Tuning

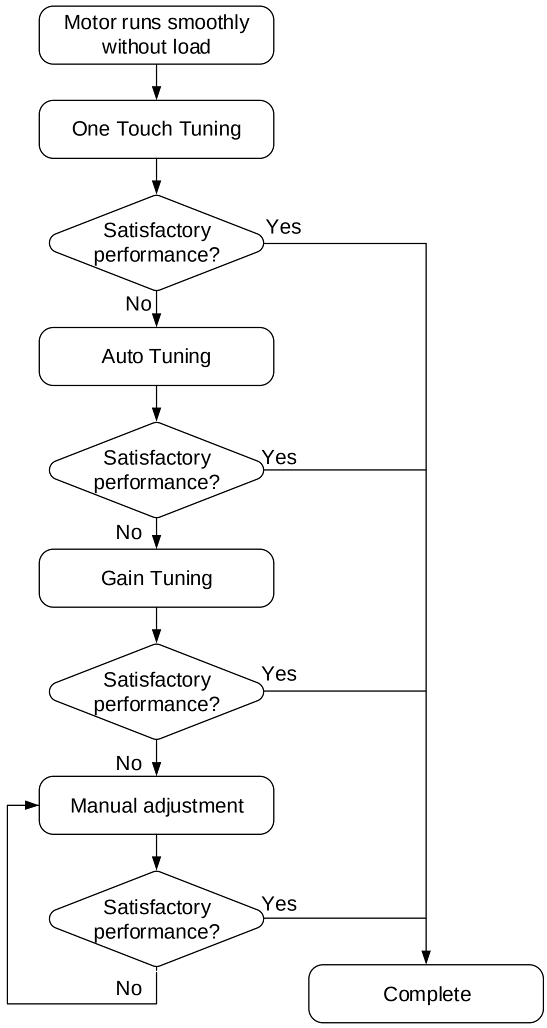
5

This chapter contains information about One Touch tuning, Auto tuning, and gain adjustment modes. Advanced users can also tune the servo system in Manual mode. In addition, this chapter also describes how to deal with the mechanical resonance and noise and the adjustments for application functions.

5

5.1 Tuning procedure

You can tune the servo drive by following this flowchart. First, start from **One Touch Tuning**. If you are not satisfied with the tuning results, then use **Auto Tuning**, **Gain Tuning**, and Manual mode in sequence to meet the requirements.



Function	Description
Inertia estimation	When you use the functions of **One Touch Tuning**, **Auto Tuning**, or Gain adjustment mode 1 (Level adjustment - Auto) with ASDA-Soft, the servo drive automatically estimates the load inertia during the tuning process. Or you can estimate the inertia with the **Inertia (Weight) Estimation** function. Whether the load inertia ratio (P1.037) is correctly set affects the speed loop bandwidth of the servo drive.
One Touch Tuning	You must use the **One Touch Tuning** function with ASDA-Soft. During the tuning process, the motor slightly moves and makes high-frequency noise. For the detailed operation procedure, refer to Section 5.3.
Auto tuning	You can use the **Auto Tuning** function with ASDA-Soft or through the panel. The command source can be the servo drive or the controller. During the tuning process, the drive controls the motor to run back-and-forth between the two positioning points. For the detailed operation procedure, refer to Section 5.4.
Gain adjustment	The servo provides five gain adjustment modes (not including Manual mode and Gain adjustment mode 4 (Reset to the default gain values)), which is set with P2.032. For the detailed operation procedure and parameter adjustment, refer to Section 5.5.
Manual adjustment	In Manual mode (P2.032 = 0), users can fine-tune all the gain parameters for optimal performance of the machine. For the detailed parameter adjustment, refer to Sections 5.6 and 5.7.

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5.2 Inertia estimation

Whether the load inertia ratio (P1.037) is correctly set affects the speed loop bandwidth of the servo drive. If set incorrectly, the system's performance cannot be optimized after tuning. When you use the functions of **One Touch Tuning**, **Auto Tuning**, or Gain adjustment mode 1 (Level adjustment - Auto) with ASDA-Soft, the servo drive automatically estimates the load inertia during the tuning process. If not using the preceding functions, you can directly use the **Inertia (Weight) Estimation** function.

The estimation of load inertia can be done without the controller's command. During the estimation process, the motor runs back-and-forth in the forward and reverse directions. If the inertia estimation cannot be done or the inertia cannot be correctly estimated in the system, estimate the load inertia ratio by yourself and set P1.037 with the estimated value.

5.2.1 Precautions for inertia estimation

Recommended settings for inertia estimation

1. Jog speed: 500 rpm or above.
2. Acceleration time from 0 rpm to 3000 rpm or deceleration time from 3,000 rpm to 0 rpm: within 200 ms.
3. Traveling distance: 1 revolution or above.

Description: if the estimated load inertia cannot be reduced to a stable value, increase the jog speed first. If the traveling distance is too long, the estimation time is longer, too.

Inertia estimation cannot be done in the following systems

1. The mechanical part only moves in a single direction.
2. The movement speed of the mechanical part is lower than 200 rpm.
3. The effective stroke of the mechanical part is shorter than the traveling distance when the motor rotates 0.5 revolution.

Inertia cannot be correctly estimated in the following systems

1. The load inertia ratio of the mechanical part changes drastically.
2. The load inertia ratio of the mechanical part is greater than 50 times.
3. The bandwidth of the mechanical part is lower than 10 Hz.
4. The viscous friction of the mechanical part is high.
5. The torque limit of the mechanical part is too low.

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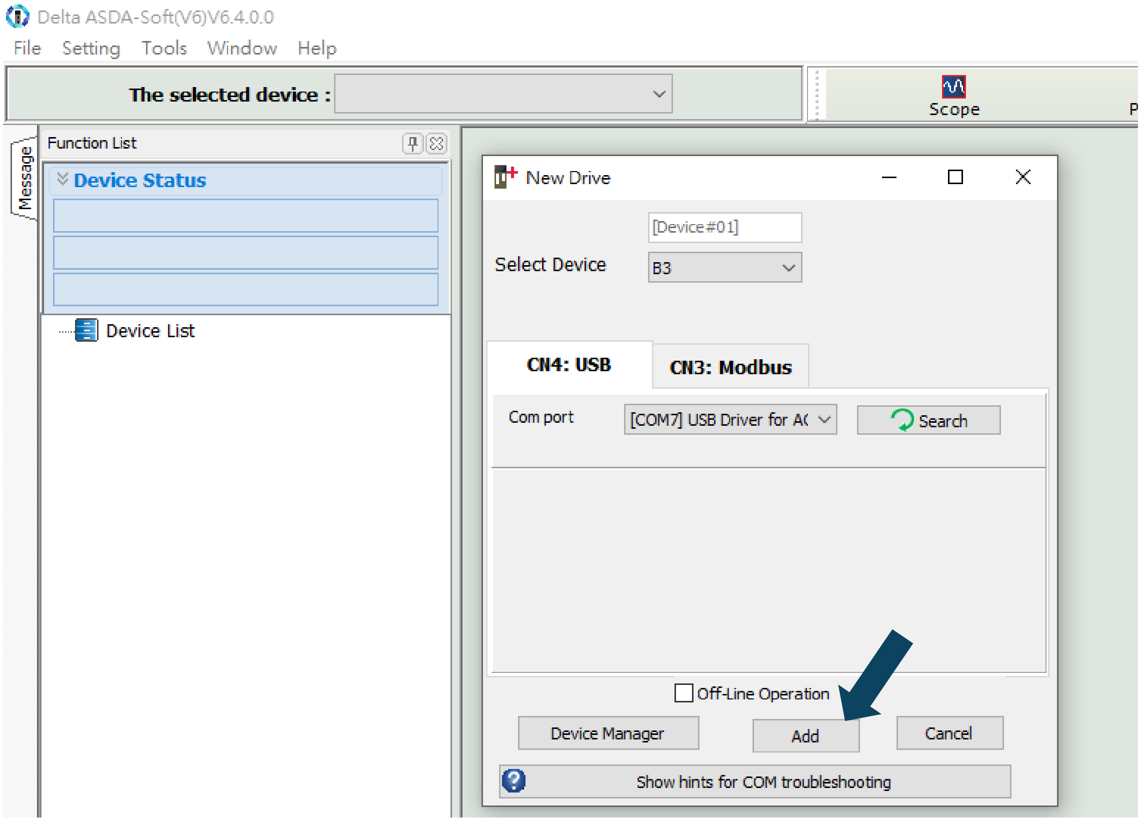
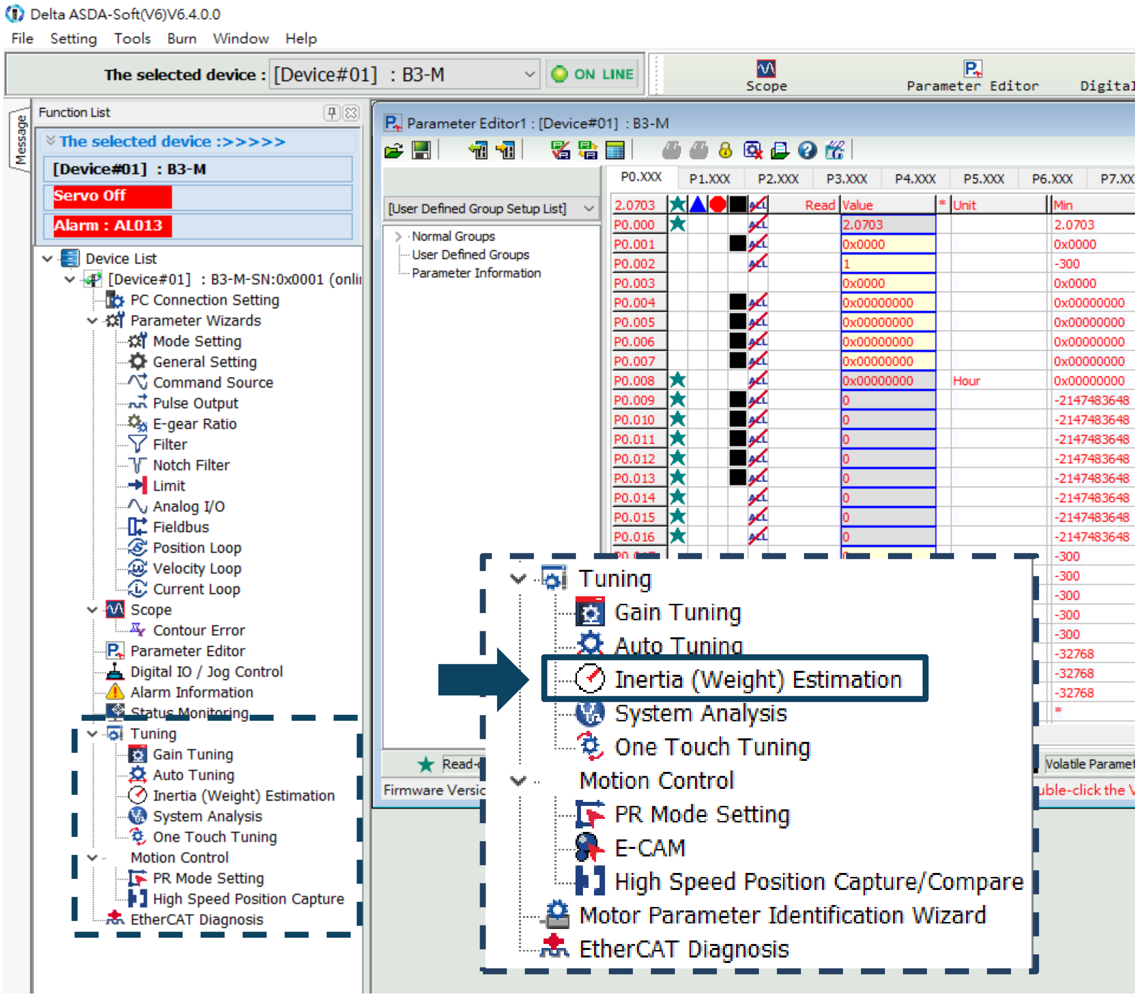
5.2.2 Inertia estimation with ASDA-Soft

Go to Delta's website to download ASDA-Soft for free to tune the servo drive. After installing ASDA-Soft, start the executable file and the screen is as follows.



Make sure your servo drive, servo motor, and power are all properly connected. Click **Search**, and the software automatically selects the corresponding communication port (USB Driver for Delta AC Servo Drive). Then, click **Add** for the ASDA-Soft to be in online mode.

When ASDA-Soft is in online mode, the program window appears as follows. Click **Inertia (Weight) Estimation** in the Function List tree view.



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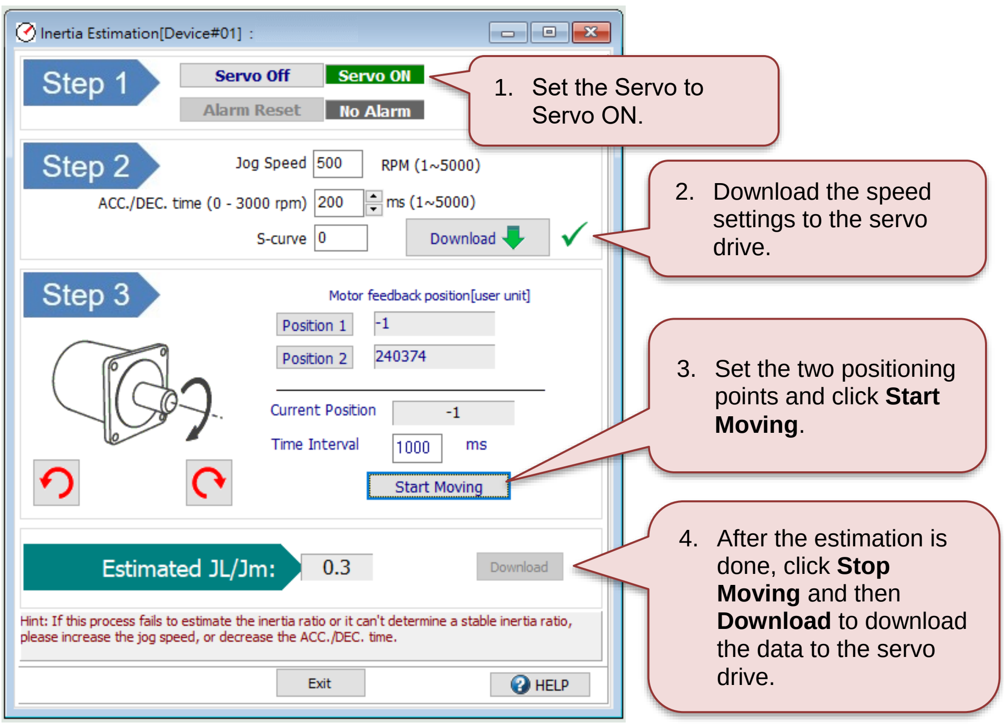
Perform the inertia estimation according to the following descriptions.

1. Set the system to the Servo ON state.
2. The default jog speed is 20 rpm and the default acceleration / deceleration time is 200 ms. For mechanical parts with limited strokes, low speed movement reduces the risk of collision. Executing positioning between two points at low speed is recommended. For mechanical parts with longer strokes or without limits, you can set the movement speed higher. After completing the settings, click the Download button, and then use the Left ( ) or Right ( ) button to rotate the motor to Position 1 and Position 2.
3. Check the acceleration / deceleration time and jog speed again. It is advisable to set the jog speed to no less than 500 rpm. Then click the Download button. After the download is complete, click **Start Moving**, and the motor regards Position 1 and Position 2 as the positive and negative limits and starts rotating in the forward and reverse directions.
4. After the estimation is complete, click **Stop Moving** and then **Download** to download the estimated load inertia ratio to the servo drive.
5. Since the new inertia ratio (weight) causes a change in the equivalent bandwidth, resonance may occur in the system. Thus, you need to use the **Gain Tuning** function to set the bandwidth and gain again when writing the new inertia ratio to the system.



5.3 One Touch Tuning

You must use the One Touch Tuning function with ASDA-Soft. During the tuning process, the motor slightly moves and makes high-frequency noise. The following table lists the parameters which settings change according to the results of one touch tuning. In One Touch Tuning mode, the vibration elimination function is enabled and the low-frequency vibration suppression function is disabled. If the two functions are enabled simultaneously, the response becomes slower.

