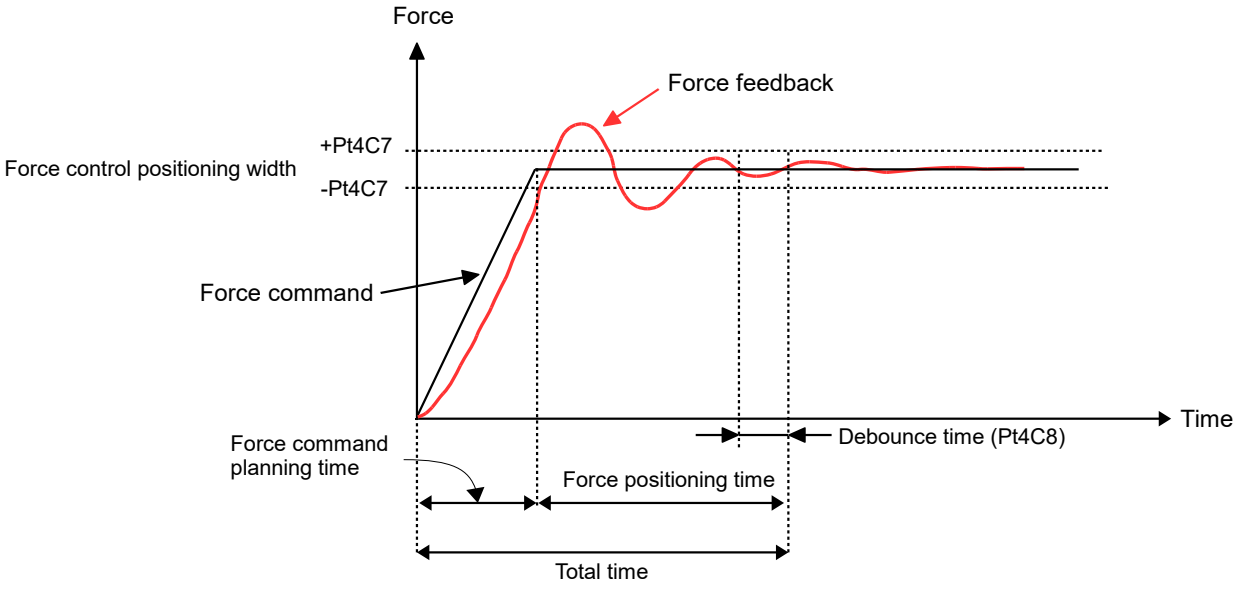


Figure 3.8.1

■ Force control positioning width

When the force deviation is less than the force control positioning width setting, it indicates force positioning. Force control positioning completion output signal (FC-IN) will be output.

Parameter	Pt4C7	Range	0~65535	Control Mode	Force control mode
Default	100	Effective	Immediately	Unit	1 mV
Description					
Force control positioning width					

- Force control debounce time

  Users can set debounce time to output force control positioning completion output signal (FC-IN) after debounce time elapses.

Parameter	Pt4C8	Range	0~65535	Control Mode	Force control mode
Default	0	Effective	Immediately	Unit	1 ms
Description					
Force control debounce time					

3.9 Force control gain tuning

The flow chart for force control gain tuning is as follows.

