Control Mode 6

This chapter describes the control structure of each mode, including gain adjustment and filters. For Position mode, you use the external pulse and commands from the internal registers. For Speed mode and Torque mode, apart from the commands from the internal registers, you can also control the servo drive by the analog voltage input. In addition to the single modes, dual modes and multi-modes are also available for meeting the application requirements.

6.1 Selecting the control mode

This servo drive provides three basic control modes, Position, Speed, and Torque, and communication modes. For the basic control mode, you can choose from single mode, dual mode, and multi-mode. The following table lists all the available modes and corresponding descriptions.

Mode		Short name	Code	Description
Single mode	Position mode (Terminal block input)	PT	00	The servo drive receives the Position command and commands the motor to run to the target position. The Position commands are communicated through the external terminal block and the signal type is pulse.
	Position mode (Internal register)	PR	01	The servo drive receives the Position command and commands the motor to run to the target position. The Position commands are issued from the internal registers (100 sets in total). Select the register number with DI signals or through communication.
	Speed mode	S	02	The servo drive receives the Speed command and commands the motor to run at the target speed. The Speed commands are issued from the internal registers (3 sets in total) or by analog voltage (-10V to +10V) which is communicated through the external terminal block. Select the command with DI signals.
	Speed mode (No analog input)	Sz	04	The servo drive receives the Speed command and commands the motor to run at the target speed. The Speed command can only be issued from the internal registers (3 sets in total) instead of through the external terminal block. Select the command with DI signals.
	Torque mode	T	03	The servo drive receives the Torque command and commands the motor to run with the target torque. The Torque commands are issued from the internal registers (3 sets in total) or by analog voltage (-10V to +10V) which is communicated through the external terminal block. Select the command with DI signals.
	Torque mode (No analog input)	Tz	05	The servo drive receives the Torque command and commands the motor to run with the target torque. The Torque command can only be issued from the internal registers (3 sets in total) instead of through the external terminal block. Select the command with DI signals.
Dual mode		PT-S	06	Switch PT and S modes with DI signals.
		PT-T	07	Switch PT and T modes with DI signals.
		PR-S	08	Switch PR and S modes with DI signals.
		PR-T	09	Switch PR and T modes with DI signals.
		S-T	0A	Switch S and T modes with DI signals.
		PT-PR	0D	Switch PT and PR modes with DI signals.
Communication mode		CANopen	0B	The dedicated communication mode for Delta's DVP-15MC PLC controller.
		DMCNET		DMCNET mode.
		CANopen	0C	CANopen mode.
		EtherCAT		EtherCAT mode.
		PROFINET		PROFINET mode.

Mode	Short name	Code	Description
Multi-mode	PT-PR-S	0E	Switch PT, PR, and S modes with DI signals.
	PT-PR-T	0F	Switch PT, PR, and T modes with DI signals.

Here are the steps to switch the control modes:

1. Switch the servo drive to Servo Off status. You can do this by setting DI.SON to off.
2. Set P1.001 by referring to the codes listed in the preceding table to set the control mode.
3. After setting the parameter, cycle the power to the servo drive.

The following sections describe the operation of each mode, including the control structure, command source and selection, command processing, and gain adjustment.

6.2 Position mode

6

The servo drive provides two input modes for position control: external pulse (PT mode) and internal register (PR mode). In PT mode, the servo drive receives the pulse command for direction (motor runs forward or reverse). You can control the rotation angle of the motor with the input pulse. The servo drive can receive pulse commands of up to 4 Mpps.

You can also accomplish position control using the internal register (PR mode) without the external pulse command. The servo drive provides 100 command registers. Set the 100 registers first before switching the drive to Servo On status. There are two ways to select the commands. One is setting DI.POS0 - DI.POS6 of CN1, and the other is directly setting the register values through communication.

6.2.1 Position command in PT mode

The PT Position command is the pulse input from the terminal block. There are three pulse types and each type has positive and negative logic that you can set in P1.000. Refer to Chapter 8 for more details.

Parameter	Function
P1.000	External pulse input type

6

6.2.2 Position command in PR mode

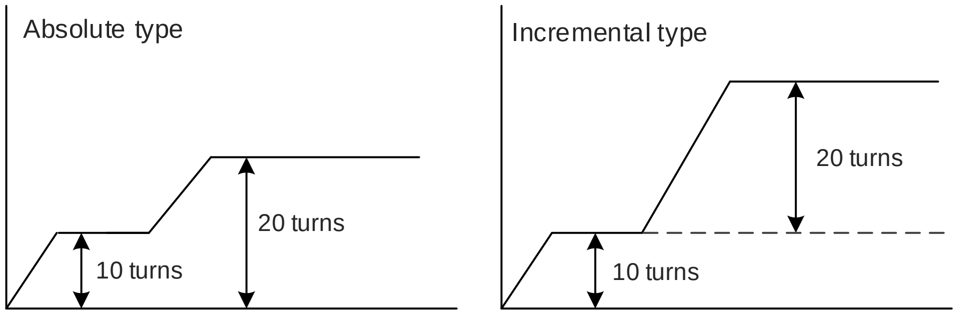
The PR command source is the 100 sets of internal command registers (P6.000 - P7.099). Use DI (0x11, 0x12, 0x13, 0x1A, 0x1B, 0x1C, 0x1E) (POS0 - POS6 of CN1) to select one of the 100 sets as the Position command and then trigger the command with DI.CTRG (0x08). See the following table for more details.

Position command	POS6	POS5	POS4	POS3	POS2	POS1	POS0	CTRG	Corresponding parameter
Homing	0	0	0	0	0	0	0	↑	P6.000
									P6.001
PR#1	0	0	0	0	0	0	1	↑	P6.002
									P6.003
…									…
PR#50	0	1	1	0	0	1	0	↑	P6.098
									P6.099
PR#51	0	1	1	0	0	1	1	↑	P7.000
									P7.001
…									…
PR#99	1	1	0	0	0	1	1	↑	P7.098
									P7.099

Status of POS0 - POS6: 0 means that DI is off (the circuit is open); 1 means that DI is on (the circuit is closed).

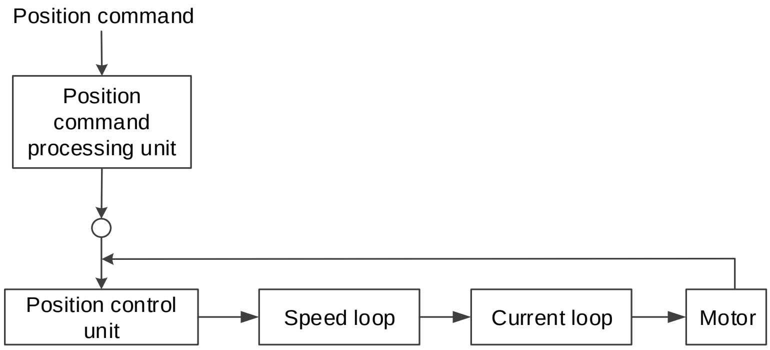
CTRG↑: this indicates the moment the DI is switched from off to on.

The absolute type and incremental type position registers are used to control the operation process. You can easily complete a periodic motor operation according to the preceding table. For example, if the Position command PR#1 is 10 turns and PR#2 is 20 turns, when PR#1 is issued first and PR#2 comes second, the difference between absolute and incremental positioning is shown in the following diagrams.

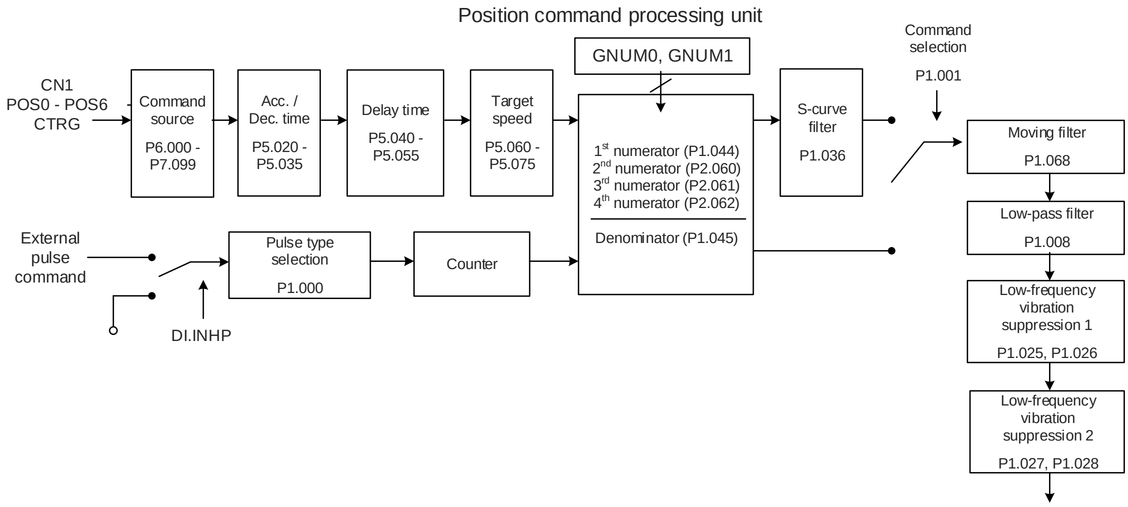


6.2.3 Control structure of Position mode

The following diagram shows the basic control structure of Position mode.



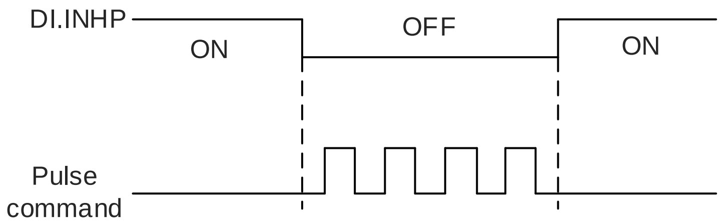
For better control, the pulse signals are processed by the Position command processing unit. The structure is shown in the following diagram.



In the diagram, the upper path is the PR mode and the lower one is the PT mode, which you can select with P1.001. You can set the E-Gear ratio in both modes to adjust the positioning resolution. In addition, you can use either a moving filter or low-pass filter to smooth the command. Refer to the following sections for more details.