Gain parameters			
Parameter No.	Function	Parameter No.	Function
P1.037	Load inertia ratio or total weight	P2.032	Gain adjustment mode
P2.000	Position control gain	P2.089	Command response gain
P2.004	Speed control gain	P2.090	Two degree of freedom mode - anti-interference gain
P2.006	Speed integral compensation	P2.094	Special bit register 3 (enable the two degree of freedom control function)
P2.031	Bandwidth response level	-	-

Filter and resonance suppression parameters			
Parameter No.	Function	Parameter No.	Function
P1.025	Low-frequency vibration suppression frequency 1	P2.044	Notch filter 2 - attenuation level
P1.026	Low-frequency vibration suppression gain 1	P2.045	Notch filter 3 - frequency
P1.027	Low-frequency vibration suppression frequency 2	P2.046	Notch filter 3 - attenuation level
P1.028	Low-frequency vibration suppression gain 2	P2.049	Speed detection filter and jitter suppression
P2.023	Notch filter 1 - frequency	P2.098	Notch filter 4 - frequency
P2.024	Notch filter 1 - attenuation level	P2.099	Notch filter 4 - attenuation level
P2.025	Resonance suppression low-pass filter	P2.101	Notch filter 5 - frequency
P2.043	Notch filter 2 - frequency	P2.102	Notch filter 5 - attenuation level

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5.3.1 Precautions for one touch tuning

One touch tuning cannot be done in the following system

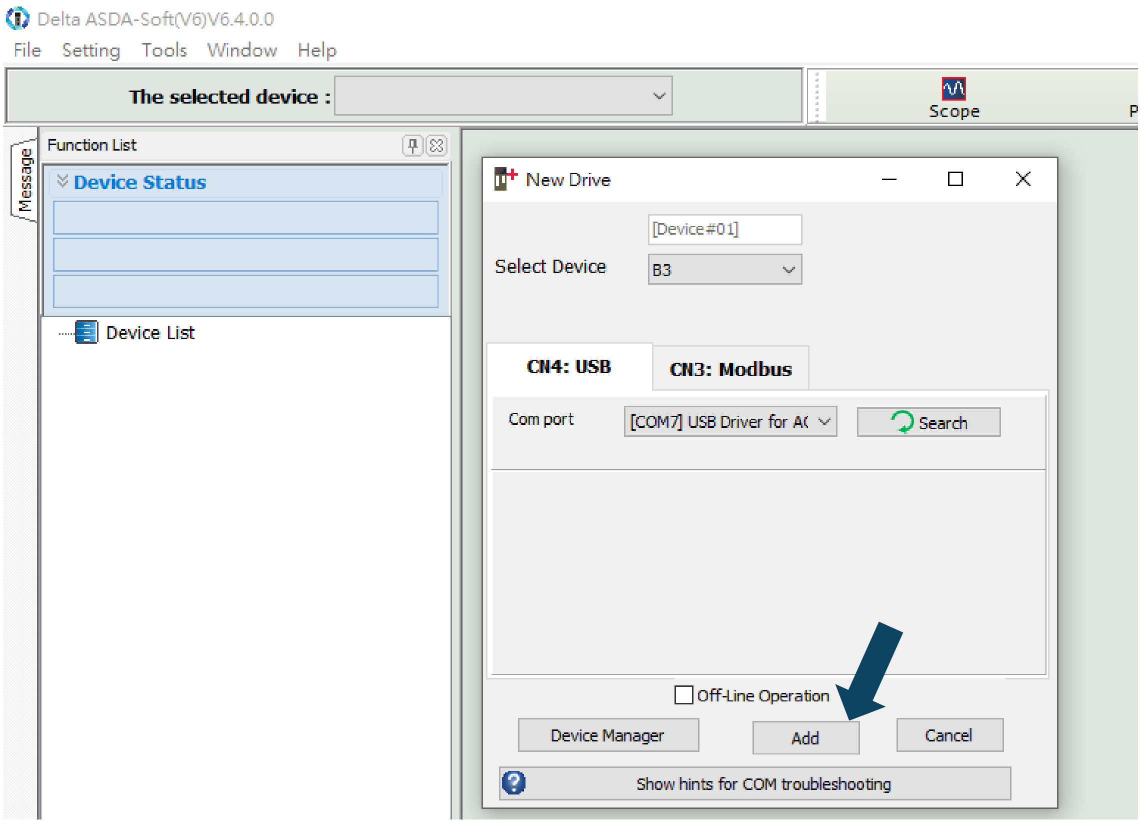
- The mechanical part only moves in a single direction.

One touch tuning cannot be correctly used in the following systems

- The load inertia ratio of the mechanical part changes drastically.
- The load inertia ratio of the mechanical part is greater than 100 times.
- The viscous friction of the mechanical part is high.
- The torque limit of the mechanical part is too low.
- The gear backlash in the mechanical part is too large.

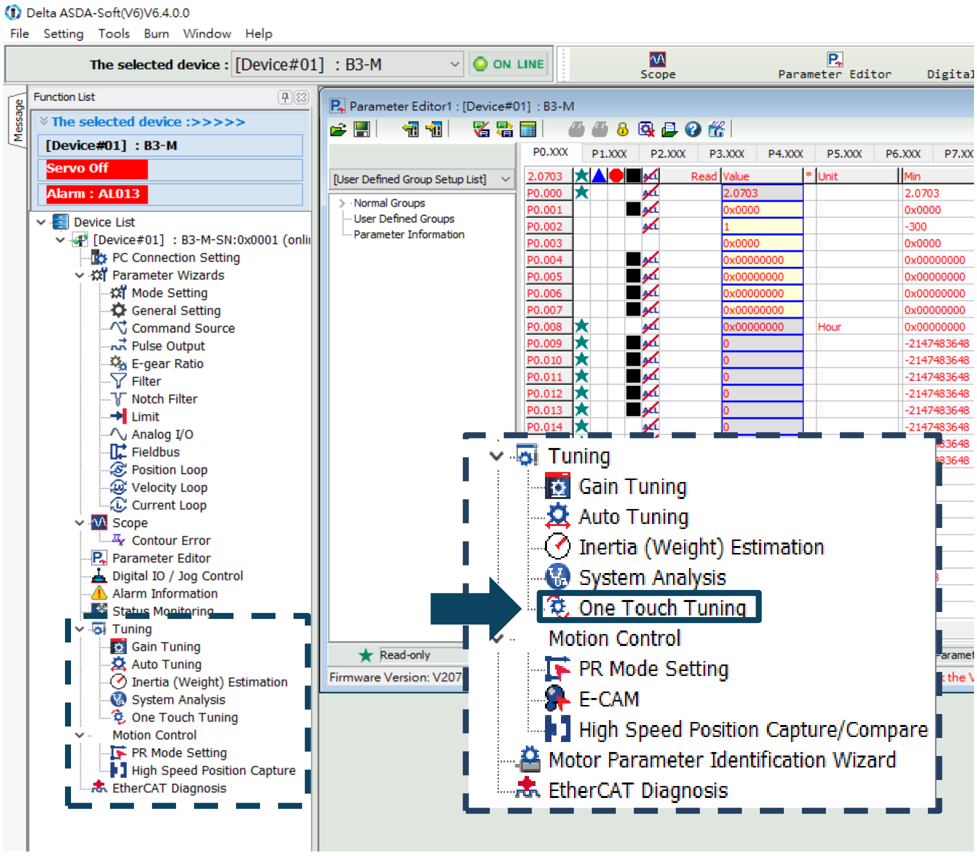
5.3.2 One touch tuning with ASDA-Soft

Go to Delta's website to download ASDA-Soft for free to tune the servo drive. After installing ASDA-Soft, start the executable file and the screen is as follows.

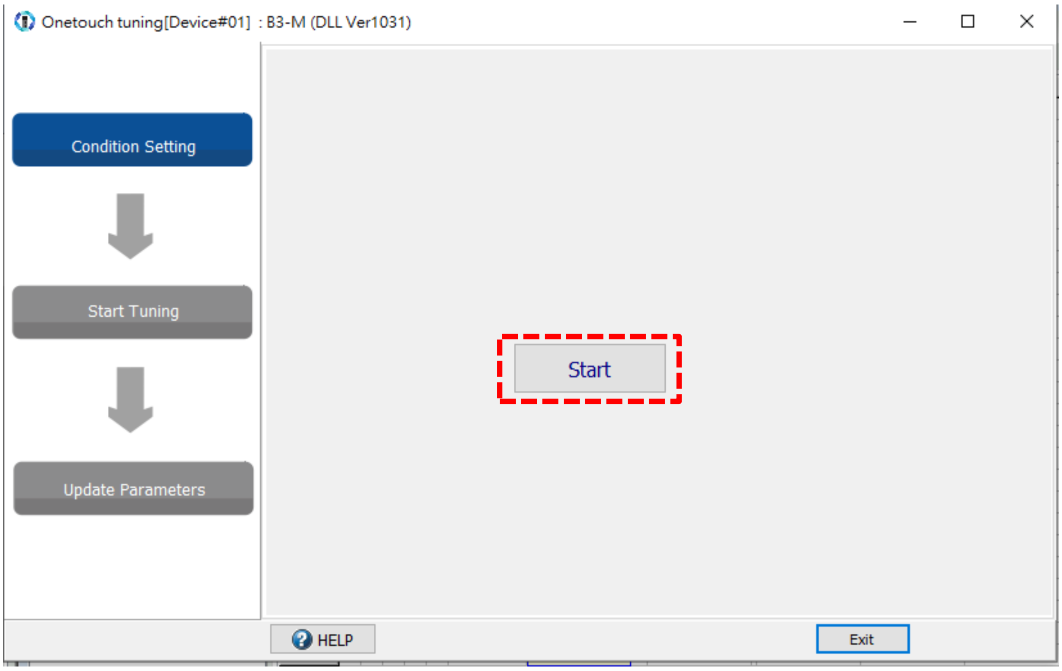


Make sure your servo drive, servo motor, and power are all properly connected. Click **Search**, and the software automatically selects the corresponding communication port (USB Driver for Delta AC Servo Drive). Then, click **Add** for the ASDA-Soft to be in online mode.

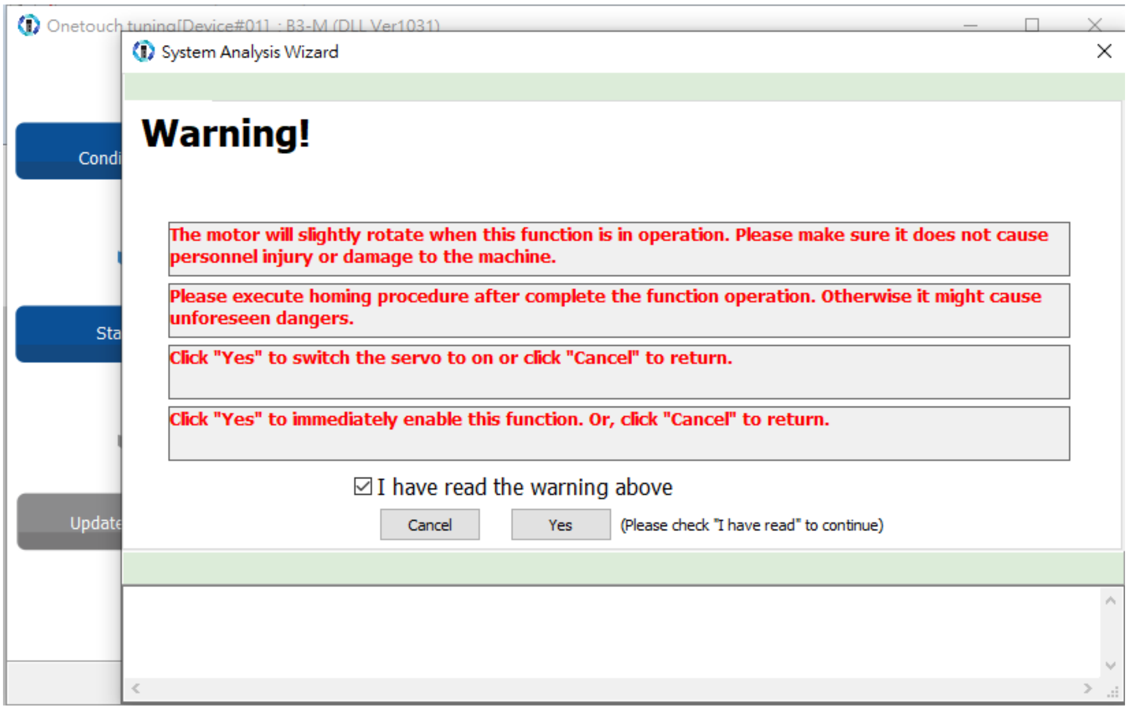
When ASDA-Soft is in online mode, the program window appears as follows. Click **One Touch Tuning** in the Function List tree view.



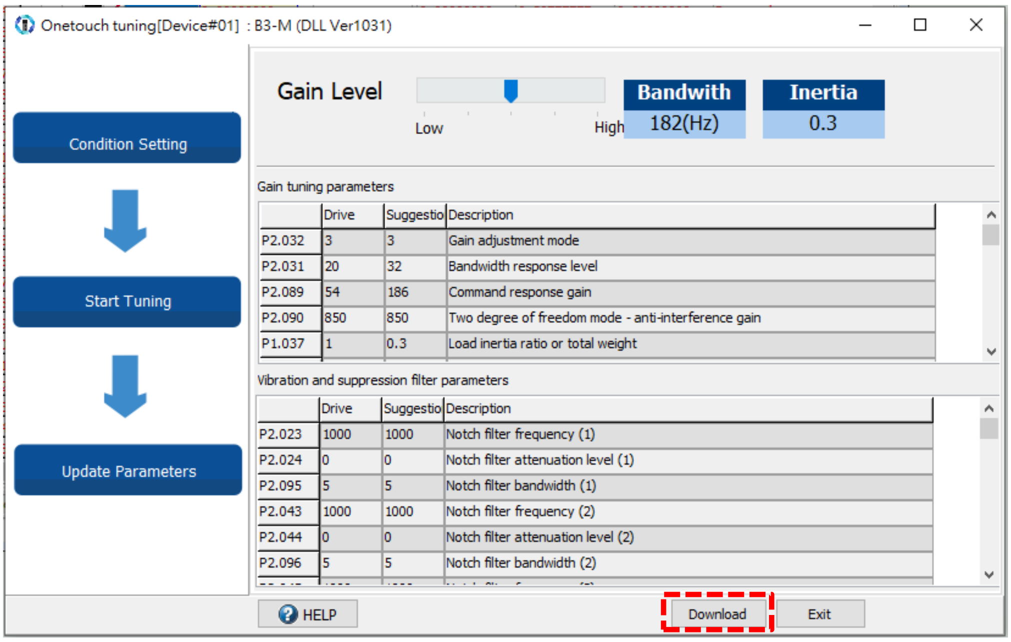
Click **Start**.



Carefully read the content in the warning window and make sure you have checked all the items one by one. Select the check box for **I have read the warning above** and click **Yes**.



The screen shows a table comparing the parameter values before and after tuning. In the screen, you can fine-tune the gain level, and the adjustments affect the settings of other relevant parameters.



Click **Download** to complete one touch tuning.

Note: if you click **Exit** without clicking **Download** first, the suggested values estimated by the one touch tuning function are not written to the servo drive.

5.4 Auto tuning

The auto tuning function enables the system to perform real-time machine inertia estimation and downloads the optimized parameters to the servo drive. You can start auto tuning with ASDA-Soft (software) or through the drive panel. The following table lists the parameters that change according to the results of auto tuning.

Gain parameters			
Parameter No.	Function	Parameter No.	Function
P1.037	Load inertia ratio or total weight	P2.031	Bandwidth response level
P2.000	Position control gain	P2.032	Gain adjustment mode
P2.002	Position feed forward gain	P2.089	Command response gain
P2.004	Speed control gain	P2.090	Two degree of freedom mode - anti-interference gain
P2.006	Speed integral compensation	P2.094	Special bit register 3 (enable the two degree of freedom control function)
P2.026	Anti-interference gain	-	-

Filter and resonance suppression parameters			
Parameter No.	Function	Parameter No.	Function
P1.025	Low-frequency vibration suppression frequency 1	P2.025	Resonance suppression low-pass filter
P1.026	Low-frequency vibration suppression gain 1	P2.043	Notch filter 2 - frequency
P1.027	Low-frequency vibration suppression frequency 2	P2.044	Notch filter 2 - attenuation level
P1.028	Low-frequency vibration suppression gain 2	P2.045	Notch filter 3 - frequency
P1.029	Auto low-frequency vibration suppression mode	P2.046	Notch filter 3 - attenuation level
P1.061	Viscous friction compensation	P2.049	Speed detection filter and jitter suppression
P1.062	Percentage of friction compensation	P2.095	Notch filter 1 - Q factor
P1.063	Constant of friction compensation	P2.096	Notch filter 2 - Q factor
P1.089	Vibration elimination 1 - anti-resonance frequency	P2.097	Notch filter 3 - Q factor
P1.090	Vibration elimination 1 - resonance frequency	P2.098	Notch filter 4 - frequency
P1.091	Vibration elimination 1 - resonance difference	P2.099	Notch filter 4 - attenuation level
P1.092	Vibration elimination 2 - anti-resonance frequency	P2.100	Notch filter 4 - Q factor
P1.093	Vibration elimination 2 - resonance frequency	P2.101	Notch filter 5 - frequency
P1.094	Vibration elimination 2 - resonance difference	P2.102	Notch filter 5 - attenuation level
P2.023	Notch filter 1 - frequency	P2.103	Notch filter 5 - Q factor
P2.024	Notch filter 1 - attenuation level	-	-

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5.4.1 Precautions for auto tuning

Recommended settings for auto tuning

1. Jog speed: 500 rpm or above.
2. Acceleration time from 0 rpm to 3000 rpm or deceleration time from 3,000 rpm to 0 rpm: within 200 ms.
3. Traveling distance: 1 revolution or above.

Description: it is advisable to set the traveling distance as the minimum distance for the motor to accelerate from zero speed to the constant speed zone, with the constant speed equal to the set jog speed. If the traveling distance is too long, the estimation time is longer, too. For mechanical parts with long strokes, it is recommended that you set the traveling distance as the working range for operation.

Auto tuning cannot be done in the following systems

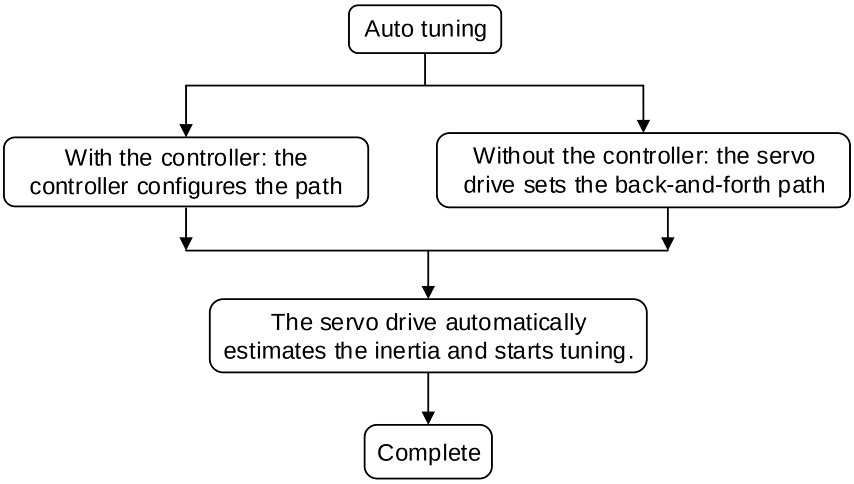
- The mechanical part only moves in a single direction.
- The movement speed of the mechanical part is lower than 200 rpm.
- The effective stroke of the mechanical part is shorter than the traveling distance when the motor rotates 0.5 revolution.

Auto tuning cannot be correctly done in the following systems

- The load inertia ratio of the mechanical part changes drastically.
- The load inertia ratio of the mechanical part is greater than 50 times.
- The bandwidth of the mechanical part is lower than 10 Hz.
- The viscous friction of the mechanical part is high.
- The torque limit of the mechanical part is too low.