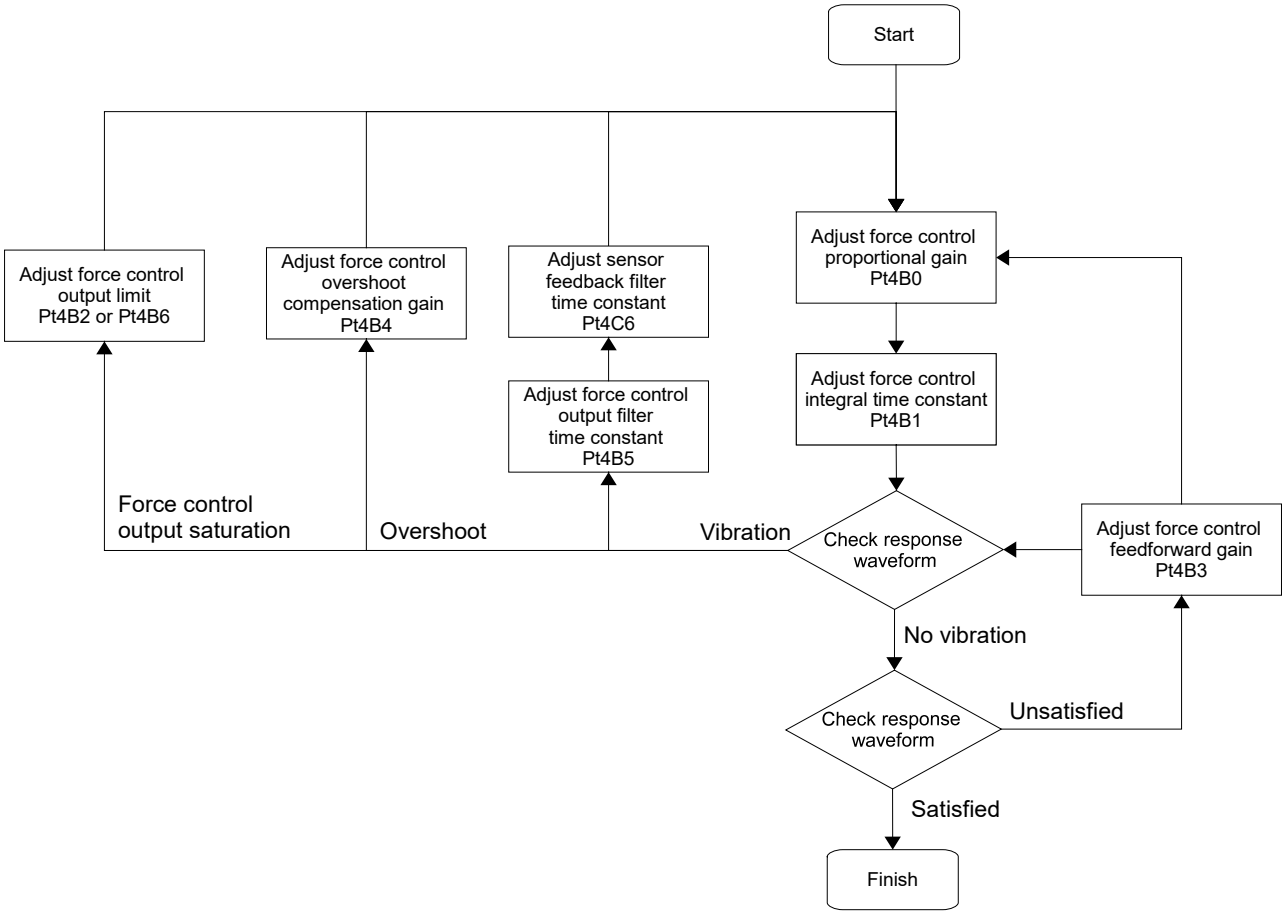


Figure 3.9.1

■ Force control proportional gain

Force control proportional gain is used to adjust the responsiveness of force control. A larger value results in a faster response, but an excessive setting may cause force overshoot or oscillation.

Parameter	Pt4B0	Range	0~65535	Control Mode	Force control mode
Default	10	Effective	Immediately	Unit	1 %/mV
Description					
Force control proportional gain					

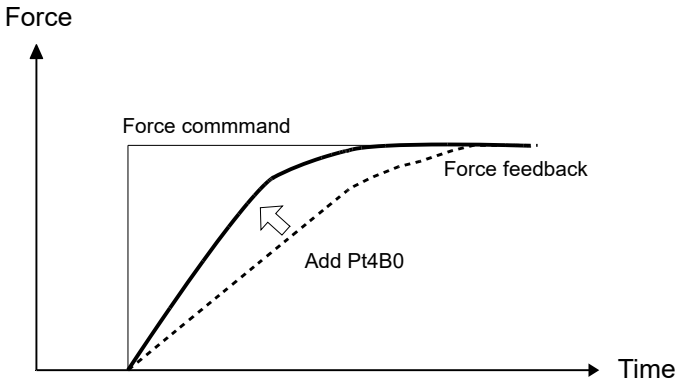


Figure 3.9.2

■ Force control integral time constant

Force control integral time constant is used to eliminate steady-state errors in force control. A smaller value results in a faster integral response but may cause system oscillation or instability.