The Pulse Command Input Inhibit (INHP) function

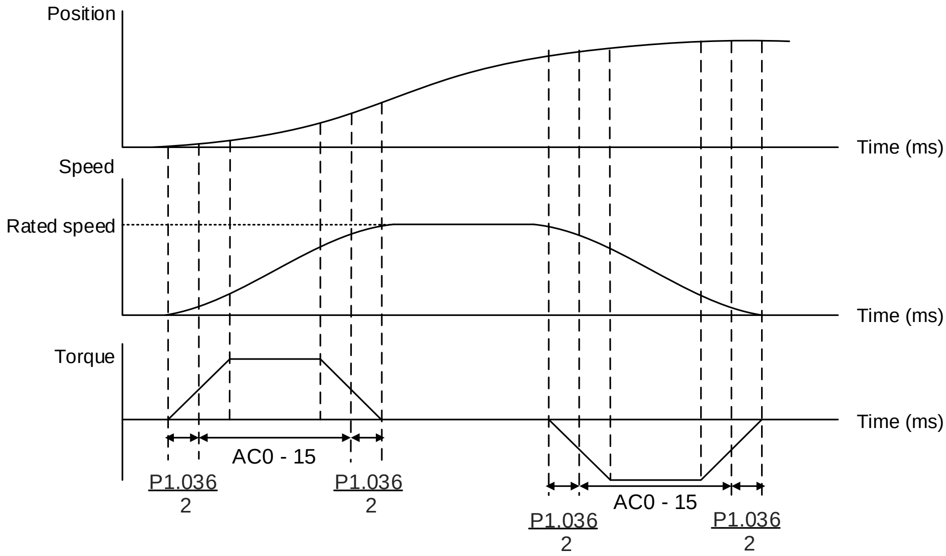
In PT mode, when DI.INHP is on, the servo drive stops receiving external pulse commands and the motor stops running. As this function is only supported by P2.013 (DI4 functional planning), setting P2.013 to 0x45 (DI.INHP) is required.



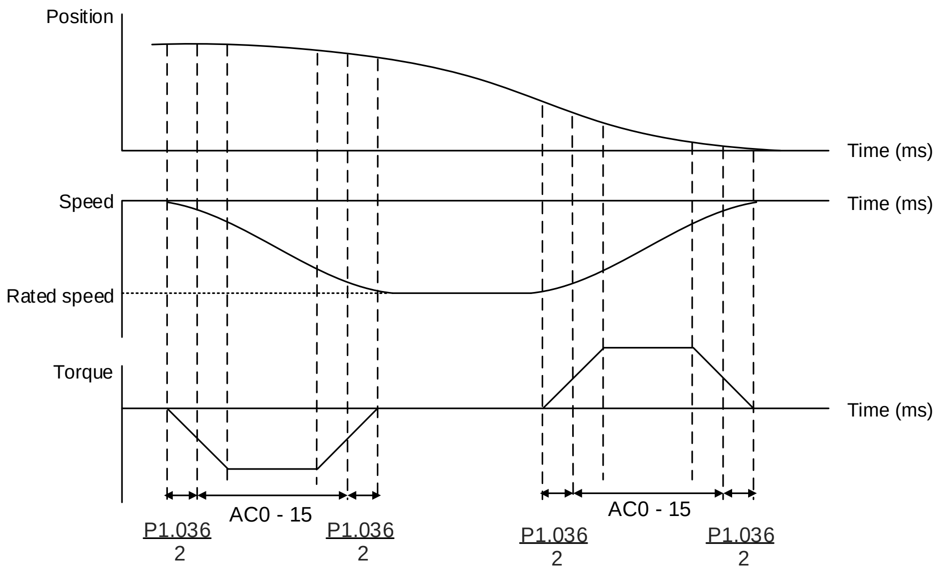
6

6.2.4 S-curve filter for Position commands

The S-curve filter for Position commands smoothes the motion command in PR mode. The filter makes the speed and acceleration continuous and reduces jerking, resulting in a smoother mechanical operation. If the load inertia increases, the motor operation is influenced by friction and inertia when the motor starts or stops rotating. Setting a larger acceleration / deceleration constant for the S-curve (P1.036) and the acceleration / deceleration time in P5.020 - P5.035 can increase the smoothness of operation. When the Position command source is the pulse input, the speed and angular acceleration are continuous, so the S-curve command filter is not necessary.



S-curve speed profile of Position command and time setting (incremental position command)



S-curve speed profile of Position command and time setting (decremental position command)

Refer to Chapter 8 for detailed descriptions of the relevant parameters.

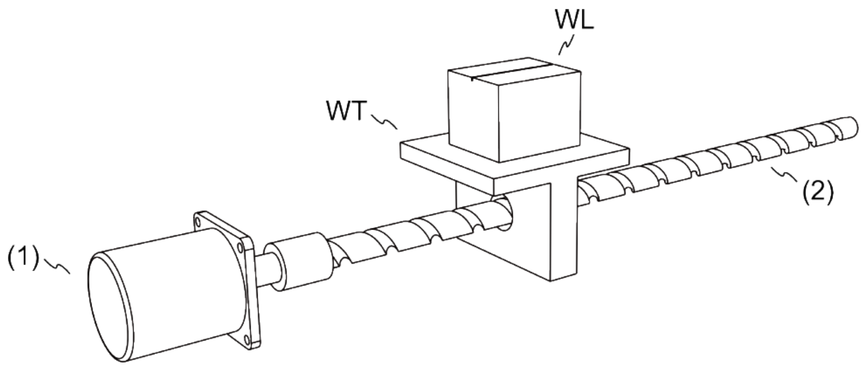
Parameter	Function
P1.036	S-curve acceleration / deceleration smoothing constant
P5.020 - P5.035	Acceleration / deceleration times (#0 - 15)

6.2.5 Electronic gear ratio (E-Gear ratio)

The electronic gear provides easy settings for the resolution. The resolution of the servo drive is 24-bit, which means 16,777,216 pulses are generated per motor revolution. Regardless of the encoder resolution (17-bit, 20-bit, or 22-bit), the E-Gear ratio is set according to the 24-bit resolution of the servo drive.

When the E-Gear ratio is 1, it means 16,777,216 pulses are generated per motor revolution; when the E-Gear ratio is 0.5, then every two pulses from the command (controller) corresponds to one pulse for the motor. However, larger E-Gear ratio might create a sharp corner in the profile and lead to a high jerk. To solve this problem, apply an S-curve command filter or a low-pass filter.

For example, if the workpiece is moved at the speed of 1 μm/pulse after you set a proper E-Gear ratio, then it means the workpiece moves 1 μm per pulse.



(1) Motor; (2) Ball screw pitch: 3 mm (equals 3,000 μm); WL: workpiece; WT: platform

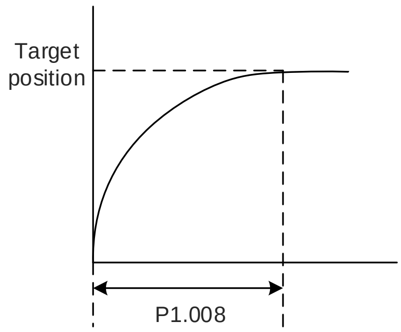
	Gear ratio	Moving distance per 1 pulse command
E-Gear is not applied	$= \frac{1}{1}$	$= \frac{3000 \frac{\mu m}{rev}}{16777216 \frac{pulse}{rev}} \times \frac{1}{1} = \frac{3000}{16777216}$ (Unit: $\frac{\mu m}{pulse}$)
E-Gear is applied	$= \frac{16777216}{3000}$	$= \frac{3000 \frac{\mu m}{rev}}{16777216 \frac{pulse}{rev}} \times \frac{16777216}{3000} = 1$ (Unit: $\frac{\mu m}{pulse}$)

Refer to Chapter 8 for detailed descriptions of the relevant parameters.

Parameter	Function
P1.044	E-Gear ratio - numerator N1
P1.045	E-Gear ratio - denominator M

6

6.2.6 Low-pass filter

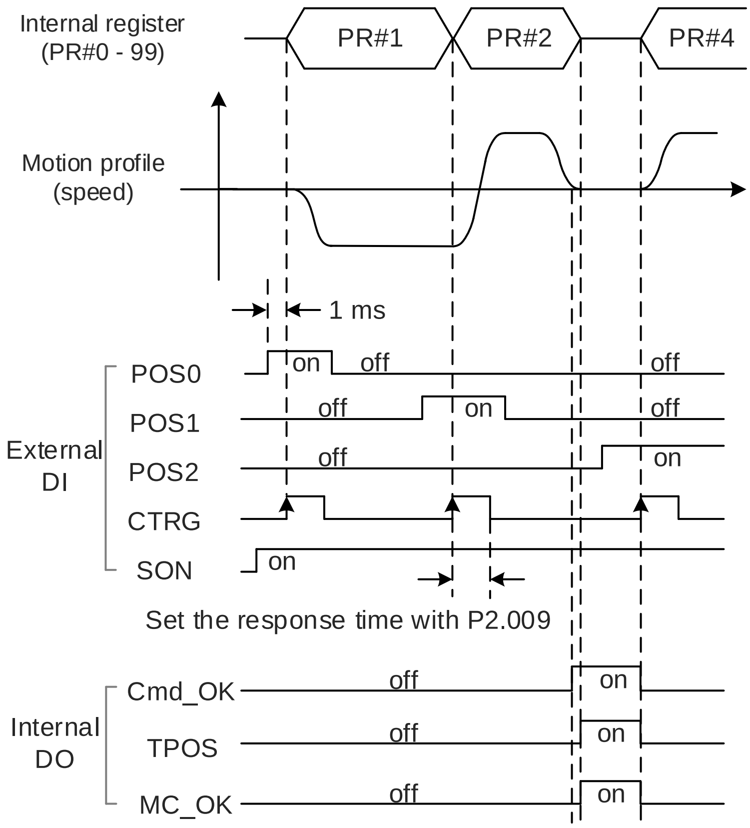


Refer to Chapter 8 for detailed descriptions of the relevant parameter.

Parameter	Function
P1.008	Position command - smoothing constant (low-pass filter)

6.2.7 Timing diagram of PR mode

In PR mode, the Position command is selected with the DI signals (POS0 - POS6 and CTRG) of CN1. Refer to Section 6.2.2 for information about the DI signals and the selected register. The timing diagrams are shown as follows.