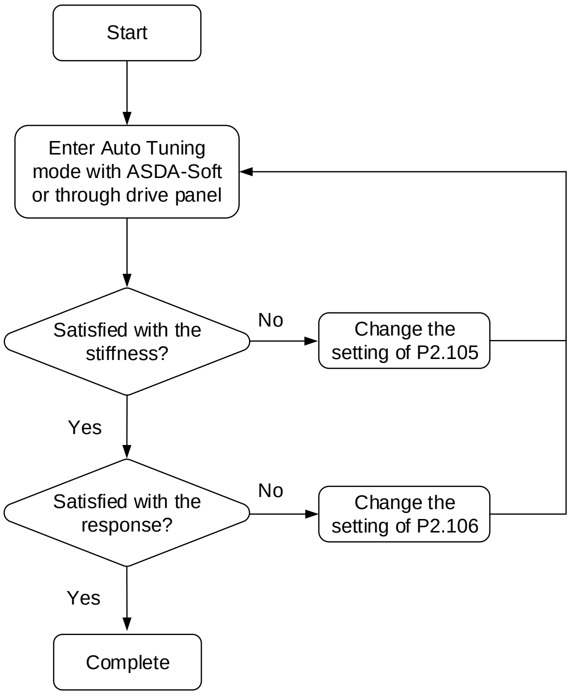
5.4.2 Flowchart of auto tuning

You can complete auto tuning through the drive panel or with ASDA-Soft. The Auto Tuning function helps you to find the most suitable parameters for your system according to the machine characteristics.



Note: when the path is configured by the controller, make sure the delay time is added to the operation cycle. Otherwise, AL08B occurs and the servo drive cannot complete auto tuning.

You can use P2.105 and P2.106 to adjust the stiffness and response in Auto Tuning mode. See the following flowchart.



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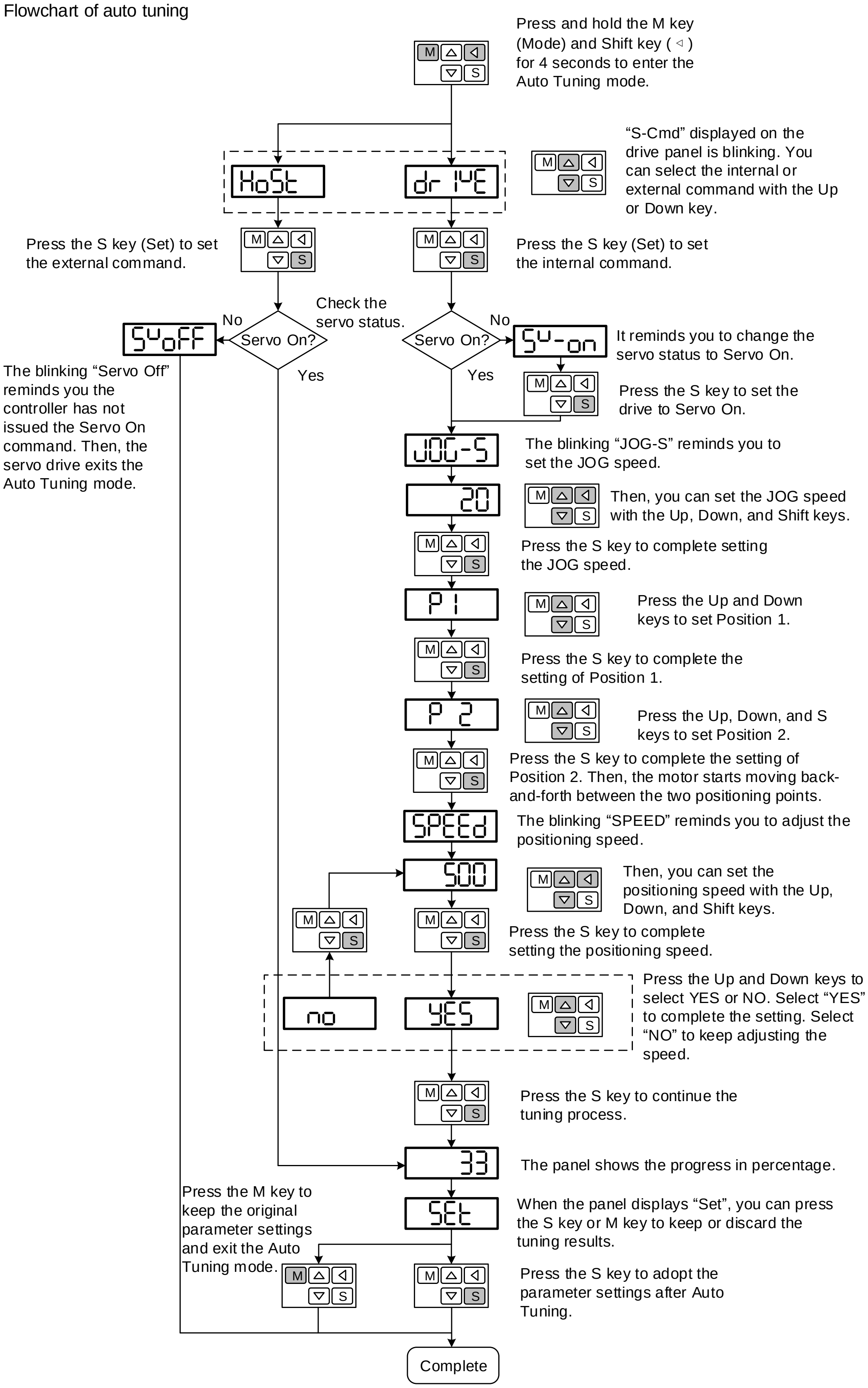
5.4.3 Auto tuning through the drive panel

You can use the drive panel to start auto tuning. Make sure the emergency stop and positive and negative limit switches work properly before you start to tune the system.

Flowchart of auto tuning



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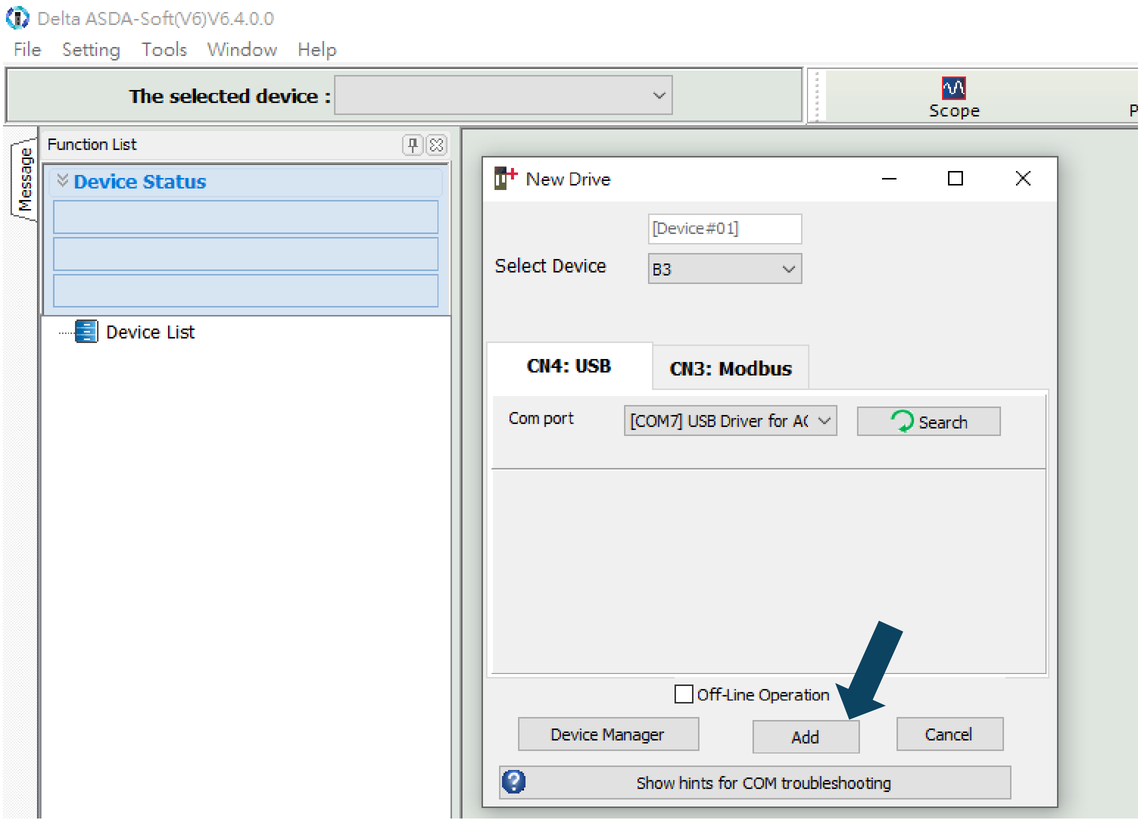
5.4.4 Auto tuning with ASDA-Soft

In addition to executing auto tuning through the drive panel, you can go to Delta's website to download ADSA-Soft for free to tune the servo drive. After installing ASDA-Soft, start the executable file and the screen is as follows.



Make sure your servo drive, servo motor, and power are all properly connected. Then click **Add** for the ASDA-Soft to be in online mode.

When ASDA-Soft is in online mode, start auto tuning according to the following steps. The following describes two auto tuning procedures, one using the controller and the other using the servo drive.

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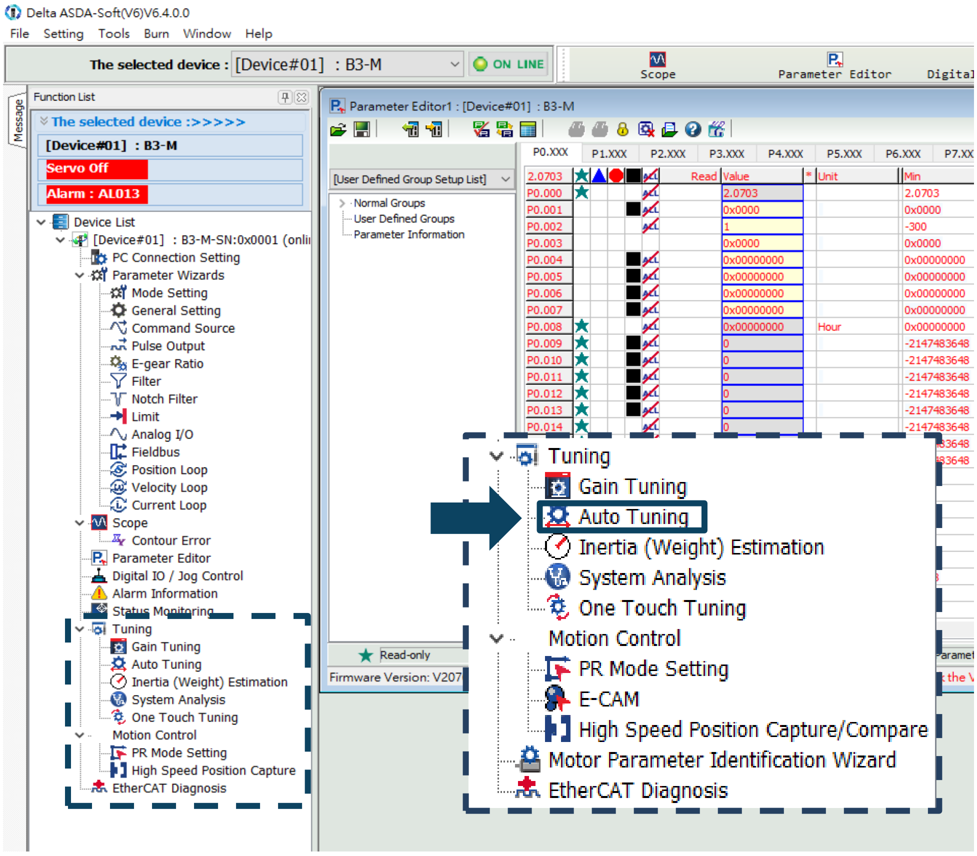
■ Auto tuning with the controller: the controller sends the commands to drive the motor.

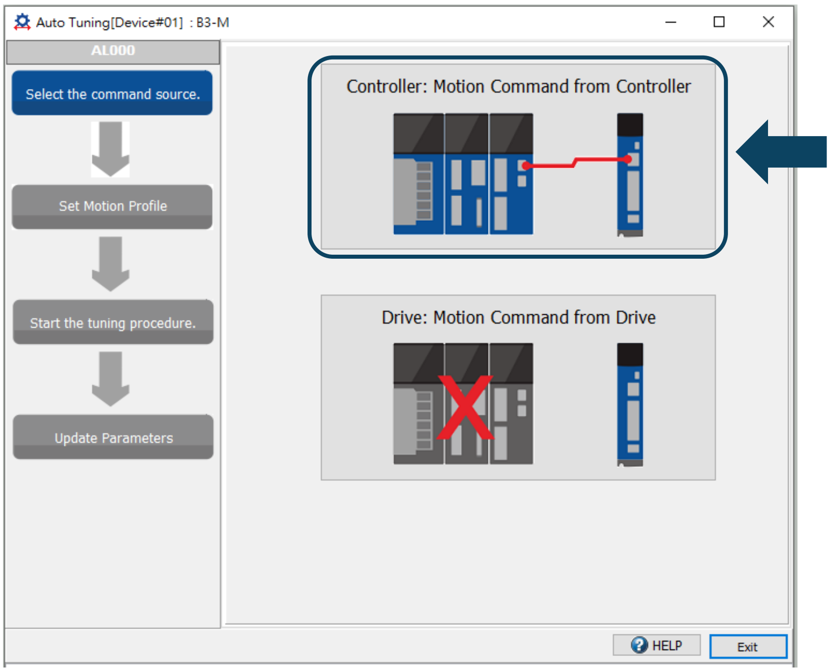
Step 1:

When ASDA-Soft is in online mode, the program window appears as follows. Click **Auto Tuning** in the Function List tree view.



Step 2:

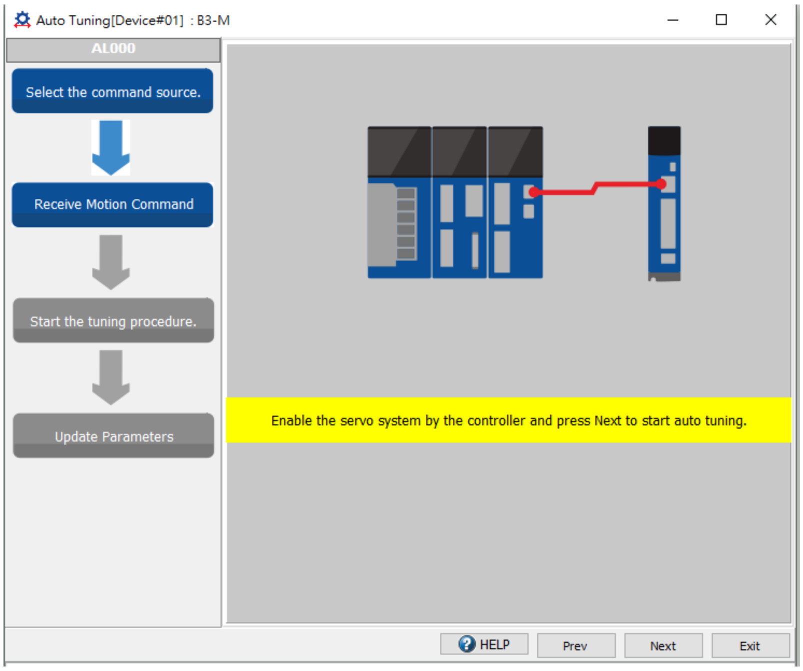
Click **Controller: Motion Command from Controller** and check for the motion / machining path.



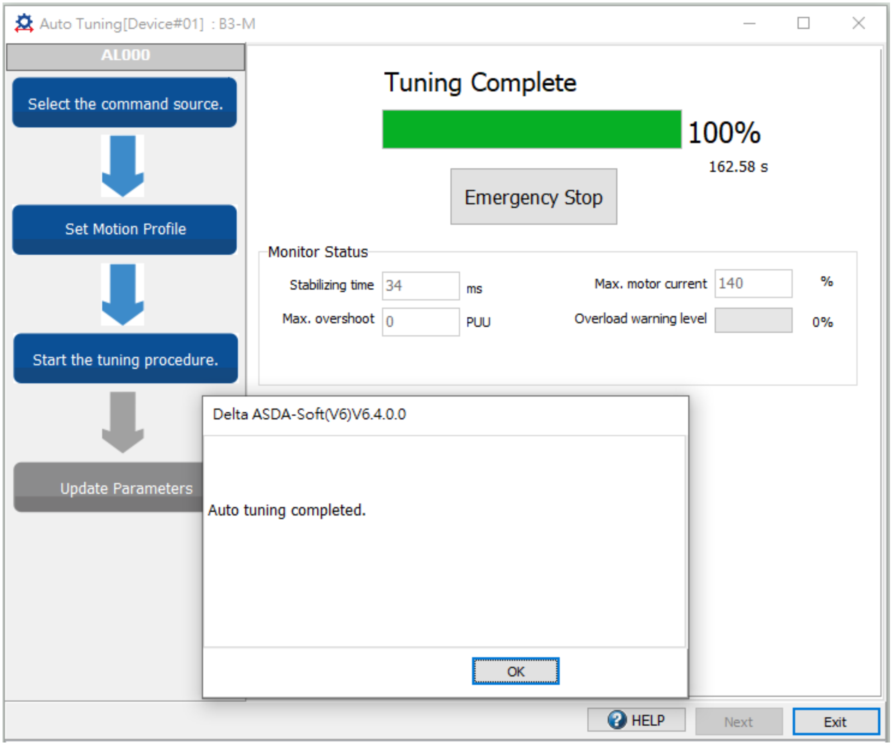
Suggestions: set the motor to operate at least one cycle in both forward and reverse directions. The delay time for reaching the positioning points in both forward and reverse directions should be no less than 1000 ms with the running speed no less than 500 rpm.