Parameter	Pt4B1	Range	15~65535	Control Mode	Force control mode
Default	65535	Effective	Immediately	Unit	0.01 ms
Description					
Force control integral time constant					

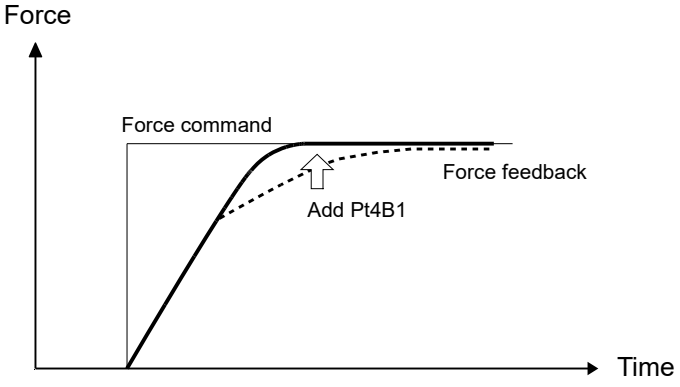


Figure 3.9.3

■ Force control feedforward gain

Force control feedforward gain can further improve force control tracking performance. It can be gradually increased, but excessive gain may cause vibration and overshoot.

Parameter	Pt4B3	Range	0~65535	Control Mode	Force control mode
Default	0	Effective	Immediately	Unit	1 %
Description					
Force control feedforward gain					

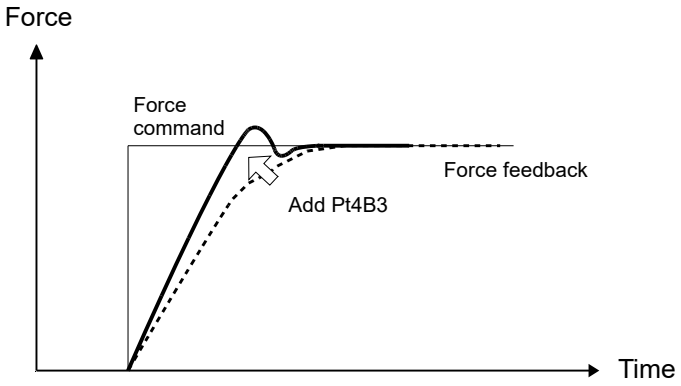


Figure 3.9.4

■ Force control overshoot compensation gain

Force control overshoot compensation can suppress overshoot in force control. Increasing the value will improve the suppression effect, but an excessive setting may cause vibration.

Parameter	Pt4B4	Range	0~65535	Control Mode	Force control mode
Default	0	Effective	Immediately	Unit	1 %
Description					
Force control overshoot compensation gain					

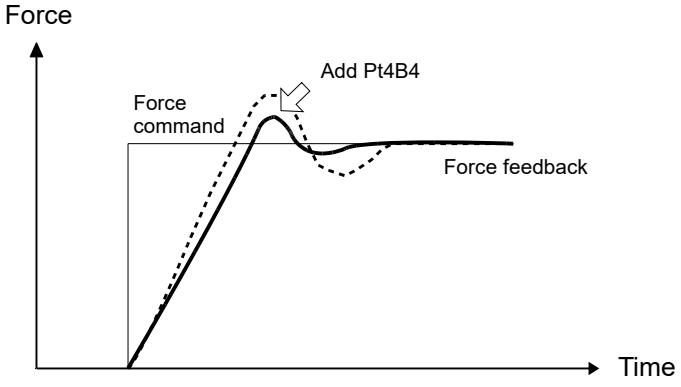


Figure 3.9.5

■ Force control output filter time constant

If vibration occurs during force control, adjusting Pt4B5 may eliminate the vibration.

Parameter	Pt4B5	Range	0~65535	Control Mode	Force control mode
Default	10	Effective	Immediately	Unit	0.01 ms
Description					
Force control output filter time constant					

3.10 Force control monitoring function

■ Status monitoring for force control with Fieldbus EtherCAT communication

The object dictionary list and description are as follows.