Note: Cmd_OK is on when the PR command is complete; TPOS is on when the position error is smaller than the value set by P1.054; MC_OK is on when Cmd_OK and TPOS are both on.

6.2.8 Gain adjustment of the position loop

There are two types of gain adjustment for the position loop: auto and manual.

■ Auto

The servo drive can complete the gain adjustment with the Auto Tuning function. Refer to Chapter 5 Tuning for a detailed description.

■ Manual

Before setting the position control unit, you have to manually set the speed control unit with P2.004 and P2.006 since a speed loop is included in the position loop. Then, set the position control gain (P2.000) and position feed forward gain (P2.002).

Description of the position control gain and position feed forward gain:

1. Position control gain: the higher the gain, the larger bandwidth for the position loop response.
2. Position feed forward gain: the higher the gain, the smaller the deviation of phase delay.

Note that the position loop bandwidth should not be larger than the speed loop bandwidth.

Calculation: $fp \leq \frac{fv}{4}$ (fv: response bandwidth (Hz) of speed loop;

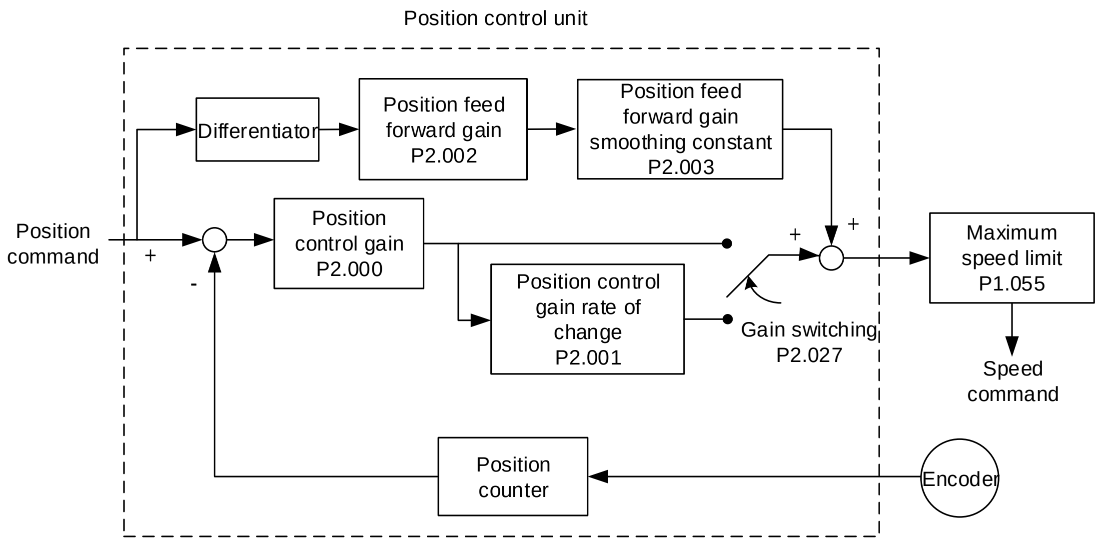
fp: response bandwidth (Hz) of position loop)

$KPP = 2 \times \pi \times fp$

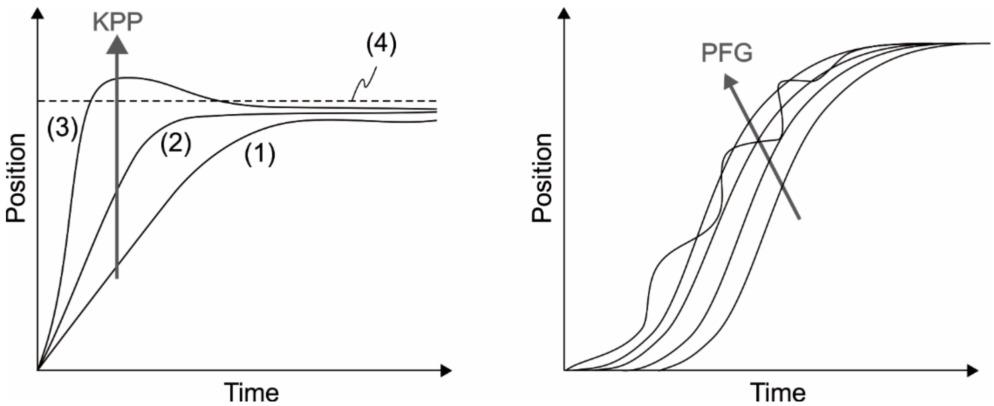
Example: if the desired position bandwidth is 20 Hz, then adjust KPP (P2.000) to 125. ($2 \times \pi \times 20$ Hz = 125)

Refer to Chapter 8 for detailed descriptions of the relevant parameters.

Parameter	Function
P2.000	Position control gain
P2.002	Position feed forward gain



When you set the value of KPP (P2.000) too high, the bandwidth for the position loop is increased and the phase margin is reduced. Meanwhile, the rotor rotates and vibrates in the forward and reverse directions. Then, you have to decrease the KPP value until the rotor stops vibrating. When the external torque is too high, the low value for KPP cannot meet the demand of reducing the position following error. In this case, increasing the position feed forward gain, PFG (P2.002), can effectively reduce the position following error.



The actual position profile changes from (1) to (3) with the increase in the KPP value.
(4) stands for the Position command.

6.2.9 Low-frequency vibration suppression in Position mode

If the machine is too flexible, vibration persists even when the motor stops after the positioning command is complete. The low-frequency vibration suppression function can reduce the machine vibration. The suppression range is between 1.0 Hz and 100.0 Hz. You can use this function with either auto or manual setting.

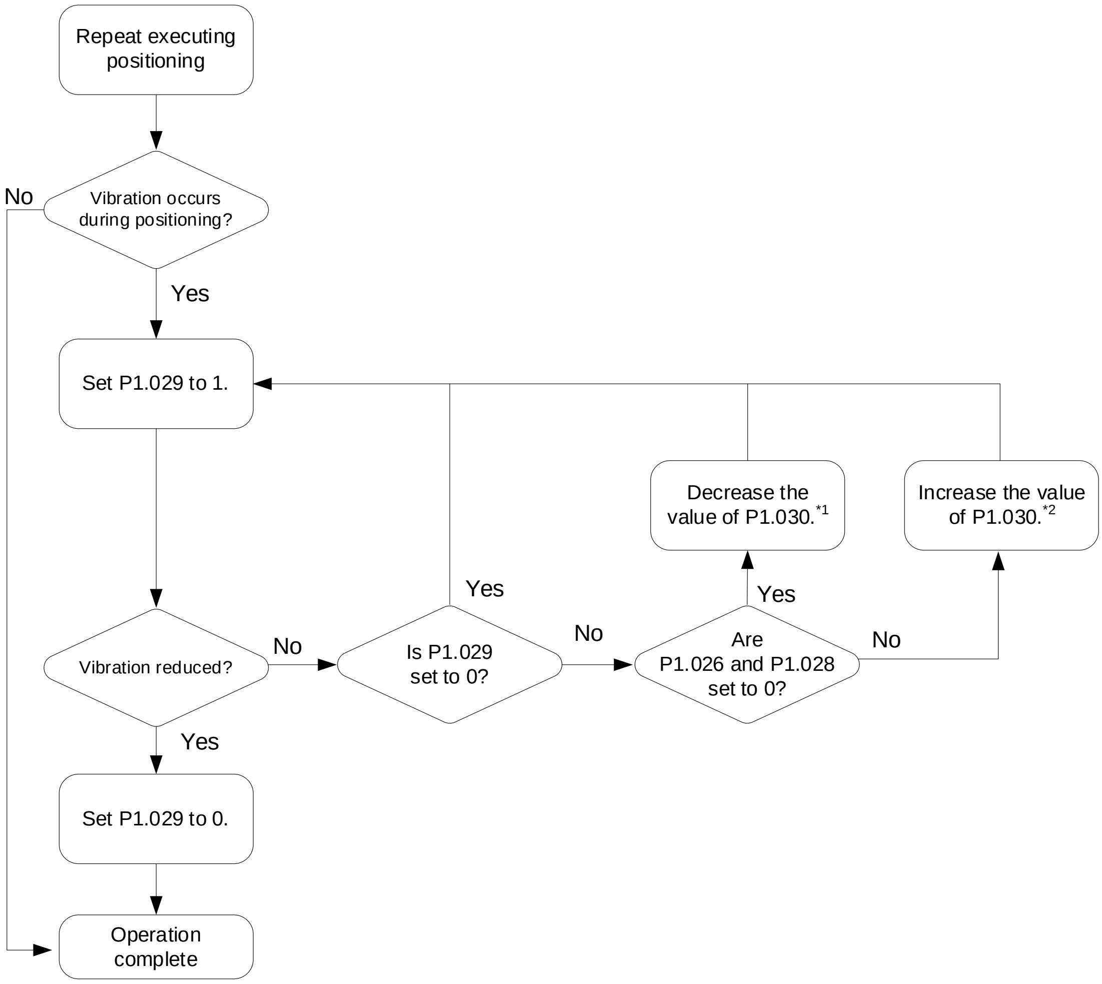
Auto setting

If you have difficulty finding the frequency, enable the auto low-frequency vibration suppression function, which automatically searches for the vibration frequency.
When you set P1.029 to 1, the system automatically disables the auto low-frequency vibration suppression function (by setting P1.026 and P1.028 to 0) and starts to search for the vibration frequency. When the detected frequency remains at the same level, the system automatically changes the settings in the following order.

1. Sets P1.029 to 0.
2. Sets P1.025 to the first frequency and sets P1.026 to 1.
3. Sets P1.027 to the second frequency and sets P1.028 to 1.

When P1.029 is automatically reset to 0, but the low-frequency vibration persists, check if P1.026 or P1.028 is set to 1. If either P1.026 or P1.028 is 1, increase the setting of P1.030 (low-frequency vibration detection). If the values of P1.026 and P1.028 are both 0, it means no vibration frequency is detected. In this case, lower the value of P1.030 and set P1.029 to 1 to search for the vibration frequency again. Note that when you set the detection level too low, it might detect noise as the low-frequency vibration.

The process of automatically searching for the vibration frequency is shown in the following flowchart.