Step 3:

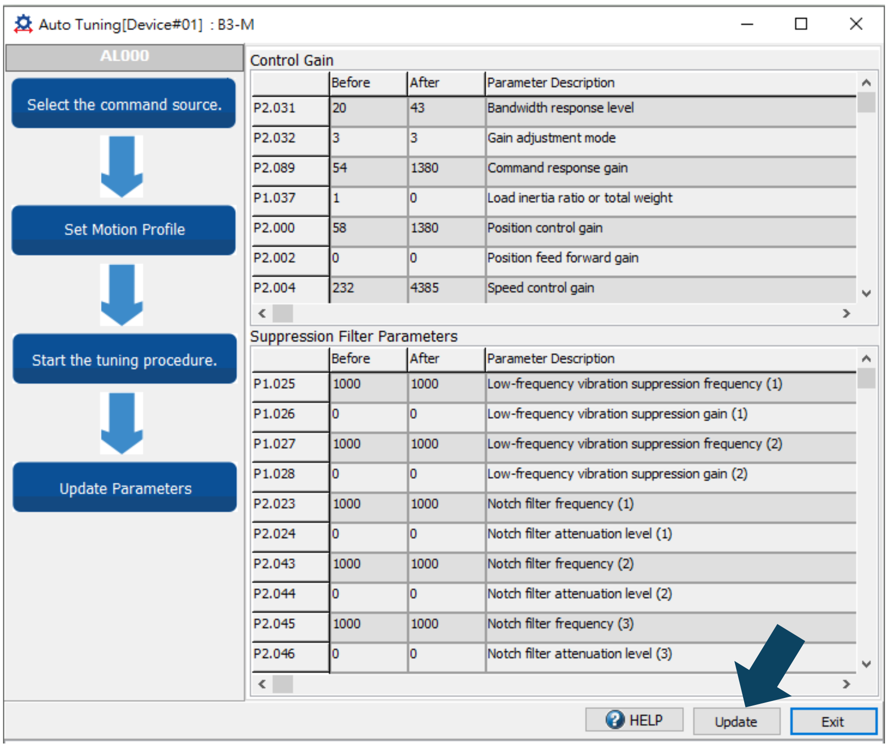
Repeatedly run the motor with the path you just set. Make sure no personnel is standing close to the machinery, and then you can click **Next** to start the auto tuning procedure.



Wait until the tuning progress bar reaches 100%, and a window with “Auto tuning completed.” appears as follows. Then click **OK**.



The screen shows a table comparing the parameter values before and after tuning.

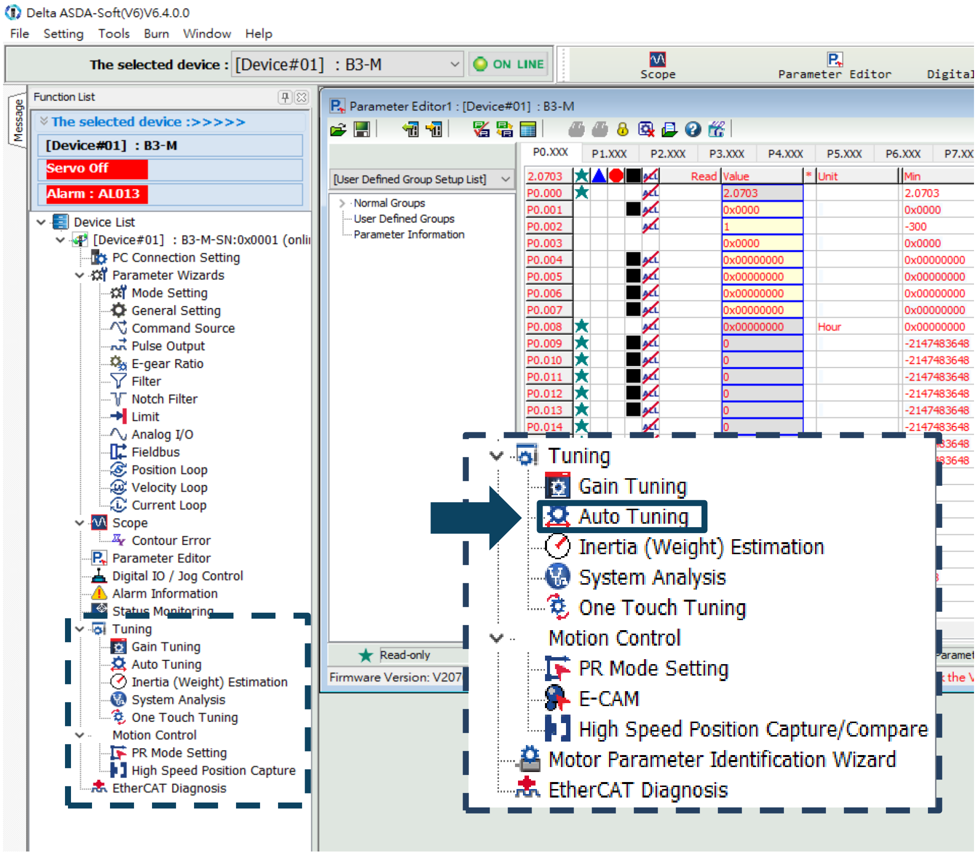


Click **Update** to complete auto tuning.

■ Auto tuning with the servo drive: the servo drive sends the commands to drive the motor.

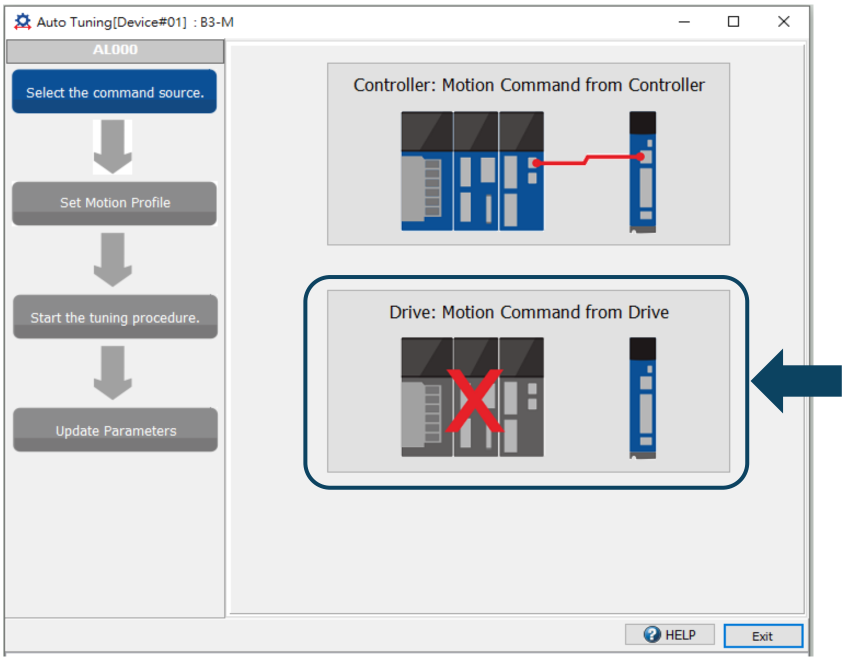
Step 1:

When ASDA-Soft is in online mode, the program window appears as follows. Click **Auto Tuning** in the Function List tree view.



Step 2:

Click **Drive: Motion Command from Drive** to enter the setting screen of motion profile.



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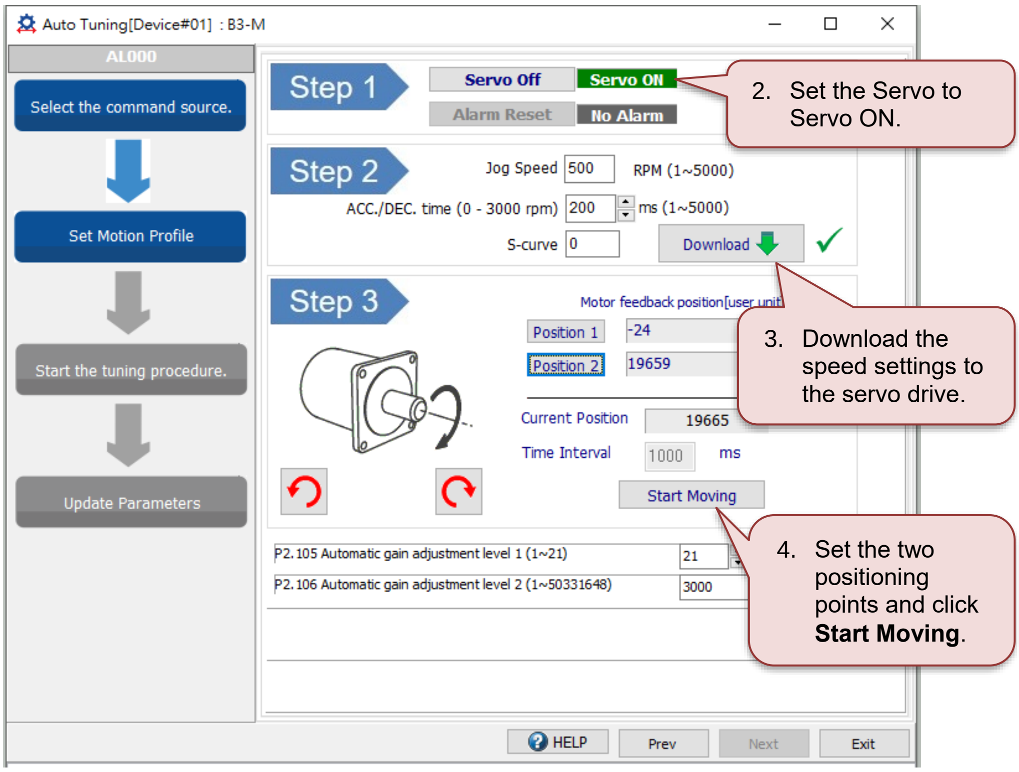
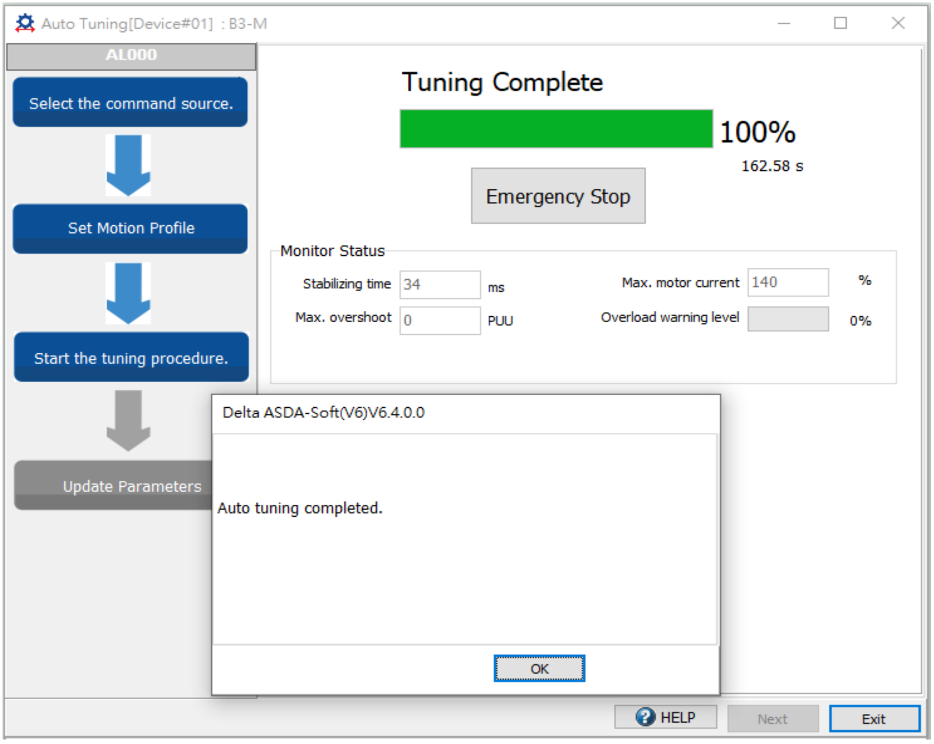
Follow these steps to set the motor running path:

1. Set P2.105 and P2.106 based on the application condition. Refer to Section 5.4.5 for details.
   - P2.105: the higher the setting value, the higher the bandwidth after auto tuning, which is applicable to devices with high stiffness or high response. On the other hand, the lower the setting value, the lower the bandwidth after auto tuning, which is applicable to devices with complex structure or low stiffness.
   - P2.106: the lower the setting value, the smaller the overshoot after auto tuning. But if the setting value is too low, the settling time may be too long.
2. Set the system to the Servo ON state.
3. The default jog speed is 20 rpm and the default acceleration / deceleration time is 200 ms. For mechanical parts with limited strokes, low speed movement reduces the risk of collision. Executing positioning with two points at low speed is recommended. For mechanical parts with longer strokes or without limits, you can set the movement speed higher. After completing the settings, click the Download button, and then use the Left ( ) or Right ( ) button to rotate the motor to Position 1 and Position 2.
4. Check the acceleration / deceleration time and jog speed again. It is advisable to set the jog speed to no less than 500 rpm. Then click the Download button. After the download is complete, click **Start Moving**, and the motor regards Position 1 and Position 2 as the positive and negative limits and starts rotating in the forward and reverse directions.
5. After completing the settings, make sure no personnel is standing close to the machinery. Then, click **Next**.
6. If the tuning results do not meet the requirements, modify the setting values of P2.105 and P2.106, or refer to Section 5.6 to manually adjust certain parameters and then perform the auto tuning again.

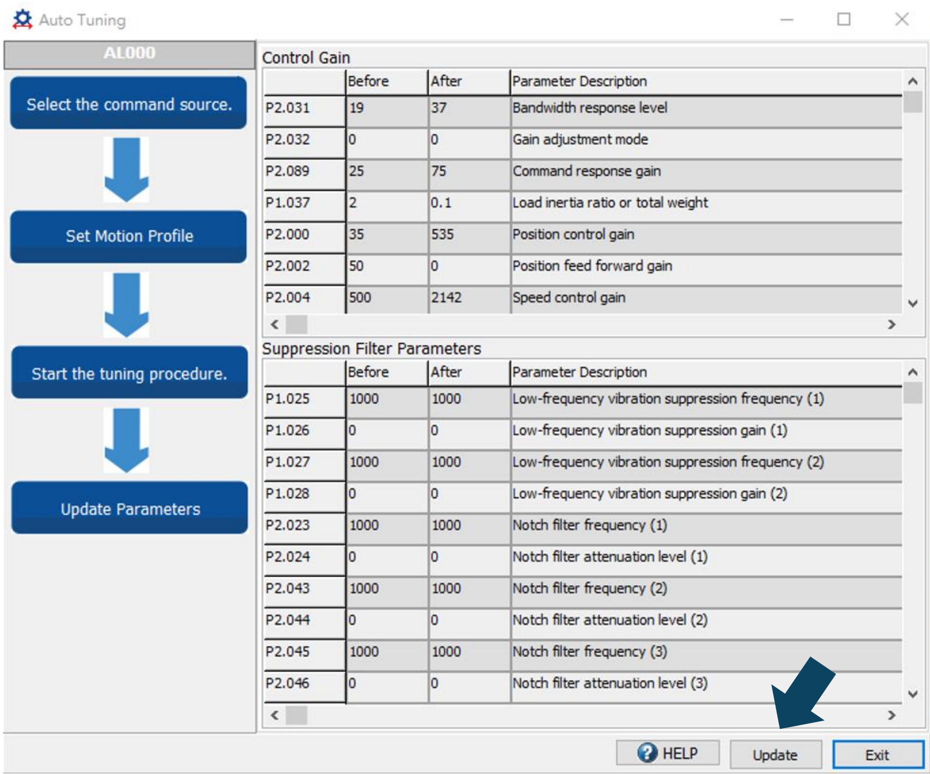


Step 3:

Wait until the tuning progress bar reaches 100%, and a window with “Auto tuning completed.” appears as follows. Then click **OK**.



The screen shows a table comparing the parameter values before and after tuning.



Click **Update** to complete auto tuning.

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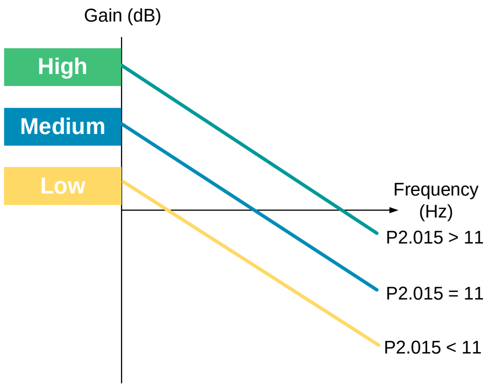
5.4.5 Parameters related to auto tuning

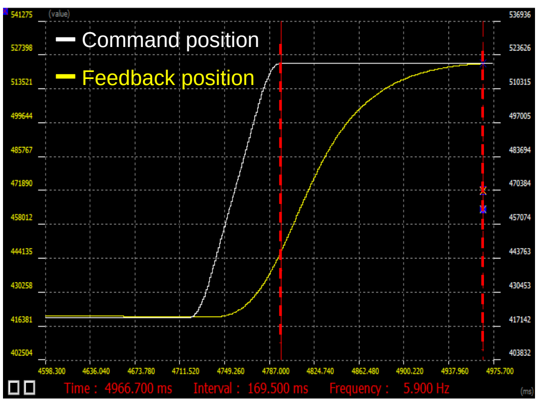
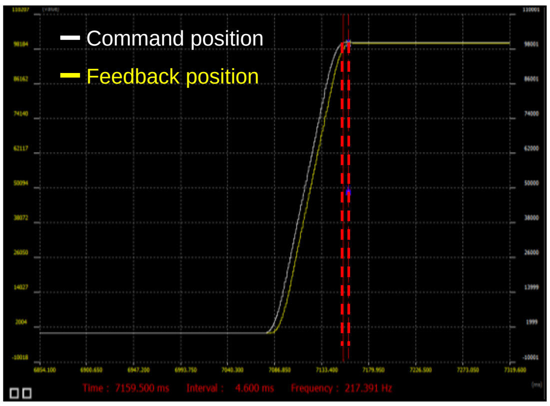
Before the auto gain adjustment starts, first set the automatic gain adjustment level 1 (P2.105) and automatic gain adjustment level 2 (P2.106), which are only available for **Auto Tuning**.

5.4.5.1 Automatic gain adjustment level 1 (P2.105) - stiffness adjustment



P2.105 defines the servo stiffness after auto tuning. The higher the setting value, the greater the bandwidth after auto tuning. On the other hand, the system margin becomes smaller, which means resonance is more likely to occur when the system is degrading. You can first use P2.105's default setting of 11 and then change the setting according to the following conditions.