Table 3.10.1

<table>
<tr><th>Index</th><th>Sub-index</th><th>Name</th><th>Data type</th><th>Access</th><th>PDO</th><th>Valid value</th><th>Unit</th></tr>
<tr><td rowspan="2">3090h</td><td rowspan="2">00h</td><td colspan="5">Force control error code</td><td>U16</td><td>ro</td><td>-</td><td>0x0 ~ 0xFFFF</td><td>-</td></tr>
<tr><td colspan="6">Causes of force control alarm. Refer to Table 5.1.1.</td></tr>
<tr><td rowspan="2">3091h</td><td rowspan="2">00h</td><td colspan="5">Force control status</td><td>I16</td><td>ro</td><td>-</td><td>0 ~ 32767</td><td>-</td></tr>
<tr><td colspan="6"><table><tr><th>Value</th><th>Definition</th></tr><tr><td>0</td><td>Force control function is not activated.</td></tr><tr><td>1</td><td>Mode switching is in progress.</td></tr><tr><td>2</td><td>Soft landing is in progress.</td></tr><tr><td>3</td><td>Force control function is in progress.</td></tr><tr><td>4</td><td>Force control function is OFF.</td></tr></table></td></tr>
<tr><td>3092h</td><td>00h</td><td colspan="5">Force error actual value</td><td>I32</td><td>ro</td><td>-</td><td>-2147483648 ~ 2147483647</td><td>mN</td></tr>
<tr><td>3093h</td><td>00h</td><td colspan="5">Force feedback actual value</td><td>I32</td><td>ro</td><td>-</td><td>-2147483648 ~ 2147483647</td><td>mN</td></tr>
</table>

■ Status monitoring for force control with Thunder

Physical quantities and servo signal statuses are as follows.

Table 3.10.2

Physical Quantity
(34) Force feedback
(35) Force command
(36) Force error
(37) Force control output command

Table 3.10.3

Servo Signal Status
(99) Force control function enable input signal (FC-ENABLE)
(100) Force control positioning completion output signal (FC-IN)
(101) Force control ready output signal (FC-RDY)

3.11 Test run

After completing the force control parameter settings, users can perform test run of force control by following the steps below.

1. Write the following PDL example to servo drive to facilitate the setting of the initial position and the near position.

```
_FC_SET_INIT_POS: //init. position
X_FC_test_run_init_pos = dFbPos;
ret;

_FC_SET_NEAR_POS: //near position
X_FC_test_run_near_pos = dFbPos;
ret;
```

2. Open “Test Run” window in Thunder to set the motion conditions, the initial position, and the near position. The setting steps are as follows:

   (1) Move the motor to the expected initial position and execute FC_SET_INIT_POS (record the motor’s current position in the variable of **the initial position**).
   (2) Next, move the motor to the expected near position and execute FC_SET_NEAR_POS (record the motor’s current position in the variable of **the near position**).
   (3) Adjust the following variables to set force control test run conditions and confirm the performance.

Table 3.11.1

Variable	Unit	Description
X_FC_test_run_press_ms	ms	Set the pressing time, that is, the duration in seconds when switching to force control mode. Example: Setting 1000 indicates a 1-second duration in force control mode.
X_FC_test_run_num	times	Set the execution times of test run. Example: Setting 5 indicates executing test run for 5 times. (Set 0 for infinite times)
FC.settle_time_ms	ms	Positioning time of force control.
FC.move_time_ms	ms	Moving time of force control.
FC.move_settle_time_ms	ms	Total time of force control.

(4) Trigger force control test run. Execute FC_TEST_RUN, and the motor will move with the motion conditions of P2P. First, the motor will move to the initial position, then to the near position to trigger force control function. The operation example and description are as follows.

Note: If an emergency stop is required during test run, press the keyboard shortcut F12.