Note:

1. When the values of P1.026 and P1.028 are both 0, it means the frequency cannot be found. It is probably because the detection level is set too high causing the low-frequency vibration not being able to be detected.
2. When the value of P1.026 or P1.028 is greater than 0, but the vibration cannot be suppressed, it is probably because the detection level is too low causing the system to detect minor frequency or noise as low-frequency vibration.
3. When the auto suppression procedure is complete, but the vibration persists, you can manually set P1.025 or P1.027 to suppress the vibration if you have identified the low frequency.

P1.030 sets the detection range for the peak-to-peak amplitude of low-frequency vibration. When the frequency is not detected, it is probably because you set the value of P1.030 too high and it exceeds the vibration range. If so, it is suggested that you decrease the value of P1.030. Note that if the value is too small, the system might detect noise as the low-frequency vibration. In this case, you can use the Scope function of ASDA-Soft and set the channel to “Position error (pulse)” to observe the peak-to-peak amplitude of the signal during positioning for setting P1.030.

Refer to Chapter 8 for detailed descriptions of the relevant parameters.

Parameter	Function
P1.029	Auto low-frequency vibration suppression mode
P1.030	Low-frequency vibration detection

Manual setting

There are two sets of low-frequency vibration suppression parameters: one is parameters P1.025 - P1.026 and the other is parameters P1.027 - P1.028. You can use these two sets of low-frequency vibration suppression parameters to reduce two different low-frequency vibrations.

Use P1.025 and P1.027 to set the frequencies when the low-frequency vibrations occur. The suppression function works only when the set frequency is close to the real vibration frequency.

Use P1.026 and P1.028 to set the response after frequency filtering. The bigger the values of P1.026 and P1.028, the better the response. However, if you set the values too high, the motor might not operate smoothly. The default values of P1.026 and P1.028 are 0, which means the two filters are disabled by default.

Refer to Chapter 8 for detailed descriptions of the relevant parameters.

Parameter	Function
P1.025	Low-frequency vibration suppression frequency 1
P1.026	Low-frequency vibration suppression gain 1
P1.027	Low-frequency vibration suppression frequency 2
P1.028	Low-frequency vibration suppression gain 2

6.3 Speed mode

There are two kinds of command sources: analog input and internal register (parameters). The analog command controls the motor speed by scaled external voltage input. The command register input controls the motor speed in two ways. Before operation, respectively set the speed values in three registers. Then, you can switch among the three sets of speed either by using DI.SPD0 and DI.SPD1 of CN1 or change the value in the register through communication. In order to deal with the problem of non-continuous speed when switching registers, you can use the S-curve acceleration and deceleration filter.

6.3.1 Selecting the Speed command source

There are two types of Speed command sources: analog voltage and internal register (parameters). Select the command source with DI signals of CN1. See the following table for more details.

Speed command number	CN1 DI signal		Command source			Content	Range
	SPD1	SPD0					
S1	0	0	Mode	S	External analog signal	Voltage difference between V_REF and GND	-10V to +10V
				Sz	N/A	Speed command is 0	0
S2	0	1	Internal register (parameter)			P1.009	-75000 to +75000
S3	1	0				P1.010	-75000 to +75000
S4	1	1				P1.011	-75000 to +75000

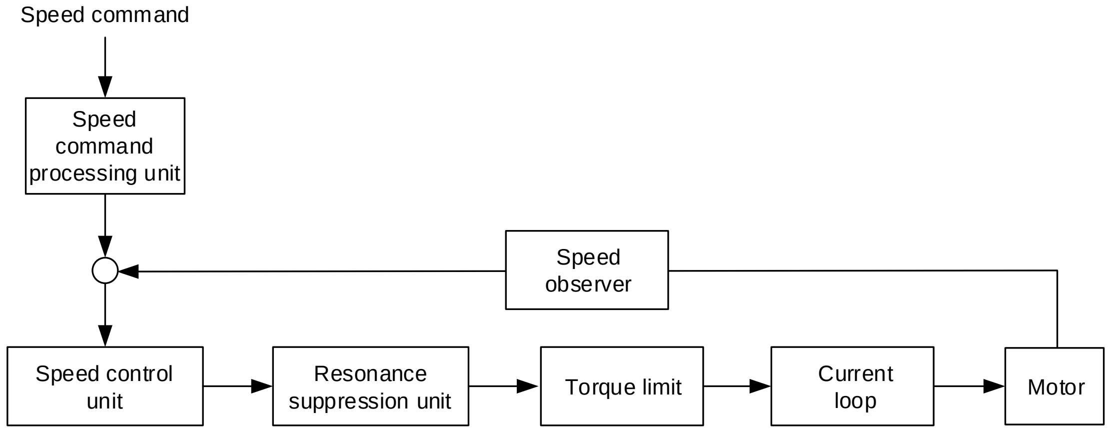
- Status of SPD0 and SPD1: 0 means that DI is off (the circuit is open); 1 means that DI is on (the circuit is closed).
- When both SPD0 and SPD1 are 0, if the drive is in Sz mode, the command is 0. Thus, if there is no need to use the analog voltage for the Speed command, you can use Sz mode to avoid the problem of zero drift in the voltage. If the drive is in S mode, then the command is the voltage difference between V_REF and GND. The range of the input voltage is between -10V and +10V, and you can adjust the corresponding speed with P1.040.
- When either one of SPD0 and SPD1 is not 0, the internal parameters become the source for the Speed command. The command is activated once the status of SPD0 and SPD1 are switched. There is no need to use DI.CTRG for triggering.
- The parameter setting range (internal register) is -75000 to +75000.
  Rotation speed = setting value x unit (0.1 rpm). For example, if P1.009 = +30000,
  then rotation speed = +30000 x 0.1 rpm = +3000 rpm

You can use the Speed command in Speed mode (S or Sz) and Torque mode (T or Tz). When the drive is in Torque mode, you can use the Speed command input as the speed limit.

6

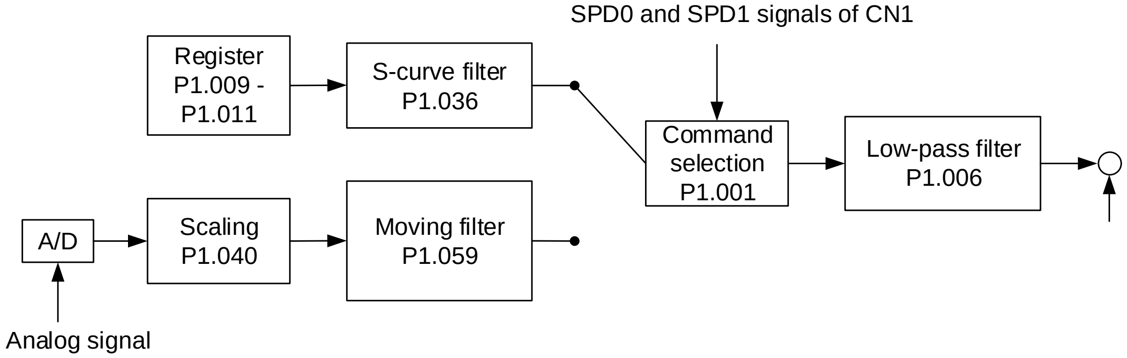
6.3.2 Control structure of Speed mode

The following diagram shows the basic control structure of Speed mode.



The Speed command processing unit selects the command source (see Section 6.3.1), including the scaling parameter (P1.040) for rotation speed corresponding to the analog voltage and the S-curve parameter (P1.036) for smoothing the speed. The speed control unit manages the gain parameters for the servo drive and calculates the current command for servo motor in real-time. The Resonance suppression unit suppresses the resonance of the machine.

The following diagram introduces the function of Speed command processing unit. Its structure is shown as follows.



The upper path is the command from the register and the lower one is the command from the external analog voltage, which you can select with the status of SPD0 and SPD1, and P1.001 (S or Sz). In this condition, the S-curve and low-pass filters are applied to achieve a smoother response.

6.3.3 Smoothing the Speed command

S-curve filter

During the process of acceleration or deceleration, the S-curve filter uses the three-stage acceleration curve and creates a smoother motion profile. Using the S-curve filter avoids jerk (rapid change of acceleration), resonance, and noise caused by abrupt changes in the speed input. You can use the following parameters for adjustment.

- The S-curve acceleration constant (P1.034) adjusts the slope of the change in acceleration.
- The S-curve deceleration constant (P1.035) adjusts the slope of the change in deceleration.
- The S-curve acceleration / deceleration smoothing constant (P1.036) improves the stability of the motor when it starts and stops.