1. It is advisable to increase P2.105 if the machine has all the following characteristics.
   - The load inertia (weight) changes slightly during machine operation.
   - Connected to transmission components with high stiffness (for example, they are direct-coupled or connected with couplings).
   - The machine requires high responsiveness.
2. It is advisable to decrease P2.105 if the machine has one of the following characteristics.
   - The load inertia (weight) changes constantly during machine operation (such as transport equipment and robot arms).
   - The machine has a transmission component with long strokes (such as a lead screw with the length of 3 m or longer or a belt with the length of 1 m or longer).

P2.105 = 1	P2.105 = 11
	

5.4.5.2 Automatic gain adjustment level 2 (P2.106) - response adjustment

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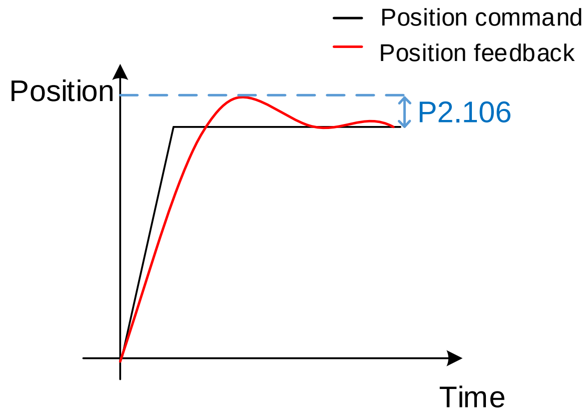
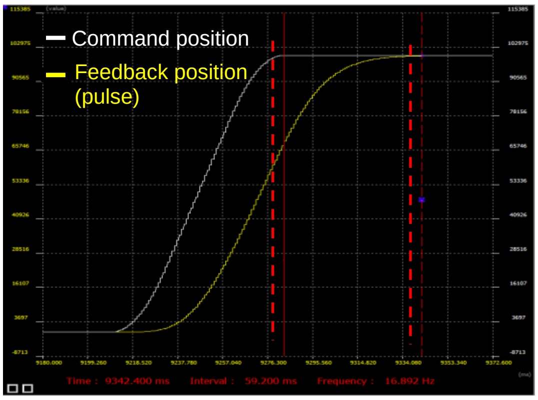
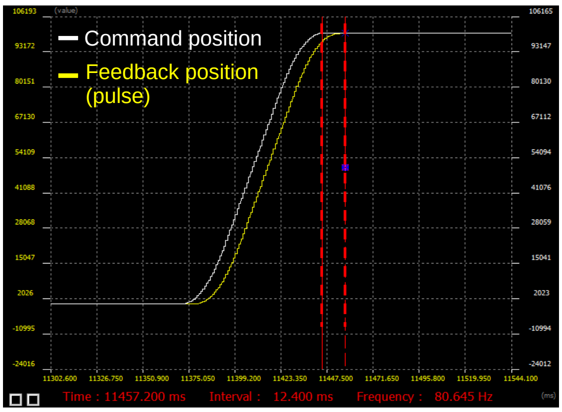
P2.106 sets the maximum overshoot. A proper setting of the amount of overshoot increases the system response. The higher the setting value, the greater the allowable amount of overshoot. For mechanical parts with higher stiffness, the setting of P2.106 affects the position loop parameters P2.000 and P2.089 instead of the parameters related to speed loop gain and filters.



Parameter setting range: 1 - 50331648 (unit: pulse); default: 2000

P2.106 = 1	P2.106 = 30000
	
Allowable amount of overshoot ≤ 1 pulse Settling time: 59.2 ms	Allowable amount of overshoot ≤ 30000 pulses Settling time: 12.4 ms

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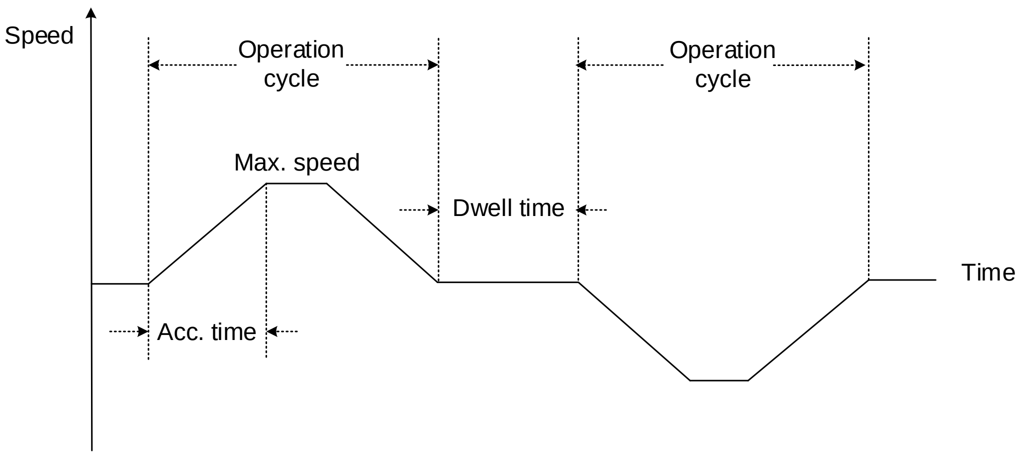
5.4.6 Alarms related to auto tuning

In Auto Tuning mode, it is vital that you program the command path. The path must contain the operation cycle (including acceleration, constant speed, and deceleration) and dwell time as shown in the following figure. When any of the settings is incorrect, the servo drive stops tuning and displays an alarm. Check the alarm causes and take corrective actions.



Alarm	Alarm name
AL08A	Auto tuning function - command error
AL08B	Auto tuning function - dwell time is too short
AL08C	Auto tuning function - inertia estimation error

5.5 Gain adjustment modes

In addition to the Auto Tuning function, the servo drive also provides the following gain adjustment modes. You can easily complete tuning by increasing or decreasing the bandwidth response level (P2.031) or the bandwidth for speed loop response (P2.126). Follow the tuning procedure in Section 5.1.

5.5.1 Differences between gain adjustment modes

Level adjustment: set the response level with P2.031 to adjust the servo bandwidth. With the load inertia ratio increased or decreased, the bandwidth corresponding to the response level set by P2.031 changes as well.
Bandwidth adjustment: set P2.126 to directly determine the servo bandwidth, which fine-tunes the bandwidth.

P2.032 value	Adjustment mode	Mode name	Inertia estimation	Parameter	
				Manual	Auto
0	Manual	Manual mode	Fixed set value of P1.037	P1.037, P2.000, P2.004, P2.006, P2.023, P2.024, P2.025, P2.043, P2.044, P2.045, P2.046, P2.049, P2.089, P2.098, P2.099, P2.101, P2.102	N/A
1	Gain adjustment mode 1	**Level adjustment** - Auto	Real-time estimation	P2.031	P1.037, P2.000, P2.004, P2.006, P2.023, P2.024, P2.025, P2.043, P2.044, P2.045, P2.046, P2.049, P2.089, P2.098, P2.099, P2.101, P2.102
2	Gain adjustment mode 2	**Level adjustment** - Semi-auto	Fixed set value of P1.037	P1.037 P2.031	P2.000, P2.004, P2.006, P2.023, P2.024, P2.025, P2.043, P2.044, P2.045, P2.046, P2.049, P2.089, P2.098, P2.099, P2.101, P2.102
3	Gain adjustment mode 3 (Available when two degree of freedom control function is enabled)	**Level adjustment** - Two degree of freedom	Fixed set value of P1.037	P1.037 P2.031 P2.089	P2.000, P2.004, P2.006, P2.023, P2.024, P2.025, P2.043, P2.044, P2.045, P2.046, P2.049, P2.098, P2.099, P2.101, P2.102
4	Gain adjustment mode 4	-	Reset to the default gain values	-	-

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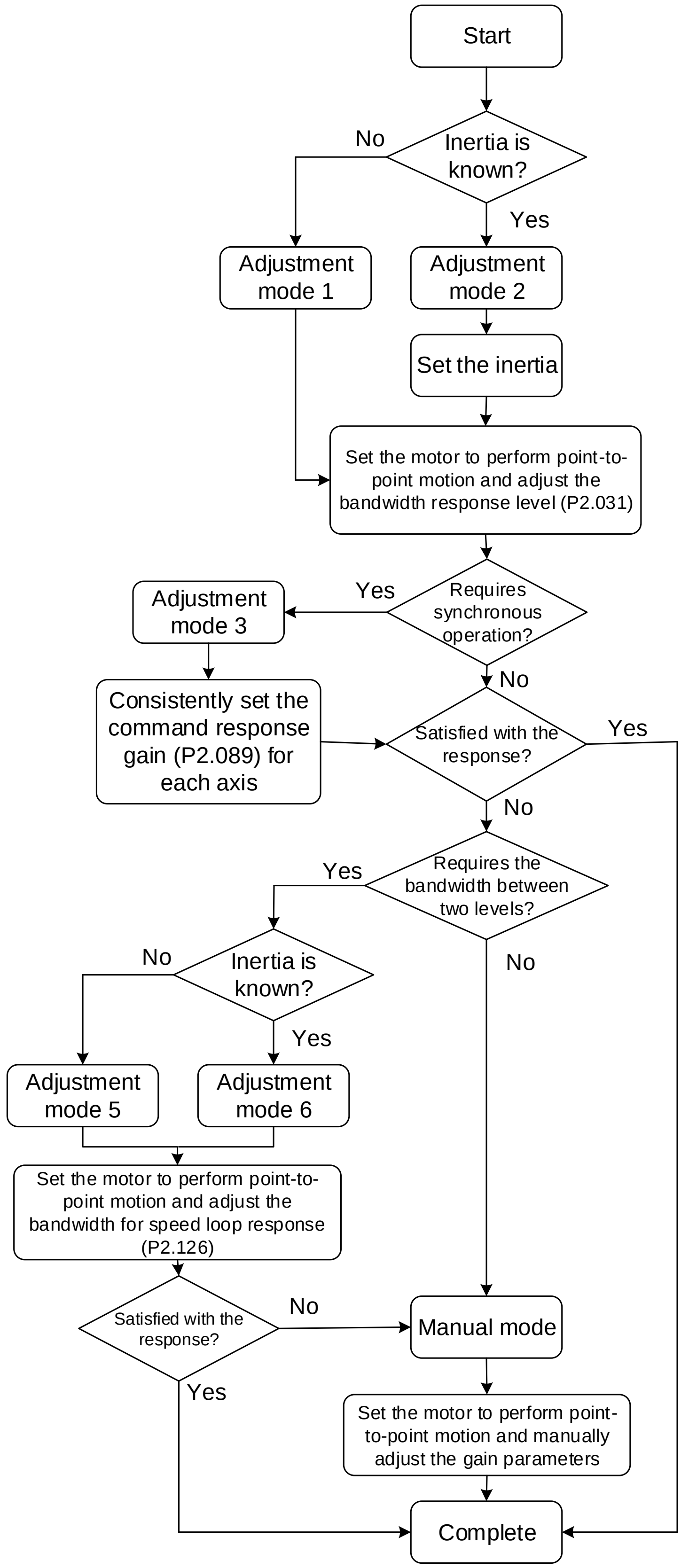
P2.032 value	Adjustment mode	Mode name	Inertia estimation	Parameter	
				Manual	Auto
5	Gain adjustment mode 5 (Same as setting P2-32 = 1 for the A2 series)	**Bandwidth adjustment** - Auto	Real-time estimation	P2.126	P1.037, P2.000, P2.004, P2.006, P2.023, P2.024, P2.025, P2.043, P2.044, P2.045, P2.046, P2.049, P2.089, P2.094, P2.098, P2.099, P2.101, P2.102
6	Gain adjustment mode 6 (Same as setting P2-32 = 2 for the A2 series)	**Bandwidth adjustment** - Semi-auto	Fixed set value of P1.037	P1.037 P2.126	P2.000, P2.004, P2.006, P2.023, P2.024, P2.025, P2.043, P2.044, P2.045, P2.046, P2.049, P2.089, P2.094, P2.098, P2.099, P2.101, P2.102

Note: when the two degree of freedom control function is disabled (P2.094 [Bit 12] = 0), the effect of Gain adjustment mode 3 is the same as that of Gain adjustment mode 2, so setting P2.089 is invalid in that scenario.

5.5.2 Flowchart of gain adjustment mode



Note: Gain adjustment modes 5 and 6 are similar to Gain adjustment modes 1 and 2 respectively. The main difference is that you can set the bandwidth for modes 5 and 6.

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5.5.3 Gain adjustment mode 1

You can use this mode when the load inertia is unknown or the inertia changes during machine operation.

The servo drive continually estimates the machine inertia and updates the value of P1.037. To reach the expected response, simply adjust the bandwidth response level (P2.031).

P2.032	Adjustment mode	Mode name	Inertia estimation	Parameter	
				Manual	Auto
1	Gain adjustment mode 1	**Level adjustment** - Auto	Real-time estimation	P2.031	P1.037, P2.000, P2.004, P2.006, P2.023, P2.024, P2.025, P2.043, P2.044, P2.045, P2.046, P2.049, P2.089, P2.098, P2.099, P2.101, P2.102

5.5.4 Gain adjustment mode 2

When the inertia cannot be successfully estimated in Gain adjustment mode 1, it is probably because the machine inertia ratio is greater than 100 times or the speed and acceleration / deceleration of the actual motor operation are too low. In this case, you can use Gain adjustment mode 2 to tune the servo system.

In Gain adjustment mode 2, you need to correctly set the machine inertia ratio in P1.037 first and then adjust the bandwidth response level (P2.031) to reach the expected response.

Note: inertia estimation is available for most machines. However, when the machine does not comply with the requirements for inertia estimation, you have to set the correct inertia ratio in P1.037.

P2.032	Adjustment mode	Mode name	Inertia estimation	Parameter	
				Manual	Auto
2	Gain adjustment mode 2	**Level adjustment** - Semi-auto	Fixed set value of P1.037	P1.037 P2.031	P2.000, P2.004, P2.006, P2.023, P2.024, P2.025, P2.043, P2.044, P2.045, P2.046, P2.049, P2.089, P2.098, P2.099, P2.101, P2.102

5.5.5 Gain adjustment mode 3

When Gain adjustment modes 1 and 2 cannot meet the requirements, try Gain adjustment mode 3 to tune the servo system. P2.089 (Command response gain) is available for manual adjustment in this mode. You can increase the gain value to shorten the response and settling time for the position command. However, if you set the parameter value too high, it might cause position overshoot and machinery vibration. This parameter is effective only when the commands are changing, such as in the acceleration / deceleration application, and adjusting this parameter can improve the response. However, when the two degree of freedom control function is disabled (P2.094 [Bit 12] is set to 0), the effect of Gain adjustment mode 3 is the same as that of Gain adjustment mode 2, so setting P2.089 is invalid in that scenario.

P2.032	Adjustment mode	Mode name	Inertia estimation	Parameter	
				Manual	Auto
3	Gain adjustment mode 3 (Available when two degree of freedom control function is enabled)	**Level adjustment** - Two degree of freedom	Fixed set value of P1.037	P1.037 P2.031 P2.089	P2.000, P2.004, P2.006, P2.023, P2.024, P2.025, P2.043, P2.044, P2.045, P2.046, P2.049, P2.098, P2.099, P2.101, P2.102

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5.5.6 Gain adjustment mode 4

When P2.032 is set to 4, the setting value of P2.032 is restored to the value set before initialization other than the default value after parameter reset (P2.008 = 10). For example, if P2.032 is 1, P2.032 is still 1 after gain initialization (P2.032 = 4).

Original setting value of P2.032	0	1	2	3
Setting value of P2.032 after parameter reset (P2.008 = 10)	1	1	1	1
Setting value of P2.032 after gain initialization (P2.032 = 4)	0	1	2	3

When P2.032 is set to 4, if the notch filters are set to Manual for manual resonance suppression, the related notch filter parameters are not reset. If the notch filters are automatically set, the related notch filter parameters and the parameters in the following tables are reset to the default. The default values of other related parameters are as follows.

Gain parameters		
Parameter No.	Default	Function
P1.037	6.0	Load inertia ratio or total weight
P2.000	36	Position control gain
P2.004	144	Speed control gain
P2.006	23	Speed integral compensation
P2.031	19	Bandwidth response level
P2.089	23	Command response gain
P2.105	11	Automatic gain adjustment level 1
P2.106	2000	Automatic gain adjustment level 2

Filter and resonance suppression parameters		
Parameter No.	Default	Function
P1.025	100.0	Low-frequency vibration suppression frequency 1
P1.026	0	Low-frequency vibration suppression gain 1
P1.027	100.0	Low-frequency vibration suppression frequency 2
P1.028	0	Low-frequency vibration suppression gain 2
P2.023	1000	Notch filter 1 - frequency
P2.024	0	Notch filter 1 - attenuation level
P2.025*	5.0	Resonance suppression low-pass filter
P2.043	1000	Notch filter 2 - frequency
P2.044	0	Notch filter 2 - attenuation level
P2.045	0	Notch filter 3 - frequency
P2.046	0	Notch filter 3 - attenuation level
P2.047	1	Auto resonance suppression mode
P2.049*	5.0	Speed detection filter and jitter suppression
P2.098	1000	Notch filter 4 - frequency
P2.099	5	Notch filter 4 - attenuation level
P2.101	100	Notch filter 5 - frequency
P2.102	0	Notch filter 5 - attenuation level

Note: when P2.032 is set to 0 and then 4, the default settings of P2.025 and P2.049 are both 0.8.

5.5.7 Gain adjustment mode 5

You can use this mode when the load inertia is unknown or the inertia changes during machine operation.

The servo drive continually estimates the machine inertia and updates the value of P1.037. To reach the expected response, simply set the bandwidth for speed loop response (P2.126) to adjust the servo stiffness or reduce the noise.

P2.032	Adjustment mode	Mode name	Inertia estimation	Parameter	
				Manual	Auto
5	Gain adjustment mode 5 (Same as setting P2-32 = 1 for the A2 series)	**Bandwidth adjustment** - Auto	Real-time estimation	P2.126	P1.037, P2.000, P2.004, P2.006, P2.023, P2.024, P2.025, P2.043, P2.044, P2.045, P2.046, P2.049, P2.089, P2.094, P2.098, P2.099, P2.101, P2.102

5.5.8 Gain adjustment mode 6

When the inertia cannot be successfully estimated in Gain adjustment mode 5, it is probably because the machine inertia ratio is greater than 100 times or the speed and acceleration / deceleration of the actual motor operation are too low. In this case, you can use Gain adjustment mode 6 to tune the servo system.