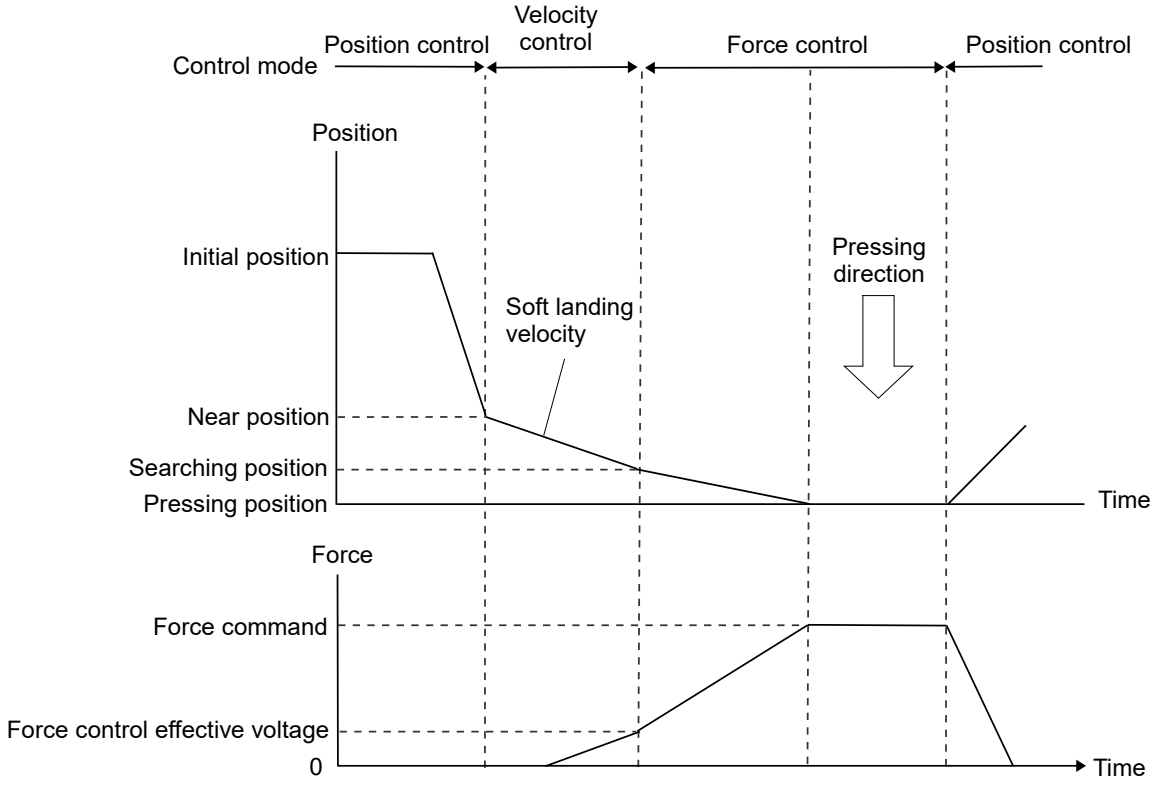


Figure 3.11.1

- **Position control - Approaching phase**

  The servo drive operates in position mode. During this phase, the motor rapidly moves from a safe position to a position close to the workpiece surface. When the motor reaches the preset near position, the control mode automatically switches to velocity mode, preparing for the soft landing process.

- **Velocity control - Soft landing phase**

  Upon entering this phase, the control mode automatically switches to velocity control. The motor continues to move steadily at the soft landing velocity until contact with the workpiece is made. Throughout this process, the servo drive continuously monitors the force feedback signal, preparing for the switching to force control mode.

- **Force control - Pressing phase**
  Once the force feedback detected by the force sensor reaches the force control effective voltage, confirming contact with the workpiece, the servo drive automatically switches to force control mode. In this mode, the servo drive adjusts its output to achieve and maintain the target pressing force.

- **Position control - Return upon completion phase**
  When force control is completed (e.g., reaching the pressing time), the servo drive switches from force control mode back to position mode. The motor then moves away from the workpiece and back to a safe position.

4. The ways to operate force control

This chapter describes the procedure examples for using force control with E series servo drive.