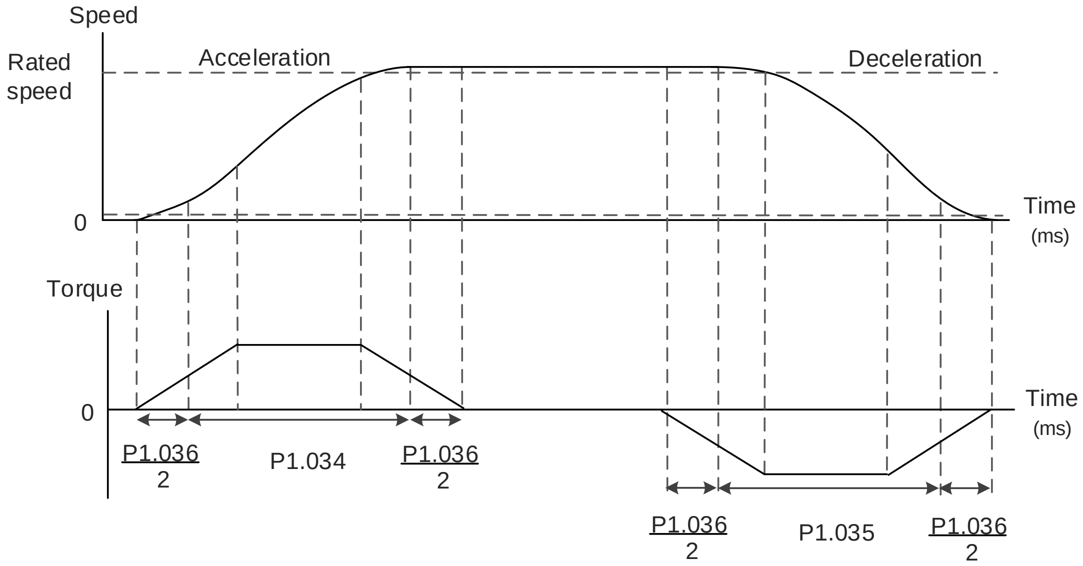


Figure 6.3.3.1 S-curve speed profile and time setting

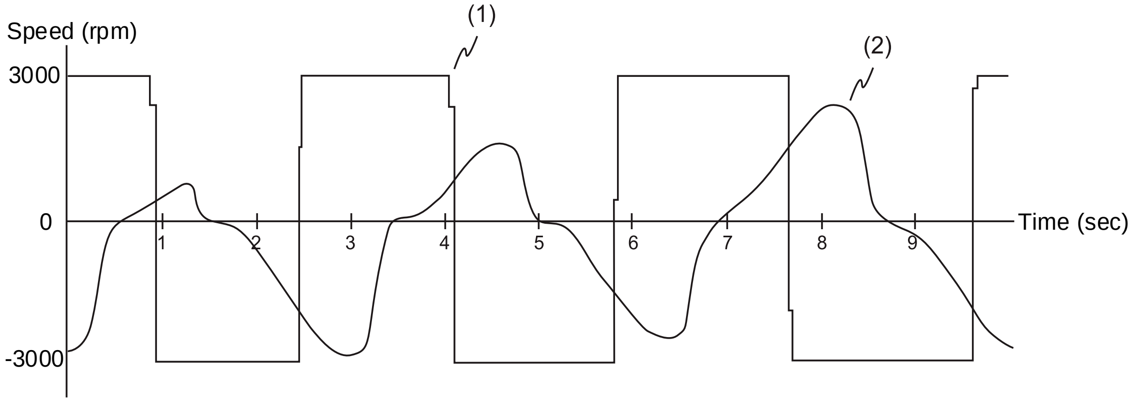
Refer to Chapter 8 for detailed descriptions of the relevant parameters.

Parameter	Function
P1.034	S-curve acceleration constant
P1.035	S-curve deceleration constant
P1.036	S-curve acceleration / deceleration smoothing constant

6

Analog Speed command filter

The Analog Speed command filter provided by the servo drive helps to stabilize the motor operation when the analog input signal (speed) changes rapidly.



(1) Analog Speed command; (2) Motor speed

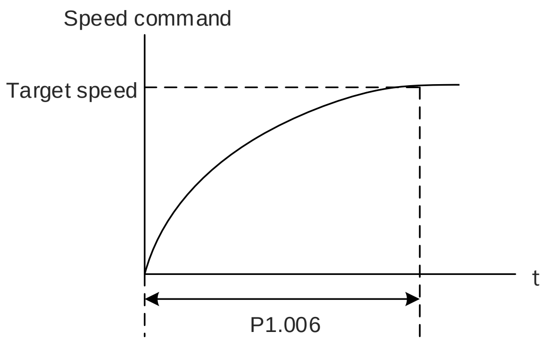
The filter for smoothing the analog input commands is the same as the S-curve filter in terms of the time program as well as the continuous speed and acceleration curves. In the preceding diagram, the slopes of the Speed command in acceleration and deceleration are different. Adjust the time settings (P1.034, P1.035, and P1.036) according to the actual application to improve the performance.

Low-pass filter for Speed commands

The low-pass filter is usually used to remove unwanted high-frequency response or noise so that the speed change is smoother.

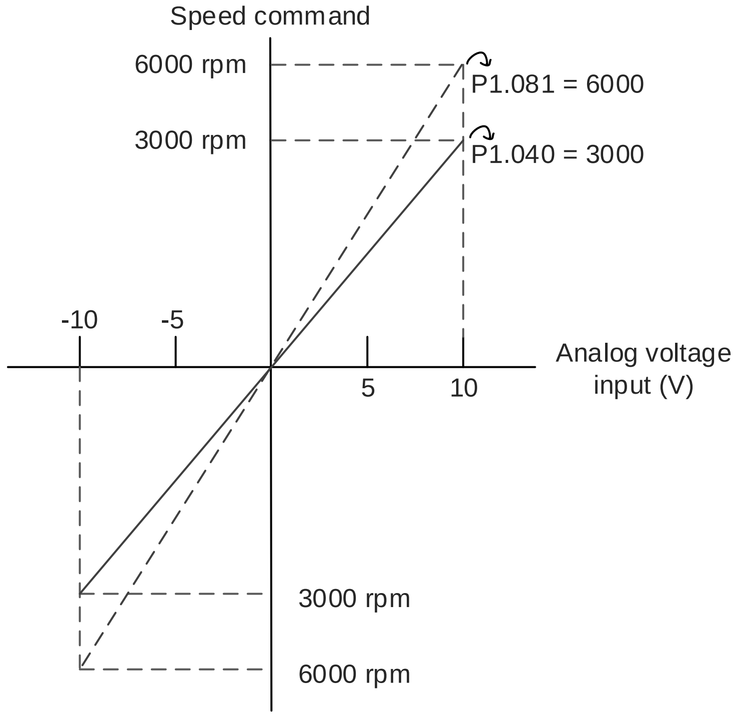
Refer to Chapter 8 for detailed descriptions of the relevant parameter.

Parameter	Function
P1.006	Speed command - smoothing constant (low-pass filter)



6.3.4 Scaling of the analog command

The Speed command is controlled by the analog voltage difference between V_REF and GND. Use P1.040 and P1.081 to adjust the slope of the speed change and its range. Moreover, you can use P1.082 to change the time constant for switching between P1.040 and P1.081.

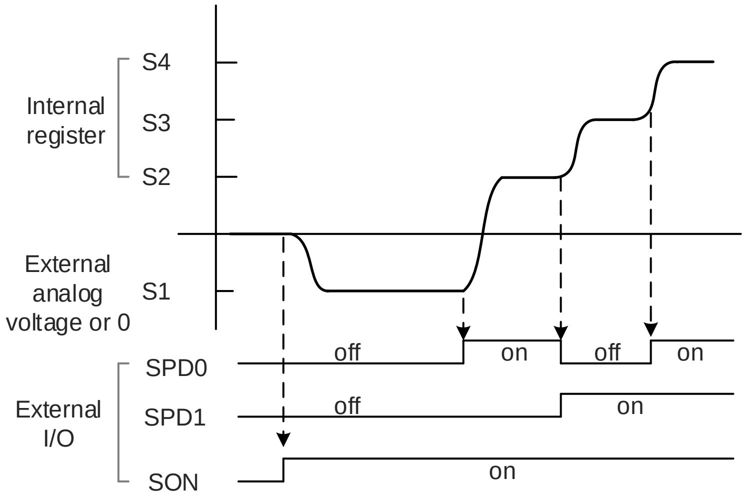


Refer to Chapter 8 for detailed descriptions of the relevant parameters.

Parameter	Function
P1.040	Maximum motor speed for analog Speed command 1
P1.081	Maximum motor speed for analog Speed command 2
P1.082	Time constant for switching between P1.040 and P1.081

6

6.3.5 Timing diagram of Speed mode



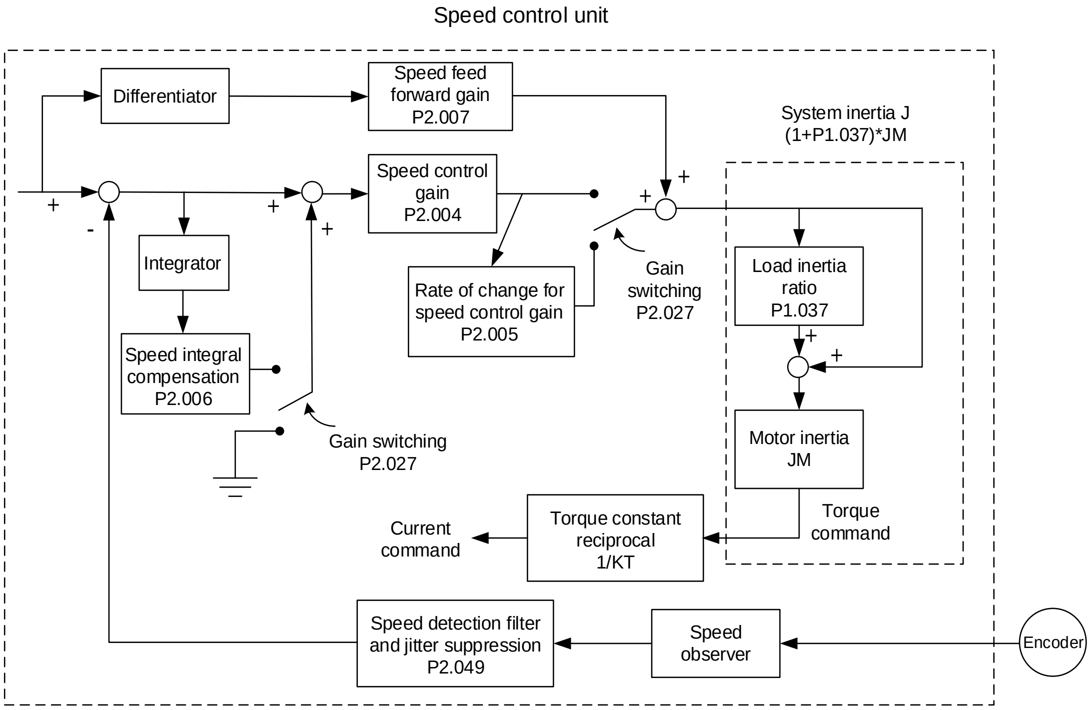
Note:

1. "off" means that DI is off (the circuit is open); "on" means that DI is on (the circuit is closed).
2. When the drive is in Sz mode, the Speed command S1 = 0; when the drive is in S mode, the Speed command S1 refers to the external analog voltage input.
3. In Servo On state, the command is selected according to the status of SPD0 and SPD1.

6

6.3.6 Gain adjustment of the speed loop

The structure of the speed control unit is shown in the following diagram.



In the speed control unit, you can adjust different types of gain manually or by using the multiple gain adjustment modes.

Manual: manually set the parameters with all auto or auxiliary functions disabled.

Gain adjustment mode: refer to Chapter 5 Tuning.

Manual mode

When you set P2.032 to 0, set the speed control gain (P2.004), speed integral compensation (P2.006), and speed feed forward gain (P2.007) as well. The parameter descriptions are as follows.