In Gain adjustment mode 6, you need to correctly set the machine inertia ratio in P1.037 first and then adjust the bandwidth for speed loop response (P2.126). Setting P2.126 higher can increase the servo stiffness and setting P2.126 lower can reduce the noise.

P2.032	Adjustment mode	Mode name	Inertia estimation	Parameter	
				Manual	Auto
6	Gain adjustment mode 6 (Same as setting P2-32 = 2 for the A2 series)	**Bandwidth adjustment** - Semi-auto	Fixed set value of P1.037	P1.037 P2.126	P2.000, P2.004, P2.006, P2.023, P2.024, P2.025, P2.043, P2.044, P2.045, P2.046, P2.049, P2.089, P2.094, P2.098, P2.099, P2.101, P2.102

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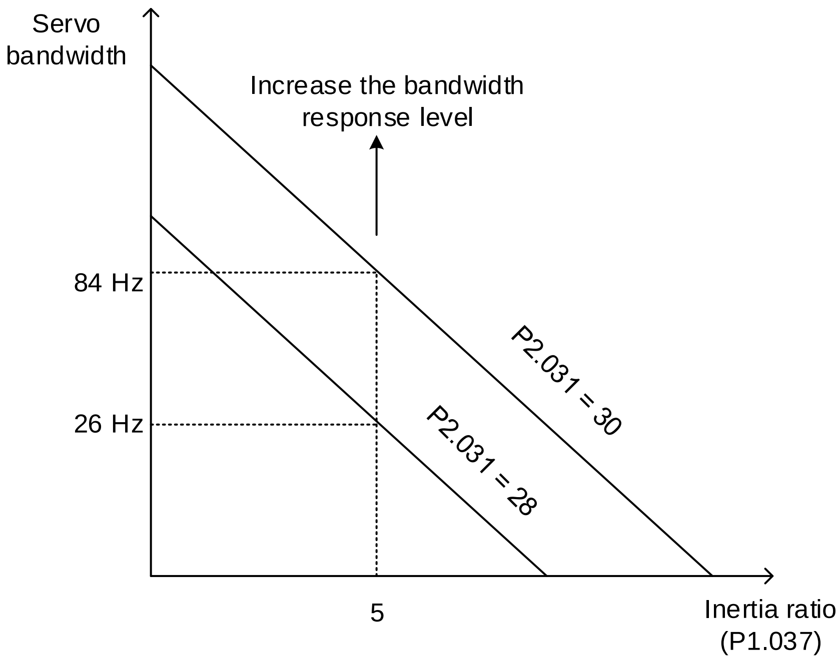
5.5.9 Parameters related to gain adjustment modes

5.5.9.1 Bandwidth response level (P2.031) - stiffness adjustment

This parameter enables you to tune the servo drive in a simple and instinctive way. When the inertia is fixed and you increase the bandwidth response level (P2.031), the servo's bandwidth increases as well. If resonance occurs, decrease the setting value of P2.031 by one or two bandwidth response levels (you should adjust the bandwidth response level according to the actual situation). For instance, if the value of P2.031 is 30, you can lower the setting to 28. When you adjust the value of this parameter, the servo drive automatically adjusts the corresponding gain parameters, such as P2.000 and P2.004.

Note: enabling the bandwidth response level reversion function (P2.125 [Bit 3]) is recommended when you are adjusting the bandwidth response level (P2.031).



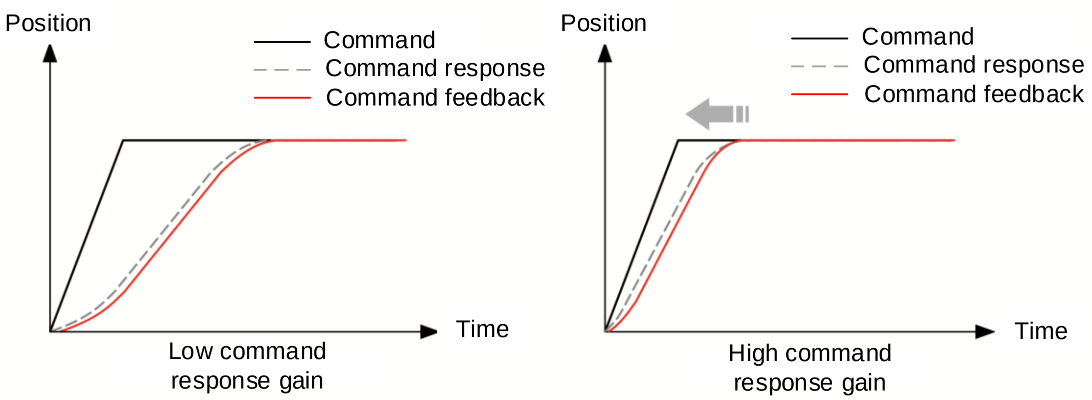
Bandwidth response level reversion (P2.125 [Bit 3])

When the bandwidth response level reversion function is enabled (P2.125 [Bit 3] = 1), the servo automatically sets the upper limit for the setting value of P2.031 to reduce hazards caused by resonance.

When the bandwidth response level reversion function is enabled, resonance caused by increasing P2.031 can be suppressed with the Notch filter. When any of the 5 sets of Notch filters is not set, the servo automatically sets that Notch filter for resonance suppression. If the resonance cannot be suppressed when P2.031 is increased, the servo automatically decreases P2.031 to the level where the resonance does not occur, and then the servo sets the last set value of P2.031 before it is decreased as the upper limit of P2.031. If requiring to further increase P2.031, disable the bandwidth response level reversion function and the upper limit is lifted.

5.5.9.2 Command response gain (P2.089) - response adjustment

P2.089 adjusts the command response gain to improve the response to the servo command. Increasing the gain can reduce the transient error between the position command and command response (in acceleration and deceleration zones). That is, the setting is effective only when the commands are changing. This parameter is available only when the two degree of freedom control function is enabled (P2.094 [Bit 12] = 1) in Position mode. (The two degree of freedom control function is enabled by default).



5.5.9.3 Bandwidth for speed loop response (P2.126) - bandwidth adjustment

P2.126 sets the bandwidth for the speed loop, and the corresponding position loop bandwidth and the speed loop bandwidth are at a fixed ratio. To fine-tune the ratio between the position bandwidth and speed bandwidth (P2.000 and P2.004) or the ratio between the proportional gain (P2.004) and integral gain (P2.006) of the speed loop, switch the system to Manual mode for operation.

Assuming that the bandwidth setting of P2.126 = BW, the recommended settings for the gain parameters are as follows.

- P2.000 = P2.004 / 4
- P2.004 = BW * 2 * π
- P2.006 = BW
- P2.026 = BW

5.6 Manual tuning of gain parameters

The position or speed response bandwidth is determined by the mechanical stiffness and the application. Generally, for applications or machines that require high-speed positioning and high precision, higher response bandwidth is required. However, increasing the response bandwidth is likely to cause mechanical resonance. Thus, machinery with higher stiffness is used to solve this problem. When the response bandwidth of the machine is unknown, you can gradually increase the gain parameter values to increase the response bandwidth. Then, decrease the gain parameter values until you hear the sound of the resonance. The following are the descriptions of the gain adjustment parameters.

- Position control gain (KPP, P2.000)

  This parameter determines the response of the position control circuit. The bigger the KPP value, the higher the bandwidth of the position loop. This lowers the following error and position error, and shortens the settling time. However, if you set the value too high, it can cause machine jitter or cause overshoot when positioning. The calculation of position loop bandwidth is as follows:

$$\text{Position loop bandwidth (Hz)} = \frac{KPP}{2\pi}$$

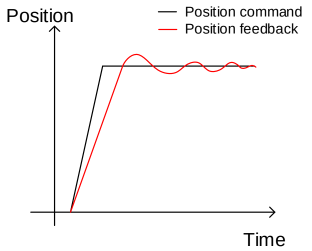
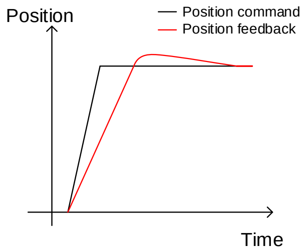
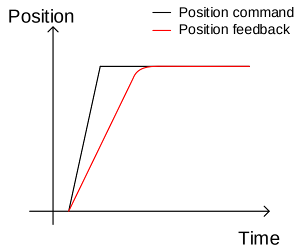
- Speed control gain (KVP, P2.004)

  This parameter determines the response of the speed control circuit. The bigger the KVP value, the higher the bandwidth of the speed loop and the lower the following error. However, if you set the value too high, it is likely to cause mechanical resonance. The speed loop bandwidth must be 4 times (or more) the position loop bandwidth; otherwise, it can cause machine jitter or cause overshoot when positioning. The calculation of speed loop bandwidth is as follows:

$$\text{Speed loop bandwidth (Hz)} = \left(\frac{KVP}{2\pi}\right) \times \left[\frac{(1 + P1.037 / 10)}{(1 + JL / JM)}\right]$$

  JM: motor inertia; JL: load inertia

  The following table illustrates the changes in position feedback when the speed loop bandwidth is 1 time, 2 times, and 4 times the position loop bandwidth.

Speed loop bandwidth: 100 Hz Position loop bandwidth: 100 Hz	Speed loop bandwidth: 100 Hz Position loop bandwidth: 50 Hz	Speed loop bandwidth: 100 Hz Position loop bandwidth: 25 Hz
		

When P1.037 (auto estimation or manually set value) is equal to the actual load inertia ratio (JL / JM), the actual speed loop bandwidth is:

$$\text{Speed loop bandwidth (Hz)} = \left(\frac{KVP}{2\pi}\right)$$

- Speed integral compensation (KVI, P2.006)

  The higher the KVI value, the better the elimination of the deviation. However, if you set the value too high, it can cause machine jitter. It is advisable to set the value as follows:

$$KVI \leq 1.5 \times \text{Speed loop bandwidth (Hz)}$$

- Resonance suppression low-pass filter (NLP, P2.025)

  A high load inertia ratio reduces the speed loop bandwidth. Therefore, you must increase the KVP value to maintain the speed loop bandwidth. Increasing the KVP value might cause mechanical resonance. Use this parameter to eliminate the noise. The higher the value, the better the capability of reducing high-frequency noise. However, if you set the value too high, it can cause instability in the speed control circuit and overshoot. It is advisable to set the value as follows:

$$NLP \leq \frac{10000}{6 \times \text{Speed loop bandwidth (Hz)}}$$

- Anti-interference gain (DST, P2.026)

  Use this parameter to increase the ability to resist external force and reduce overshoot during acceleration / deceleration. The default value is 0. Adjusting this value in Manual mode is not suggested unless it is for fine-tuning the results of auto tuning.

  Note: this gain parameter is not available when the two degree of freedom control function is enabled (P2.094 [Bit 12] = 1).

- Position feed forward gain (PFG, P2.002)

  This parameter can reduce the position error and shorten the settling time. However, if you set the value too high, it might cause overshoot when positioning. When the resolution of the pulse command is low, adjusting this parameter might cause noise. In this case, try using P2.003, P1.008, and P1.068 to eliminate the noise.

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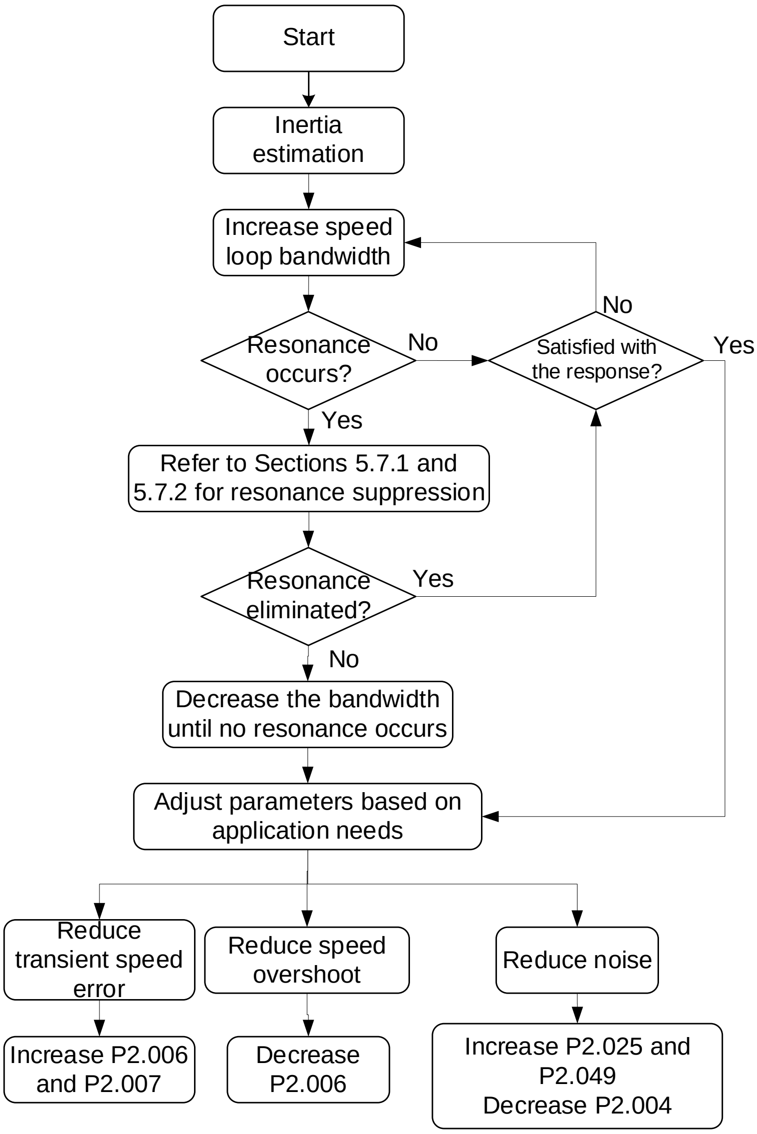
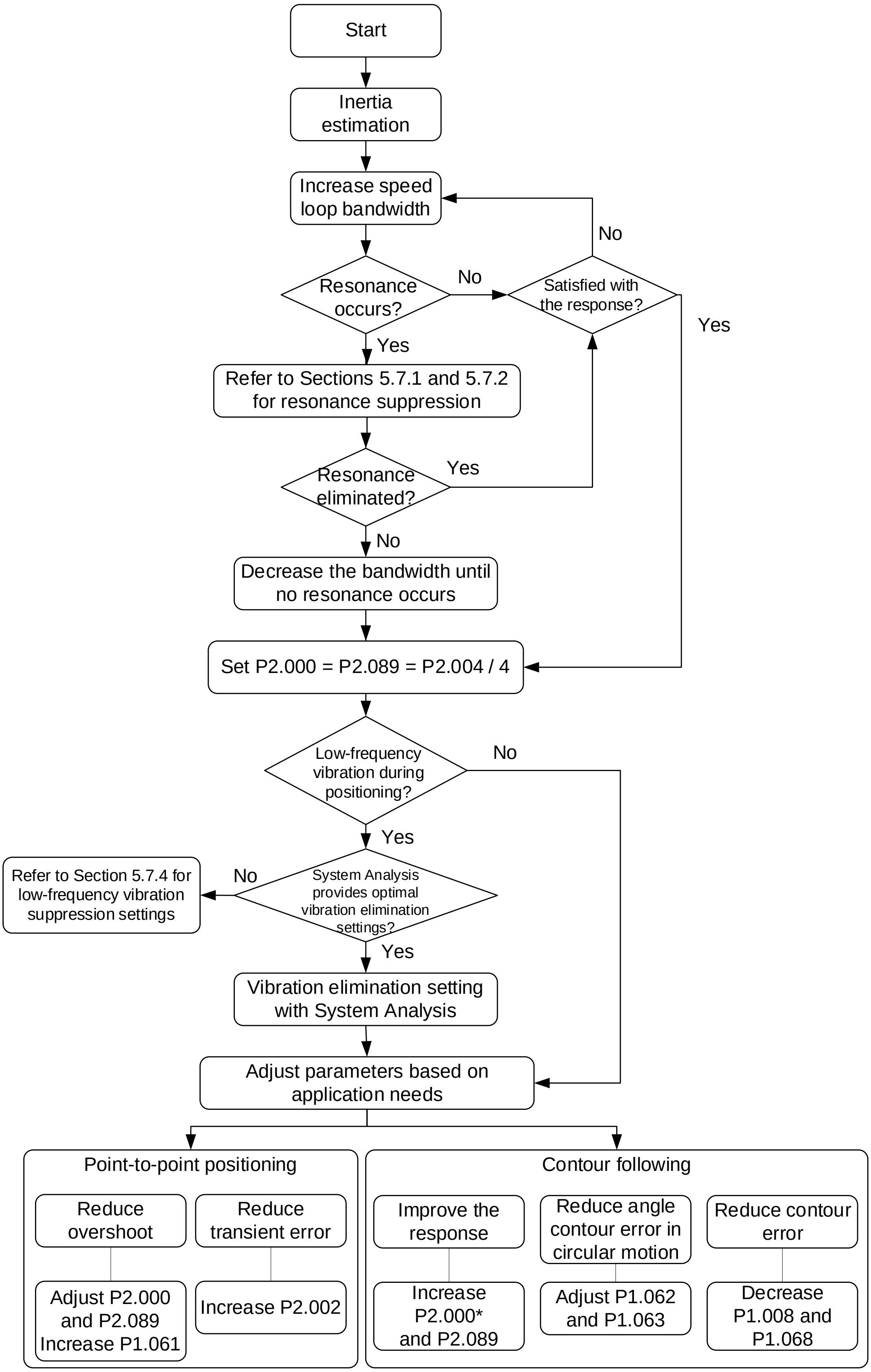
5.6.1 Flowchart of manual tuning in Speed mode



5.6.2 Flowchart of manual tuning in Position mode



Note: it is advisable to set P2.004 four times (or more) the setting value of P2.000; otherwise a jitter occurs in the corner contour.