4.1 Operate force control with EtherCAT communication

1. Complete the setting procedure in chapter 3 and ensure that test run can be operated normally.
2. Use the host controller to move the motor from the initial position to the near position in cyclic synchronous position mode (csp).
3. After reaching the near position, set 6060h (Mode of operation) to -2 to switch to force control mode. The servo drive will automatically switch between profile velocity mode and force control mode and execute force control.
4. Monitor the relevant statuses by reading objects (refer to section 3.10) and ensure that force feedback has reached the set value.
5. After force control is completed, update the target position of the axis on the controller. Align the target position 607Ah (Target position) with the actual position 6064h (Position actual value).
6. Set 6060h (Mode of operation) to 8 to disable force control, switch back to cyclic synchronous position mode, and move the motor to the initial position.

4.2 Operate force control with pulse input

1. Complete the setting procedure in chapter 3 and ensure that test run can be operated normally.
2. Use the host controller to move the motor from the initial position to the near position in position mode.
3. Set force control function enable input (FC-ENABLE) signal to ON to switch to force control mode.
4. Read the relevant statuses (refer to section 3.10) for monitoring and ensure that force feedback has reached the set value.
5. After force control is completed, update the target position of the axis on the controller. Align the pulse command with the actual feedback position.
6. Set force control function enable input (FC-ENABLE) signal to OFF to disable force control, switch back to position mode, and move the motor to the initial position.

5. Troubleshooting

5.1 Relevant alarms

When force control alarm AL.d0A occurs, check the cause of the alarm and the corrective actions via force control function interface in Thunder or by observing the variable FC.err.all. The description of the corresponding bits for variable FC.err.all is shown in the table below.

Table 5.1.1

bit	Alarm Name	Cause	Corrective Action
0	Force deviation overflow	Force deviation exceeds the alarm value for overflow force control deviation (Pt4C5).	(1) The sensor feedback may be abnormal. Check if the force sensor feedback signal is normal. (2) Check if the force command value setting is too sharp and properly adjust force control command slope limit (Pt4CF). (3) Check if the alarm value for overflow force control deviation (Pt4C5) is appropriate. (4) The force control gain is not properly tuned. Refer to the description in section 3.9 Force control gain tuning.
1	Force sensor feedback overflow	Force sensor feedback exceeds the alarm value for overflow force control feedback (Pt4CA).	(1) The sensor feedback may be abnormal. Check if the force sensor feedback signal is normal. (2) The force control gain is not properly tuned. Refer to the description in section 3.9 Force control gain tuning. (3) Check if the alarm value for overflow force control feedback (Pt4CA) is appropriate. (4) Mechanical factors (such as mechanical interference). Ensure that the motion path is free of interference.
2	Time limit is exceeded during soft landing	During soft landing execution, the servo drive fails to detect that the force feedback has reached the effective voltage (Pt4CC) within the set time (Pt4CB), indicating unsuccessful contact.	(1) The sensor feedback may be abnormal. Check if the force sensor feedback signal is normal. (2) The soft landing velocity is too fast / slow, affecting the force detection. Refer to section 3.7 Force control soft landing setting to properly adjust the relevant parameters. (3) Poor mechanical contact, possibly due to uneven contact surfaces or foreign objects.
3	Overtravel warning is triggered during force control	Overtravel warning is triggered during force control.	Check if the motor's travel distance exceeds the overtravel position during force control.

bit	Alarm Name	Cause	Corrective Action
4	The motor exceeds the range of travel distance protection in force control	During force control, the actual position of motor exceeds the set protection range (Pt4BE, Pt4BF).	(1) The sensor feedback may be abnormal. Check if the force sensor feedback signal is normal. (2) The force control gain is not properly tuned. Refer to the description in section 3.9 Force control gain tuning. (3) Check if the upper limit of force control travel distance protection (Pt4BE) and the lower limit of force control travel distance protection (Pt4BF) are appropriate. (4) The force command is set too large / small, causing the motor to move outside the set range in force control.
5	The force controller reaches the limit value for a long time during force control	Force control output exceeds the force control output limit (Pt4B2 or Pt4B6) and lasts longer than Pt4CD.	(1) The sensor feedback may be abnormal. Check if the force sensor feedback signal is normal. (2) The force control gain is not properly tuned. Refer to the description in section 3.9 Force control gain tuning. (3) Refer to section 3.6 Force control safety protection setting, and properly adjust Pt4B2 or Pt4B6, as well as Pt4CD. (4) Possible insufficient motor torque or insufficient drive current output. Chek and re-evaluate the motor and drive models.