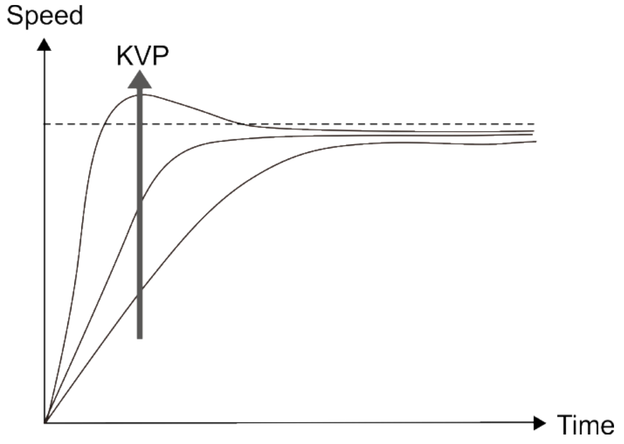
Speed control gain: the higher the gain, the larger the bandwidth for the speed loop response.
Speed integral compensation: increasing this gain increases the low frequency rigidity and reduces the steady-state error. However, the phase margin becomes smaller. If you set this gain too high, it reduces the system stability.
Speed feed forward gain: the higher the gain, the smaller the deviation of phase delay.

Refer to Chapter 8 for detailed descriptions of the relevant parameters.

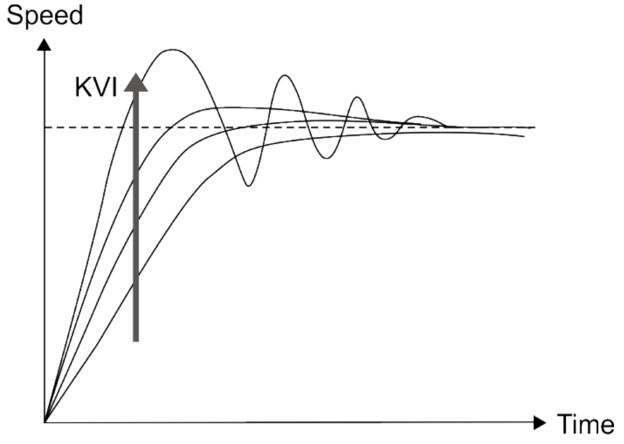
Parameter	Function
P2.004	Speed control gain
P2.006	Speed integral compensation
P2.007	Speed feed forward gain

Here, the step response is used to illustrate the basic principles for proportional gain (KVP), integral gain (KVI), and feed forward gain (KVF). Refer to the following examples.

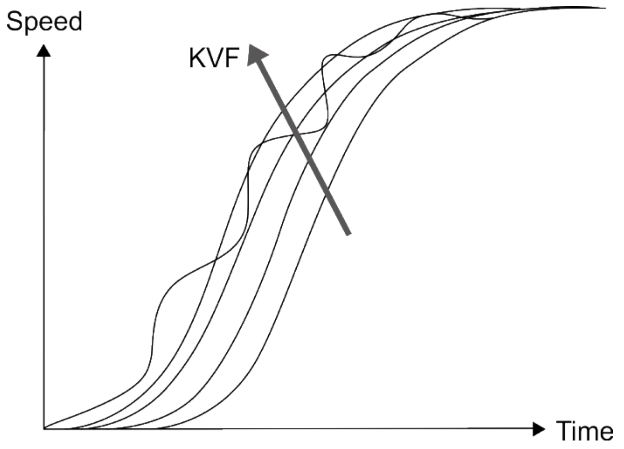
Time domain



The higher the KVP value, the larger the bandwidth. The time of the speed increase will also be shorter. However, if the KVP value is set too high, the phase margin is too small. The effect is not as good as KVI for the steady-state error but is better for the effect on following error.



The higher the KVI value, the larger the low-frequency gain. It shortens the time for the steady-state error to reduce to zero. However, it does not significantly reduce the following error.



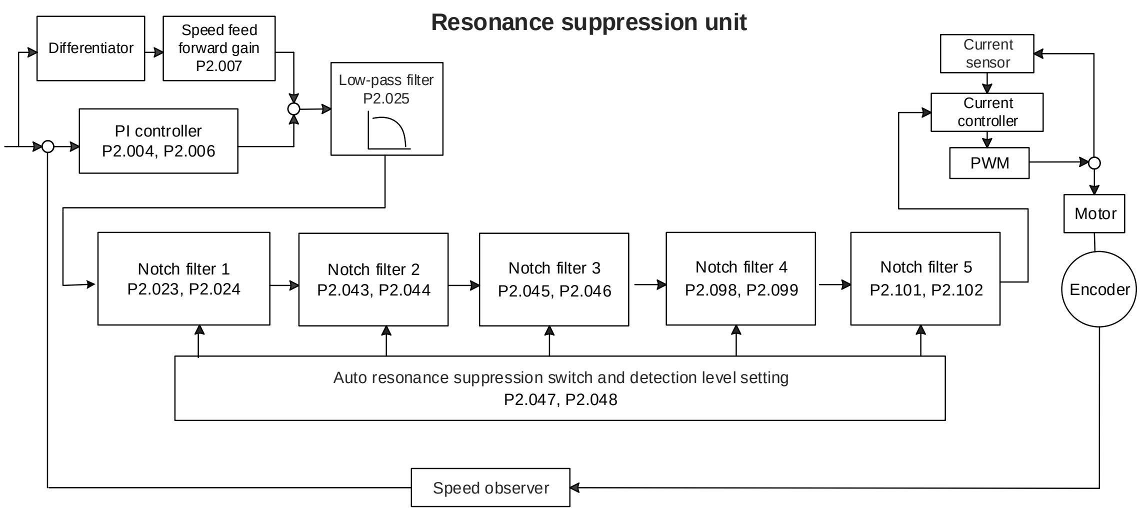
The closer the KVF value is to 1, the more complete the forward compensation.
The following error becomes very small.
However, a KVF value that is set too high also causes vibration.

6.3.7 Resonance suppression unit

When resonance occurs, it is probably because the stiffness of the control system is too high or the response bandwidth is too great. Eliminating these two factors can improve the situation. In addition, you can use the low-pass filter (P2.025) and Notch filter (P2.023, P2.024, P2.043 - P2.046, and P2.095 - P2.103) to suppress the resonance if you want the control parameters to remain unchanged.

Refer to Chapter 8 for detailed descriptions of the relevant parameters.

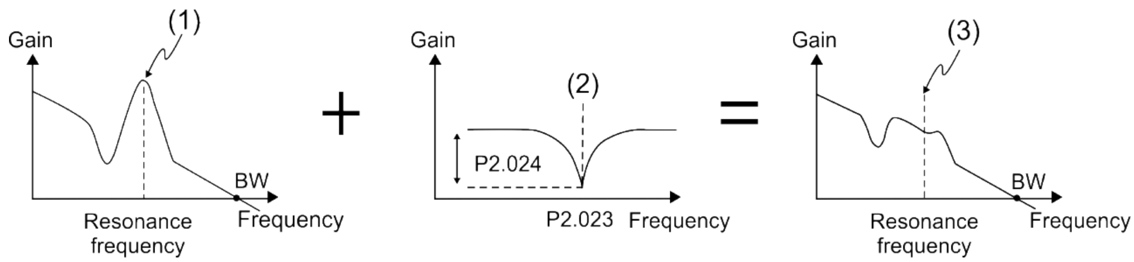
Parameter	Function
P2.023	Notch filter 1 - frequency
P2.024	Notch filter 1 - attenuation level
P2.025	Resonance suppression low-pass filter
P2.043	Notch filter 2 - frequency
P2.044	Notch filter 2 - attenuation level
P2.045	Notch filter 3 - frequency
P2.046	Notch filter 3 - attenuation level
P2.095	Notch filter 1 - Q factor
P2.096	Notch filter 2 - Q factor
P2.097	Notch filter 3 - Q factor
P2.098	Notch filter 4 - frequency
P2.099	Notch filter 4 - attenuation level
P2.100	Notch filter 4 - Q factor
P2.101	Notch filter 5 - frequency
P2.102	Notch filter 5 - attenuation level
P2.103	Notch filter 5 - Q factor



The servo drive provides two methods to suppress the resonance: one is the Notch filter and the other is the low-pass filter. See the following diagrams for the results of using these filters.

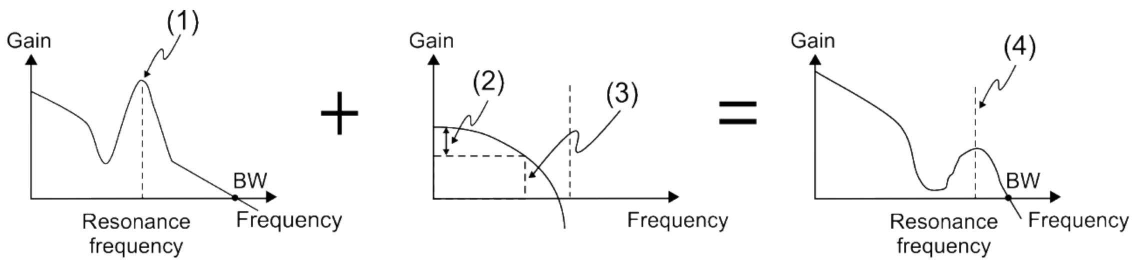
System open-loop gain with resonance:

- Notch filter



(1) Resonance point; (2) Notch filter; (3) Resonance point suppressed by the Notch filter

- Low-pass filter



(1) Resonance point; (2) Attenuation rate (-3 dB);

(3) Low-pass filter (Cutoff frequency of low-pass filter = 1000 / P2.025 Hz);

(4) Resonance point suppressed by the low-pass filter

To conclude from these two examples, if you increase the value of P2.025 from 0, the bandwidth (BW) becomes smaller. Although it solves the problem of resonance, it also reduces the response bandwidth and phase margin, making the system unstable.

If knowing the resonance frequency, you can suppress the resonance by using the Notch filter, which is better than using the low-pass filter in this condition. The setting range for the frequency of the Notch filter is 50 - 5000 Hz and the attenuation level is 0 - 40 dB. If the resonance frequency drifts significantly with time or due to other causes, using the low-pass filter to reduce the resonance is suggested.