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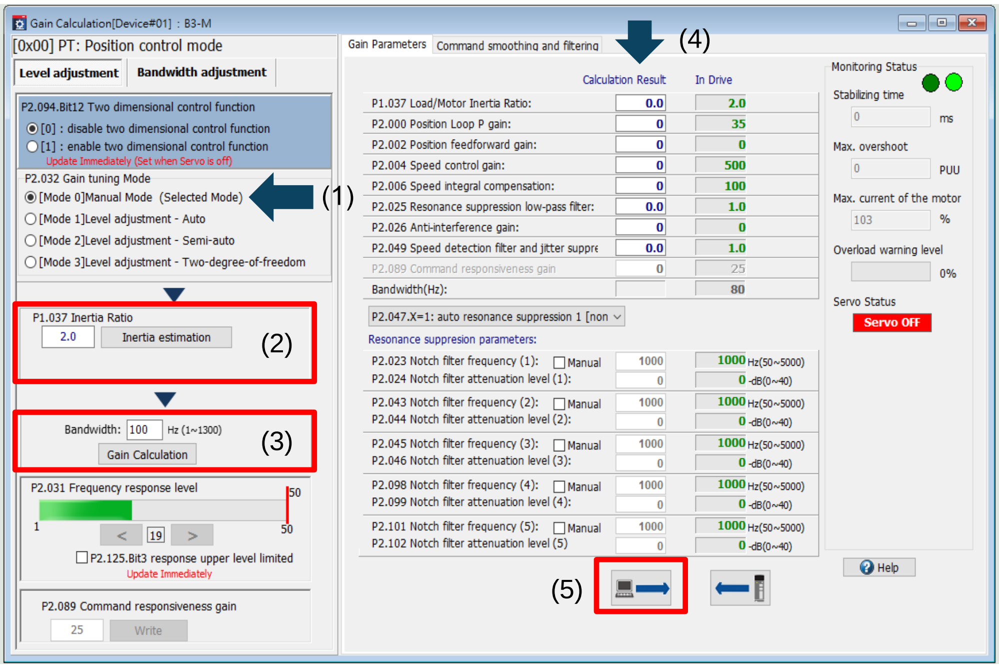
5.6.3 Manual tuning with ASDA-Soft

1. Select **[Mode 0] Manual Mode**.
2. Click **Inertia estimation**.
3. Set the bandwidth, click **Gain Calculation**, and the Calculation Result field on the right shows the corresponding parameter settings according to the set speed loop bandwidth.
4. Fine-tune the values in the Calculation Result field. It is advisable to set P2.004 four times (or more) the setting value of P2.000.
5. After fine-tuning the parameters, click the button to write the parameters to the servo drive.

Note: for parameter settings of the two degree of freedom control function in Manual mode (P2.032 = 0), refer to Section 5.7.5.3.



5.7 Mechanical resonance suppression and noise elimination

When mechanical resonance occurs, it is probably because the stiffness of the servo drive control system is too high or the response bandwidth is too great. Eliminating these two factors can improve the situation. During the tuning process, when you gradually increase the servo response bandwidth, the frequency at the resonance point is likely to be reached, causing noise and vibration. In this case, use the following filters to effectively eliminate the noise and vibration and therefore increase the response bandwidth.

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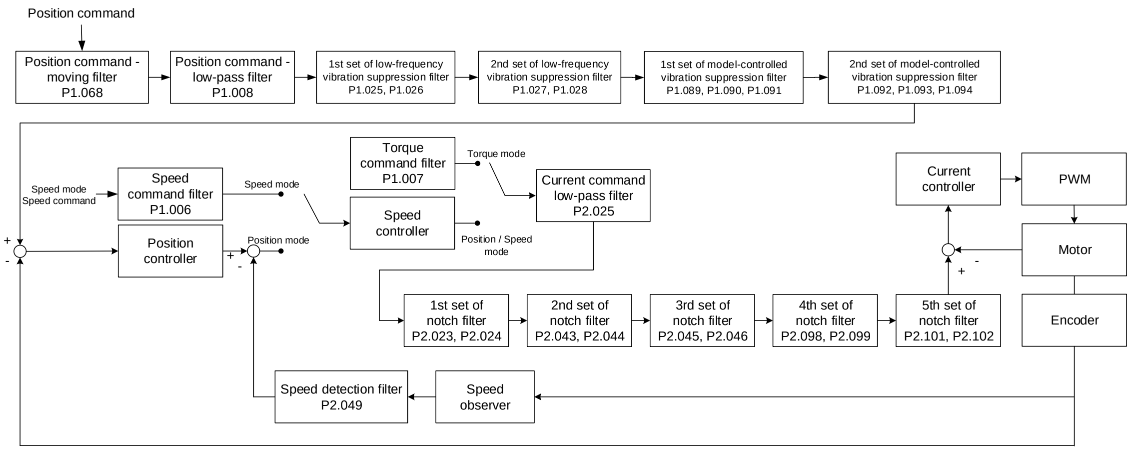
Block diagram of filter setting



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5.7.1 Notch filter

5.7.1.1 Function restriction

1. The Notch filter frequency settings (P2.023, P2.043, P2.045, P2.098, and P2.101) must be 2 times (or more) the speed loop bandwidth (P2.004 / 2π), or it might lead to system divergence.
2. It is recommended that the notch depth (magnitude) of the resonance point should remain at -15 to -10 dB after resonance suppression.

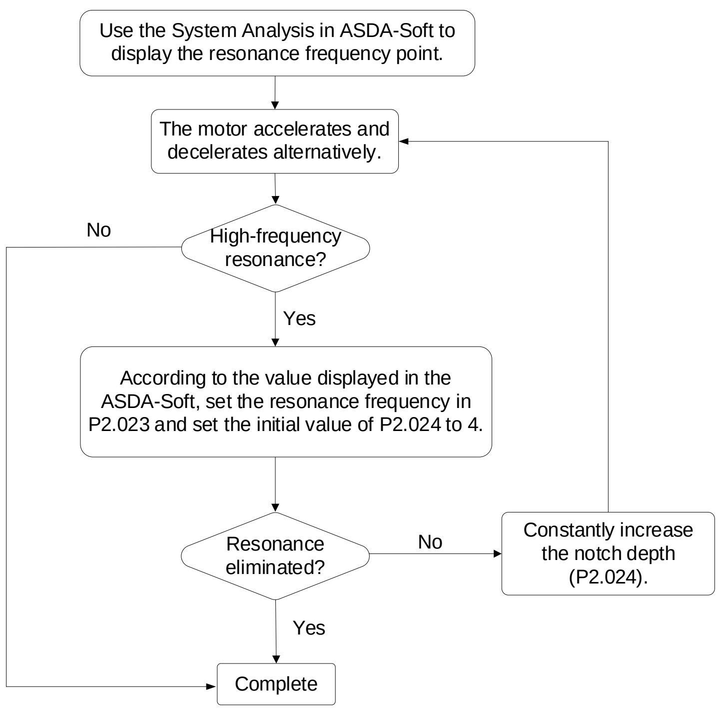
Note: it is recommended that you set the Analysis Type to **Speed Open-loop** in the System Analysis of ASDA-Soft; the zero-crossing frequency is the speed loop bandwidth.

5.7.1.2 Function description

The servo provides 5 sets of notch filters with the frequency setting range of 50 to 5000 Hz. Each set of notch filter supports the function of auto resonance suppression (P2.047 and P2.048). In addition, you can suppress the resonance manually. The precautions and operation procedure for manual resonance suppression are as follows.

- Use the **System Analysis** function in ASDA-Soft V6 to find the resonance frequency.
- The sudden loss of load inertia is likely to cause resonance. It is advisable to tune the servo drive at maximum load.
- If the resonance frequency is incorrectly set, the noise and vibration might be worse.
- The higher the attenuation level and Q factor, the better the effect of resonance suppression. However, if the values are set too high, it results in phase lag and causes resonance at other frequencies.

Flowchart of manual resonance suppression:



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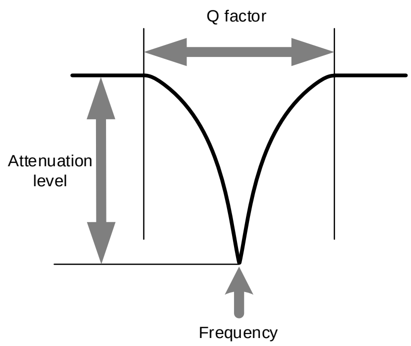
5.7.1.3 Parameter descriptions

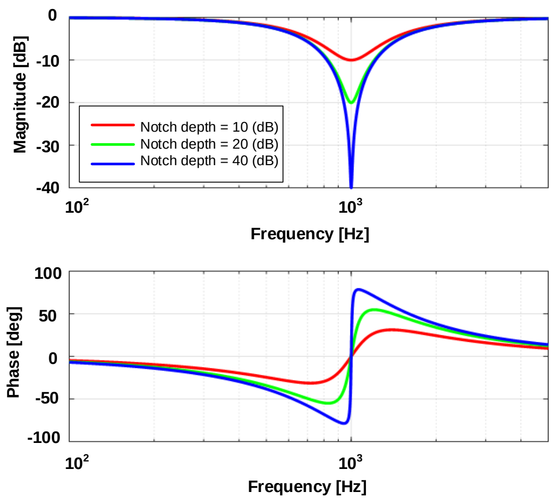
A notch filter is used to remove frequencies within a specific range. You can set the three parameters, including frequency, attenuation level, and Q factor, for each set of notch filter. The following describes the parameters of attenuation level (notch depth) and Q factor.



Attenuation level of notch filter

The attenuation level of the notch filter determines the notch depth (magnitude) of the frequency to be filtered. Properly set the attenuation level to effectively suppress the vibration. The higher the setting value, the better the effect of resonance suppression, but the phase margin of the system becomes smaller. When you set the value too high, the phase margin may become insufficient, causing resonance at other frequencies.

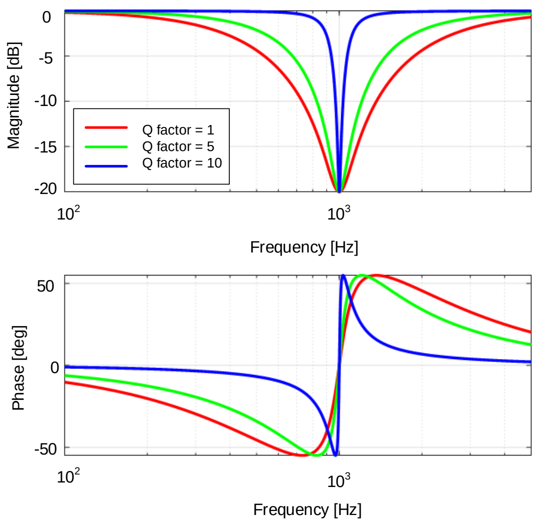
When the attenuation level of the notch filter is set to 0, it means the filter function is disabled.



Q factor of notch filter

The Q factor of the notch filter determines the frequency range (amount of signal) around the specific frequency to be filtered. **The higher the Q factor, the narrower the filtered frequency band**, and thus the phase margin of the system is **less** affected. In general, for systems with higher inertia or lower stiffness, the Q factor at the resonance point is relatively high.

If the Q factor is set too high, the resonance cannot be completely suppressed, and it is likely to cause resonance at the cut-off frequencies around the resonance point. In this case, set the Q factor lower to improve the condition.



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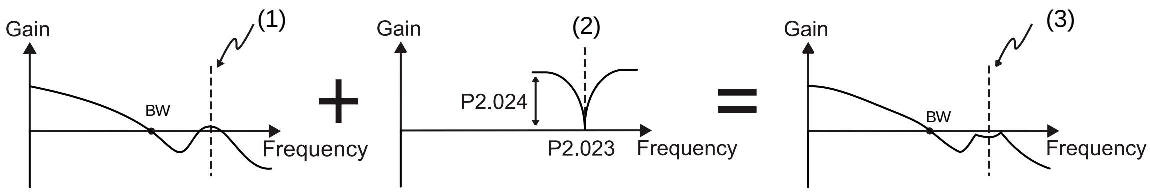
5.7.1.4 Application example

It is advisable to perform domain-frequency analysis and time-domain analysis alternately for comparing and monitoring the results.

Frequency-domain analysis

Draw Bode plots by setting the Analysis Type to **Speed Open-loop** in the System Analysis of ASDA-Soft. The following figure shows the speed open-loop gain with resonance. Set the frequency at the resonance point as the frequency of the notch filter and gradually increase the attenuation level (notch depth) of the notch filter in the corresponding parameter. When increasing the notch depth, you can set the Analysis Type to **Speed Open-loop** in the System Analysis* to check if the resonance point is neutralized. If the notch depth is too shallow, resonance might occur in the system again. If the notch depth is too deep, the phase margin of the system will be sacrificed, making it difficult to increase the bandwidth afterwards. It is recommended that the notch depth (magnitude) of the resonance point should remain at -15 to -10 dB after resonance suppression.

Note: when the frequency setting is lower than 100 Hz, it is advisable to select the check box for **Enable Low Frequency Analysis** in the System Analysis of ASDA-Soft. If the check box is not selected, the zero-crossing frequency might not be correctly detected or the low-frequency resonance point might be ignored or regarded as noise.



(1) Resonance point; (2) Notch filter; (3) Resonance point after resonance suppression

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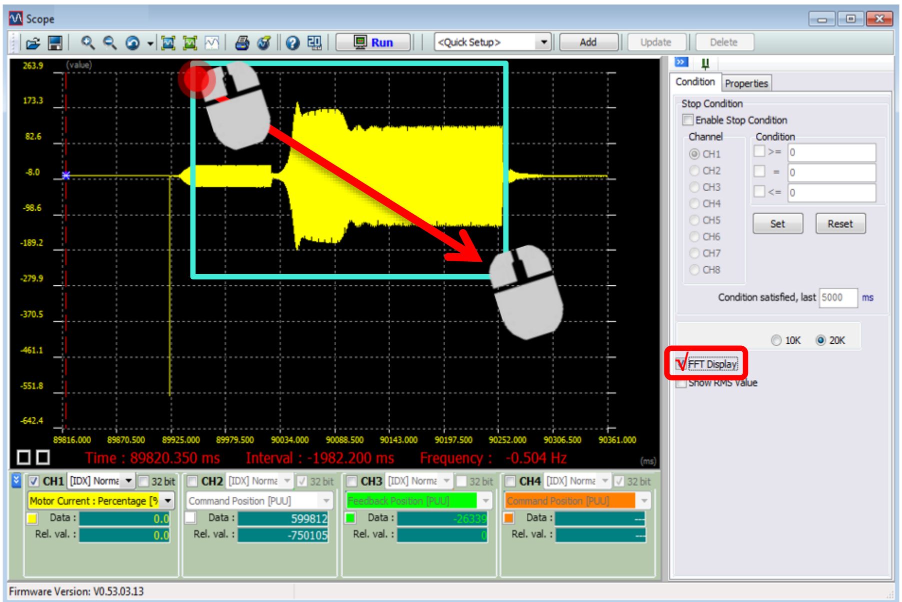
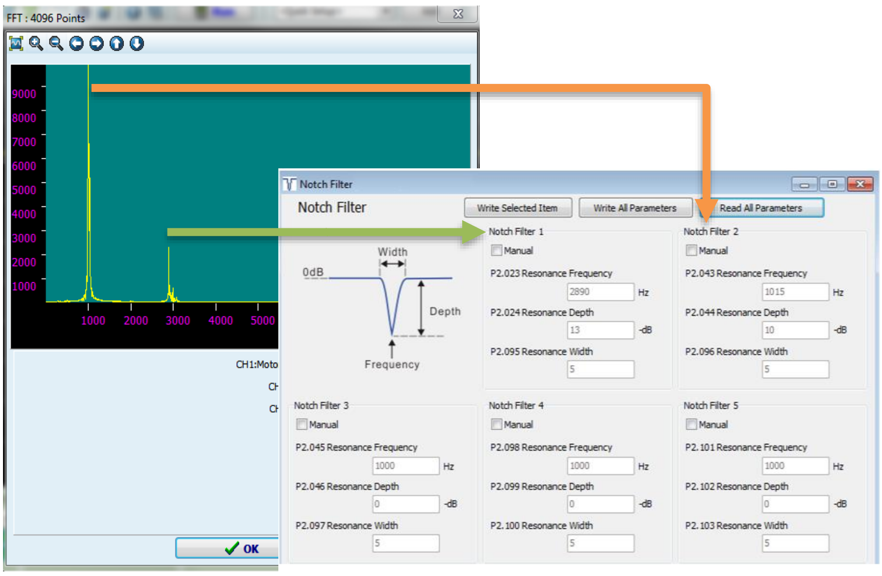
Time-domain analysis

1. Execute the Scope function in ASDA-Soft and select **Motor Current: Percentage [%]** for the channel.
2. Click **Run**, and the scope collects the current data when the motor is operating.
3. Click **Stop**, and the operation status of the motor is displayed in the software interface.
4. Select the check box for **FFT Display**, then left-click and drag the mouse to select the area with data displayed, and the spectrum appears on the screen.



According to the spectrum, we can find two resonance points at the frequencies of 1015 Hz and 2890 Hz. In the following figure, P2.047.X is set to 1 or 2 for the servo to automatically fill in the resonance suppression parameters. To set the resonance points for manual resonance suppression, select the check box for **Manual** under the specific set of notch filter, and then the corresponding bit of P2.047.Y or P2.047.Z is automatically set to 1. In this case, you can manually set the resonance suppression parameters.



Relevant parameter

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
P2.043	Notch filter 2 - frequency
P2.044	Notch filter 2 - attenuation level
P2.045	Notch filter 3 - frequency
P2.046	Notch filter 3 - attenuation level
P2.047	Auto resonance suppression mode
P2.048	Auto resonance detection 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

5

5.7.2 Resonance suppression low-pass filter

5.7.2.1 Function restriction

It is recommended that the filter bandwidth (1000 / P2.025) should be 8 times (or more) the speed loop bandwidth (P2.004 / 2π).

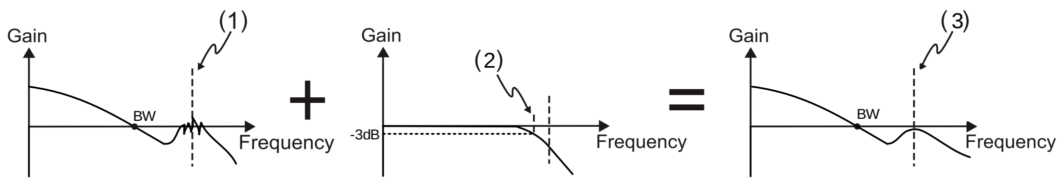
Note: it is recommended that you set the Analysis Type to **Speed Open-loop** in the System Analysis of ASDA-Soft; the zero-crossing frequency is the speed loop bandwidth.