6.4 Torque mode

The Torque control mode (T or Tz) is suitable for torque control applications, such as printing machines and winding machines. There are two kinds of command sources: analog input and internal register (parameters). The analog command input uses scaled external voltage to control the torque of the motor while the register input uses the internal parameters (P1.012 - P1.014) for the Torque command.

6.4.1 Selecting the Torque command source

There are two types of Torque command sources: external analog voltage and internal parameters.
Select the command source with DI signals of CN1. See the following table for more details.

<table>
<tr><th rowspan="2">Torque command number</th><th colspan="2">CN1 DI signal</th><th rowspan="2" colspan="3">Command source</th><th rowspan="2">Content</th></tr>
<tr><th>TCM1</th><th>TCM0</th></tr>
<tr><td rowspan="2">T1</td><td rowspan="2">0</td><td rowspan="2">0</td><td rowspan="2">Mode</td><td>T</td><td>External analog signal</td><td>Voltage difference between T_REF and GND</td></tr>
<tr><td>Tz</td><td>N/A</td><td>Torque command is 0</td></tr>
<tr><td>T2</td><td>0</td><td>1</td><td rowspan="3" colspan="3">Internal register (parameter)</td><td>P1.012</td></tr>
<tr><td>T3</td><td>1</td><td>0</td><td>P1.013</td></tr>
<tr><td>T4</td><td>1</td><td>1</td><td>P1.014</td></tr>
</table>

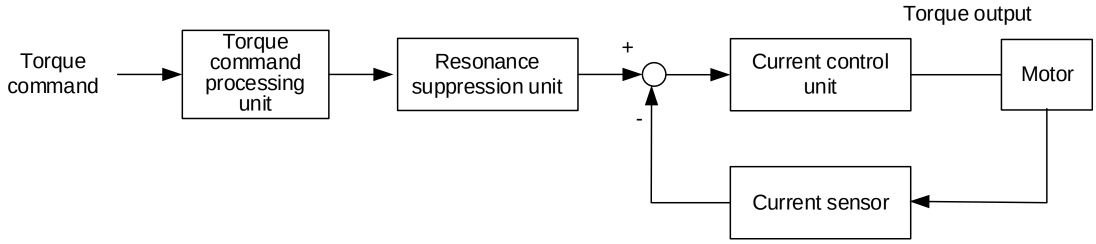
- Status of TCM0 and TCM1: 0 means that DI is off (the circuit is open); 1 means that DI is on (the circuit is closed).
- When both TCM0 and TCM1 are 0, if the drive is in Tz mode, the command is 0. Thus, if there is no need to use the analog voltage for the Torque command, you can use Tz mode to avoid the problem of zero drift in the voltage. If the drive is in T mode, then the command is the voltage difference between T_REF and GND. The range of the input voltage is between -10V and +10V, and you can adjust the corresponding torque with P1.041.
- When either one of TCM0 or TCM1 is not 0, the internal parameters become the source for the Torque command. The command is activated once the status of TCM0 and TCM1 are switched. There is no need to use DI.CTRG for triggering.

You can use the Torque command in Torque mode (T or Tz) and Speed mode (S or Sz). When the drive is in Speed mode, you can use the Torque command input as the torque limit.

6

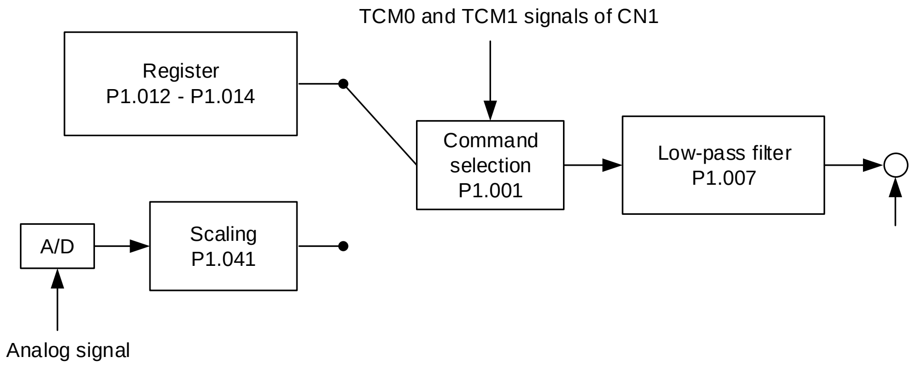
6.4.2 Control structure of Torque mode

The following diagram shows the basic control structure of Torque mode.



The Torque command processing unit selects the command source (see Section 6.4.1), including the scaling parameter (P1.041) for the torque corresponding to the analog voltage and the low-pass filter (P1.007) for smoothing the torque. The current control unit manages the gain parameters for the servo drive and calculates the current for servo motor in real-time.

The structure of Torque command processing unit is as follows.

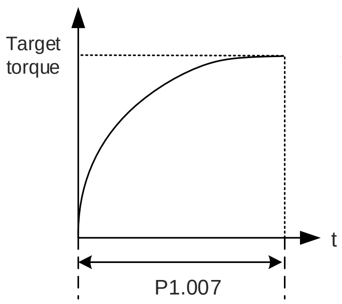


The upper path is the command from the register and the lower one is the command from the external analog voltage, which you can select with the status of TCM0 and TCM1, and P1.001 (T or Tz). Adjust the torque with the analog voltage scaling (P1.041) and smooth the response with the low-pass filter (P1.007).

6.4.3 Smoothing the Torque command

Refer to Chapter 8 for detailed descriptions of the relevant parameter.

Parameter	Function
P1.007	Torque command - smoothing constant (low-pass filter)

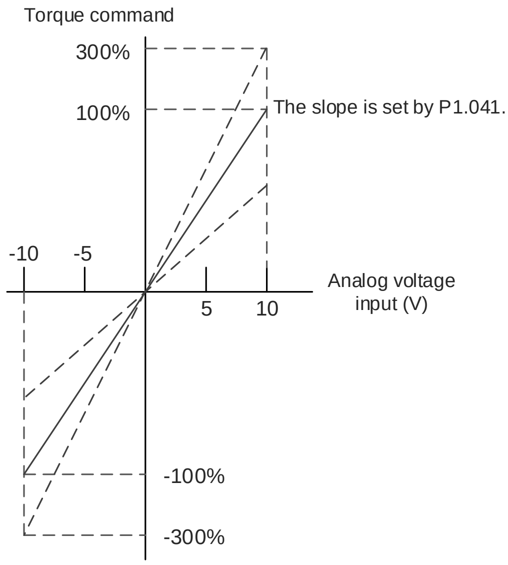


6.4.4 Scaling of the analog command

The Torque command is controlled by the analog voltage difference between T_REF and GND. Adjust the torque slope and its range with P1.041.

For example:

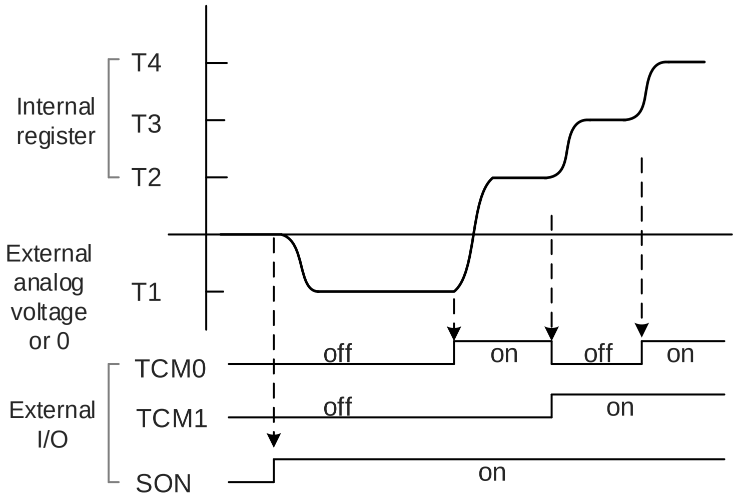
1. If you set P1.041 to 100 and the external input voltage is 10V, the Torque command is 100% of the rated torque.
2. If you set P1.041 to 300 and the external input voltage is 10V, the Torque command is 300% of the rated torque.



Refer to Chapter 8 for detailed descriptions of the relevant parameter.

Parameter	Function
P1.041	Maximum output for analog Torque command

6.4.5 Timing diagram of Torque mode



Note:

1. “off” means that DI is off (the circuit is open); “on” means that DI is on (the circuit is closed).
2. When the drive is in Tz mode, the Torque command T1 = 0; when the drive is in T mode, the Torque command T1 refers to the external analog voltage input.
3. In Servo On state, the command is selected according to the status of TCM0 and TCM1.

6.5 Dual mode

Apart from the single modes for controlling the position, speed, and torque of the motor, there are also dual modes and multi-modes available for operation (see Section 6.1).

Mode	Short name	Code	Description
Dual mode	PT-S	06	Switch PT and S modes with DI.S-P.
	PT-T	07	Switch PT and T modes with DI.T-P.
	PR-S	08	Switch PR and S modes with DI.S-P.
	PR-T	09	Switch PR and T modes with DI.T-P.
	S-T	0A	Switch S and T modes with DI.S-T.
	PT-PR	0D	Switch PT and PR modes with DI.PT-PR.
Multi-mode	PT-PR-S	0E	Switch PT, PR, and S modes with DI.S-P and DI.PT-PR.
	PT-PR-T	0F	Switch PT, PR, and T modes with DI.T-P and DI.PT-PR.

The dual mode for Sz and Tz is not supported. To avoid occupying too many digital inputs in the dual or multi-mode, Speed and Torque modes can use the external analog voltage as the command source to reduce the use of DI points (SPD0, SPD1 or TCM0, TCM1). In addition, the PT mode can use the pulse input to reduce the use of DI points (POS0 - POS6).

To refer to the table of default DI/DO functions or to change the DI/DO functions, see Section 3.3 for more information.

6

6.5.1 Speed / Position dual mode

Speed / Position dual mode includes PT-S and PR-S. The command source for PT-S comes from the external pulse while the source for PR-S comes from the internal parameters (P6.000 - P7.099). You can control the Speed command with the external analog voltage or the internal parameters (P1.009 - P1.011). The switch between Speed and Position modes is controlled by DI.S-P (0x18). The switch between PT and PR for Position mode is controlled by DI.PT-PR (0x2B). The following timing diagram illustrates the PR-S mode. The switch between Position and Speed commands in PR-S mode is controlled by DI signals.

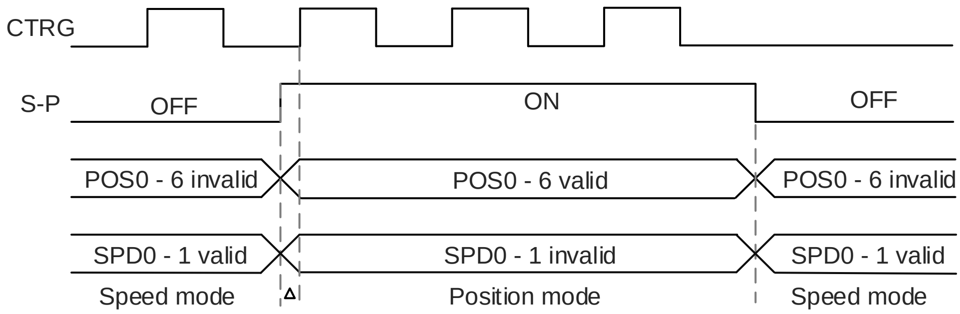


Figure 6.5.1.1 Speed / Position dual mode

In Speed mode (DI.S-P is off), you select the Speed command with DI.SPD0 and DI.SPD1, and DI.CTRG is not applicable. When the drive switches to Position mode (DI.S-P is on), since the Position command has not been issued (it waits for the rising edge of DI.CTRG), the motor stops (indicated by △ in the preceding figure). The Position command is selected with DI.POS0 - DI.POS6 when the rising edge of DI.CTRG is triggered, and then the motor operates to the specified position. When DI.S-P is off, the drive returns to the Speed mode. Refer to the introduction of single mode for the DI signals and the selected commands.

6.5.2 Speed / Torque dual mode

Speed / Torque dual mode includes only S-T. The source of the Speed command can be the external analog voltage or the internal parameters (P1.009 - P1.011), which you select with DI.SPD0 and DI.SPD1. Similarly, the source of the Torque command can be the external analog voltage or the internal parameters (P1.012 - P1.014), which you select with DI.TCM0 and DI.TCM1. The following timing diagram illustrates the S-T mode. The switch between Speed and Torque modes is controlled by DI.S-T (0x19).

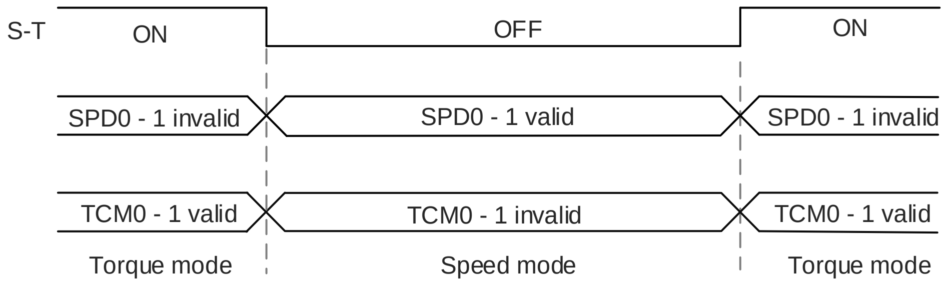


Figure 6.5.2.1 Speed / Torque dual mode

In Torque mode (DI.S-T is on), you select the Torque command with DI.TCM0 and DI.TCM1. When the drive switches to Speed mode (DI.S-T is off), you select the Speed command with DI.SPD0 and DI.SPD1. Then the motor operates according to the Speed command. When DI.S-T is on, the drive returns to the Torque mode. Refer to the introduction of single mode for the DI signals and the selected commands.

6

6.5.3 Torque / Position dual mode

Torque / Position dual mode includes PT-T and PR-T. The command source for PT-T comes from the external pulse while the source for PR-T comes from the internal parameters (P6.000 - P7.099). You can control the Torque command with the external analog voltage or the internal parameters (P1.012 - P1.014). The switch between Torque and Position modes is controlled by DI.T-P (0x20). The switch between PT and PR for Position mode is controlled by DI.PT-PR (0x2B). The following timing diagram illustrates the PR-T mode. The switch between Position and Torque commands in PR-T mode is controlled by DI signals.

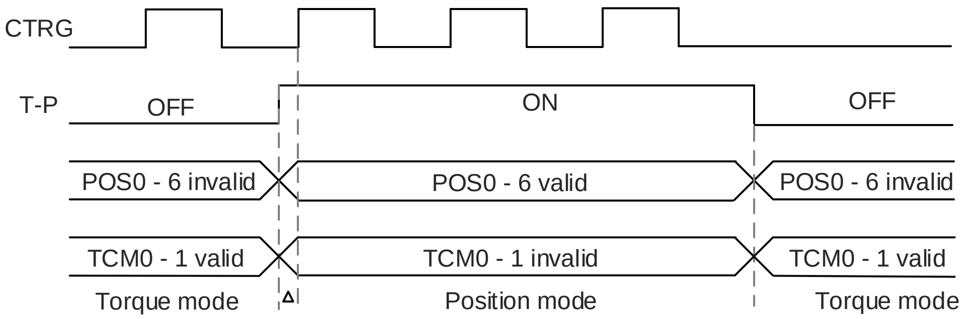


Figure 6.5.3.1 Torque / Position dual mode

In Torque mode (DI.T-P is off), you select the Torque command with DI.TCM0 and DI.TCM1, and DI.CTRG is not applicable. When the drive switches to Position mode (DI.T-P is off), since the Position command has not been issued (it waits for the rising edge of DI.CTRG), the motor stops (indicated by △ in the preceding figure). The Position command is selected with DI.POS0 - DI.POS6 when the rising edge of DI.CTRG is triggered, and then the motor operates to the specified position. When DI.T-P is off, the drive returns to the Torque mode. Refer to the introduction of single mode for the DI signals and the selected commands.

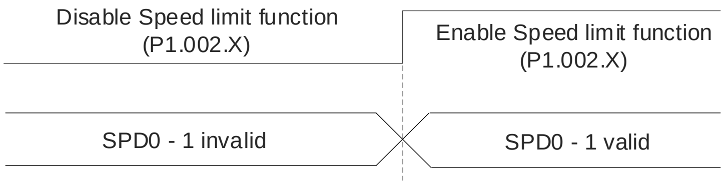
6

6.6 Others

6.6.1 Applying the speed limit

The maximum motor speed in each mode (Position, Speed, and Torque) is determined by the internal parameter P1.055. The methods for using the Speed limit command and Speed command are the same. You can use either the external analog voltage or the internal parameters (P1.009 - P1.011). Refer to Section 6.3.1 for more details.

The speed limit is applicable only in Torque mode (T or Tz) for controlling the motor's maximum speed. If you are using the external analog voltage in Torque mode, you can use the available DI signals to set SPD0 and SPD1 for the motor speed limit value (internal parameters). If there is no DI signals available, use the analog voltage input for the Speed limit command. When you set P1.002.X (disable / enable Speed limit function) to 1, the Speed limit function is enabled. The timing diagram is shown as follows.

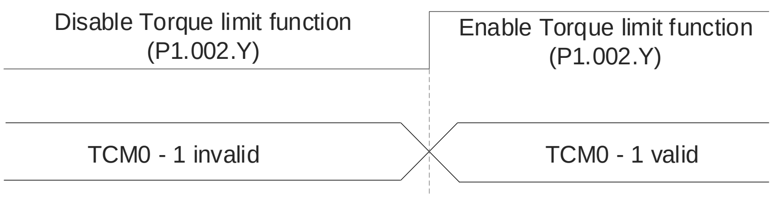


Source selection for Speed limit command

6.6.2 Applying the torque limit

The methods for using the Torque limit command and Torque command are the same. You can use either the external analog voltage or the internal parameters (P1.012 - P1.014). Refer to Section 6.4.1 for more details.

The torque limit is applicable in Position mode (PT or PR) or Speed mode (S) for limiting the motor torque output. If you are using the external pulse in Position mode or using the external analog voltage in Speed mode, you can use the available DI signals to set TCM0 and TCM1 for the torque limit command (internal parameters). If there is no DI signals available, use the analog voltage input for the Torque limit command. When you set P1.002.Y (disable / enable Torque limit function) to 1, the Torque limit function is enabled. The timing diagram is shown as follows.



Source selection for Torque limit command

6

6.6.3 Analog monitoring

You can find the required voltage signal with analog monitoring. The servo drive provides two analog channels. Refer to Chapter 3 for more information about wiring.

Refer to Chapter 8 for detailed descriptions of the relevant parameters.

Parameter	Function
P0.003	Analog output monitoring
P1.003	Encoder pulse output polarity
P1.004	MON1 analog monitor output proportion
P1.005	MON2 analog monitor output proportion
P4.020	Analog monitor output (Ch1) - offset compensation value
P4.021	Analog monitor output (Ch2) - offset compensation value

Example:

If the analog voltage output is 8V when the motor speed is 1,000 rpm and the maximum speed of the motor is 5,000 rpm, the setting of P1.004 is as follows.

$$P1.004 = \frac{\text{Required speed}}{\text{Max. speed}} \times 100\% = \frac{1000\text{ rpm}}{5000\text{ rpm}} \times 100\% = 20\%$$

You can calculate the voltage output corresponding to the current motor speed with the following formula.

Motor speed	MON1 analog monitor output
300 rpm	$MON1 = 8V \times \frac{\text{Current speed}}{\text{Max. speed} \times \frac{P1.004}{100}} \times 100\% = 8V \times \frac{300\text{ rpm}}{5000\text{ rpm} \times \frac{20}{100}} \times 100\% = 2.4V$
900 rpm	$MON1 = 8V \times \frac{\text{Current speed}}{\text{Max. speed} \times \frac{P1.004}{100}} \times 100\% = 8V \times \frac{900\text{ rpm}}{5000\text{ rpm} \times \frac{20}{100}} \times 100\% = 7.2V$

Voltage drift

When voltage drift occurs, the voltage level defined as zero voltage is different from the set zero point. To fix this problem, use DOF1 (P4.020) and DOF2 (P4.021) to calibrate the offset voltage output. The voltage level for analog monitoring output is ±8V. If the output voltage exceeds the range, it is limited within ±8V. The resolution is 10 bits, which is equivalent to 13 mV/LSB.