5.7.2.2 Function description

The current command generated in the speed loop is filtered by the resonance suppression low-pass filter, which reduces the interference of high-frequency resonance or noise to current control. Since the filter causes a delay in the current command, when increasing the servo response bandwidth, you must set the time constant for the low-pass filter (P2.025) smaller. However, it causes greater noise during motor operation.

5.7.2.3 Application example

Draw Bode plots by setting the Analysis Type to **Speed Open-loop** in the System Analysis of ASDA-Soft. When there is more than one resonance point and the distribution of the resonance points is not wide, it is advisable to use the resonance suppression low-pass filter to suppress the resonance occurring at the resonance points within a specified range.
If the resonance frequency is known, the Notch filter works better than the resonance suppression low-pass filter for resonance suppression. If the spectrum displays multiple resonance points which are densely distributed, or the resonance frequency drifts significantly with time or due to other causes, use the resonance suppression low-pass filter instead.
When P2.025 is gradually increased, the filter bandwidth becomes smaller. Although resonance does not occur in this condition, the servo response is slower and the phase margin is reduced. If the ratio between the filter bandwidth (1000 / P2.025) and speed loop bandwidth (P2.004 / 2π) is too small, the system becomes unstable.



(1) Resonance point;

(2) Resonance suppression low-pass filter (Cut-off frequency of low-pass filter = 1000 / P2.025 Hz);

(3) Resonance point after resonance suppression

Relevant parameter

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

Parameter	Function
P2.025	Resonance suppression low-pass filter

5.7.3 Speed detection filter

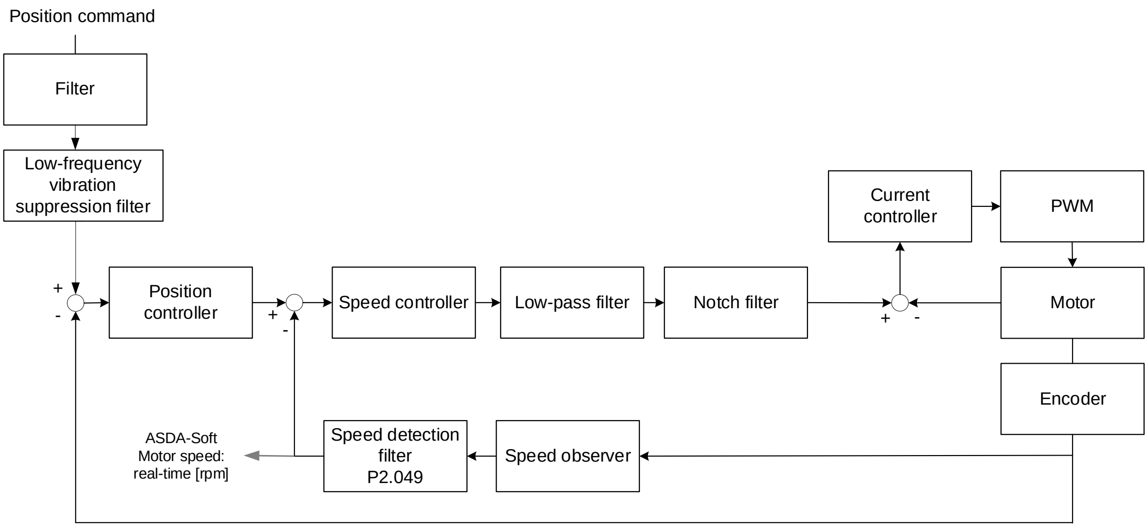
5.7.3.1 Function restriction

It is recommended that the filter bandwidth (1000 / P2.049) should be 8 times (or more) the speed loop bandwidth (P2.004 / 2π).

Note: it is recommended that you set the Analysis Type to **Speed Open-loop** in the System Analysis of ASDA-Soft; the zero-crossing frequency is the speed loop bandwidth.

5.7.3.2 Function description

When the motor speed is unstable, use this function to reduce the jitter in the motor speed. You can obtain the speed information after the position feedback signal from the encoder is processed by the speed observer. You can use the Scope function of ASDA-Soft to monitor the speed signal processed by the speed detection filter by setting the channel to **Motor speed: real-time [rpm]**.



You can set P2.084.U to select the speed observer.

P2.084.U	Speed observer	Filter bandwidth	Applicable range
0	Speed observer 1	1000 / P2.049	Available for high resolution encoders.
1	Speed observer 2	The bandwidth cannot be adjusted.	Available for encoders or linear scales with low resolution, such as rotary encoders with the single-turn resolution smaller than 40000 pulse/rev used in low speed (< 100 rpm) application, or linear encoders with the resolution greater than 5 µm/pulse.
2	Speed observer 3	1000 / P2.049	

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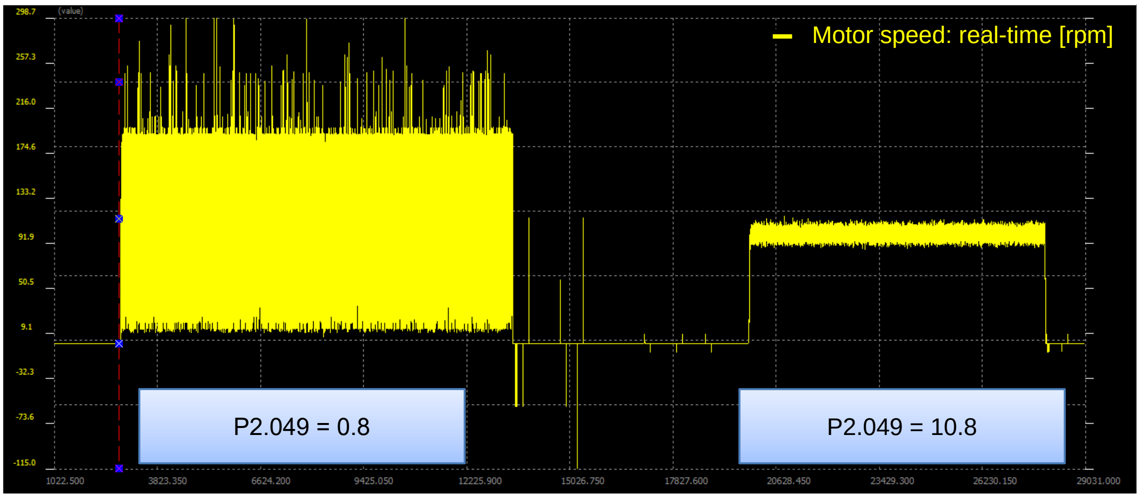
5.7.3.3 Application example

The following figure illustrates the difference between setting P2.049 to 0.8 and 10.8 when the speed observer 1 is used (P2.084.U = 0). You need to select a suitable speed observer for different installation methods for mechanical parts or different motors and then verify if the results meet the requirements.



Relevant parameter

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

Parameter	Function
P2.049	Speed detection filter and jitter suppression
P2.084	Special function for low resolution motor

5.7.4 Low-frequency vibration suppression filter

5.7.4.1 Function restriction

5

1. Set the control mode (P1.001.YX) to Position mode (PT or PR).
2. Frequency range: 1.0 Hz to 100.0 Hz.
3. If the low-frequency vibration suppression function and the vibration elimination function are enabled simultaneously, the system response becomes slower.

5.7.4.2 Function description

The low-frequency vibration suppression filter is also called position command notch filter. The low-frequency vibration suppression function filters the frequencies causing mechanical vibration but delays the system response time.
If the machine stiffness is insufficient, mechanical vibration persists even when the motor stops after the positioning command is complete. The low-frequency vibration suppression function can reduce the mechanical vibration. The suppression range is between 1.0 Hz and 100.0 Hz.
The servo provides both manual and auto settings for the function of low-frequency vibration suppression. During the auto tuning process, the auto low-frequency vibration suppression function is enabled and properly set.

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

1. Automatically resets P1.029 to 0.
2. Sets P1.025 as the first set of frequency and P1.026 to 1.
3. Sets P1.027 as the second set of frequency and 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 enabled automatically. If the values of P1.026 and P1.028 are both 0, it means no frequency is detected. Lower the value of P1.030 (Low-frequency vibration detection) and set P1.029 to 1 to search for the vibration frequency again. 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 the setting value of P1.030 is higher than the vibration of the machine. If so, it is suggested that you decrease the value of P1.030. Note that if the value is set too small, the system might mistakenly regard 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 reference of setting P1.030.

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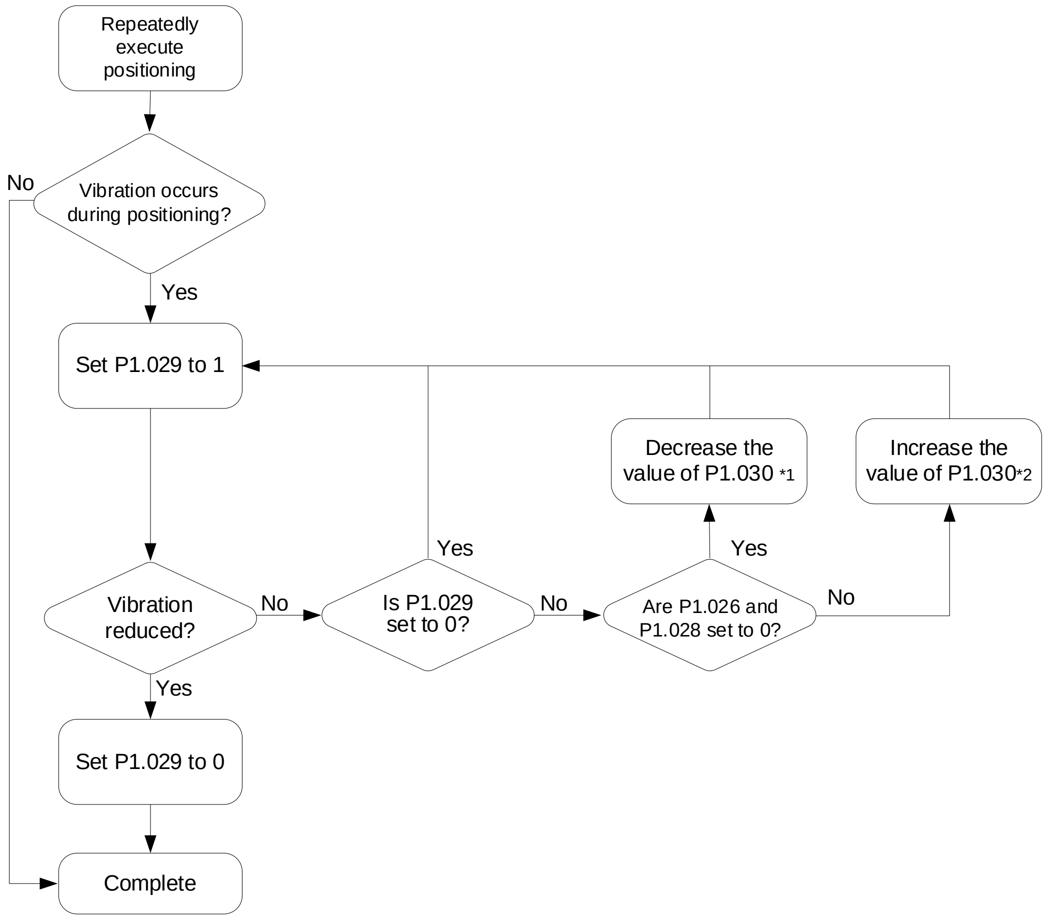
Flowchart of auto low-frequency vibration suppression:



Note:

1. When the values of P1.026 and P1.028 are both 0, it means no frequency is detected. It is probably because P1.030 (Low-frequency vibration detection) is set too high so that the low-frequency vibration is not detected.
2. When the value of P1.026 or P1.028 is greater than 0, but the vibration persists, it is probably because P1.030 is set too low, causing the system to mistakenly regard minor frequency or noise as the low-frequency vibration.

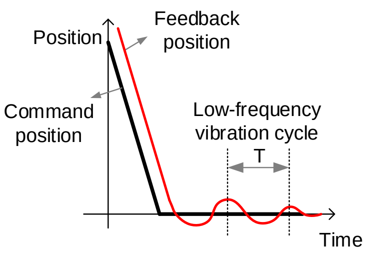
Manual setting:

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 vibration frequency. 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 parameters to reduce two different low-frequency vibrations. Use P1.025 and P1.027 to set the frequencies for low-frequency vibration suppression. The filter function works only when the parameter setting is close to the actual 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.

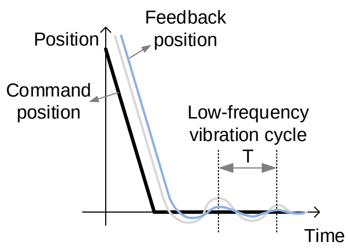
5.7.4.3 Application example

During position settling, if a vibration with the frequency lower than 100 Hz (not the high-frequency noise when the motor is moving) occurs and it is difficult to identify the frequency with the **System Analysis** function in ASDA-Soft, use the low-frequency vibration suppression function to suppress the vibration caused by the specific frequency. Setting the low-frequency vibration suppression filter makes the system more stable but lowers the response. When the frequency setting is the same for the two sets of low-frequency vibration suppression filter, the effect of vibration suppression is doubled.

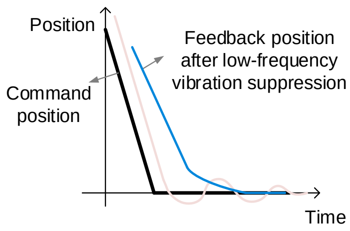
If the frequency of the low-frequency vibration in the system varies during the operation, such as in the long-distance belt drive system, the vibration frequency may be different at two positioning points. In this case, set two sets of low-frequency vibration suppression individually.



1. Set P1.025 and P1.026.
   P1.025 = 1 / T
   P1.026 = 1



2. If the vibration is smaller but not completely eliminated, you can set another set of low-frequency vibration suppression with the same frequency. The effect of vibration suppression is doubled.
   P1.027 = 1 / T
   P1.028 = 1



3. If the vibration is completely eliminated but the response is too slow, gradually increase P1.026.
   P1.026 = 2

Relevant parameter

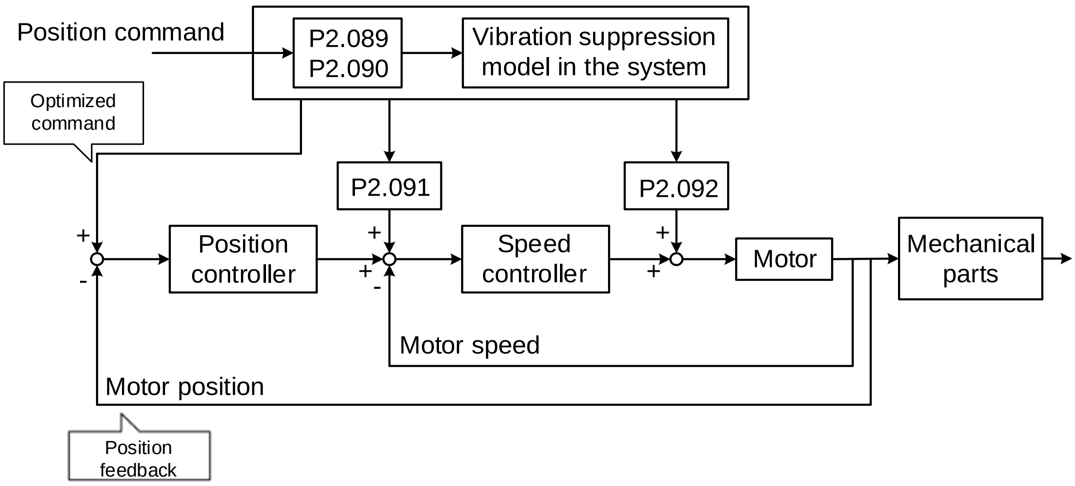
Refer to Chapter 8 for detailed descriptions of the relevant parameters.

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

5

5.7.5 Model-controlled vibration suppression filter

The idea of model-following control is to build a virtual model of the real physical system in the servo drive in digital format. The virtual model processes the position command planned by the user and generates an optimized position command. At the same time, the model designs optimized position feed forward and speed feed forward, so the feedback system follows the optimized position command, achieving the expected response. If the response designed by the system does not meet your requirements, fine-tune the parameters P2.091 and P2.092.



5.7.5.1 Restrictions of the two degree of freedom control function

Setting P2.094 [Bit 12] to 1 enables the two degree of freedom control mode, but you need to pay attention to the following restrictions.

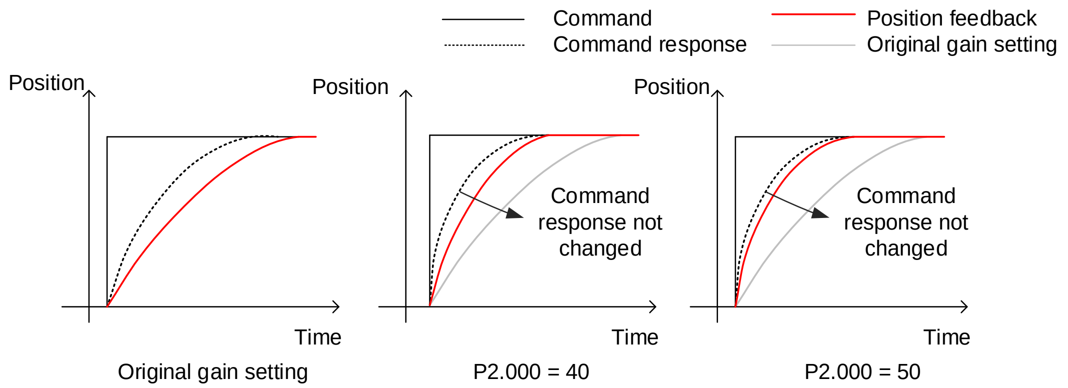
1. Set the control mode (P1.001.YX) to Position mode (PT or PR).
2. Set the inertia ratio (P1.037) correctly when using this function.
3. The setting of anti-interference gain (P2.026) is invalid when this function is used.

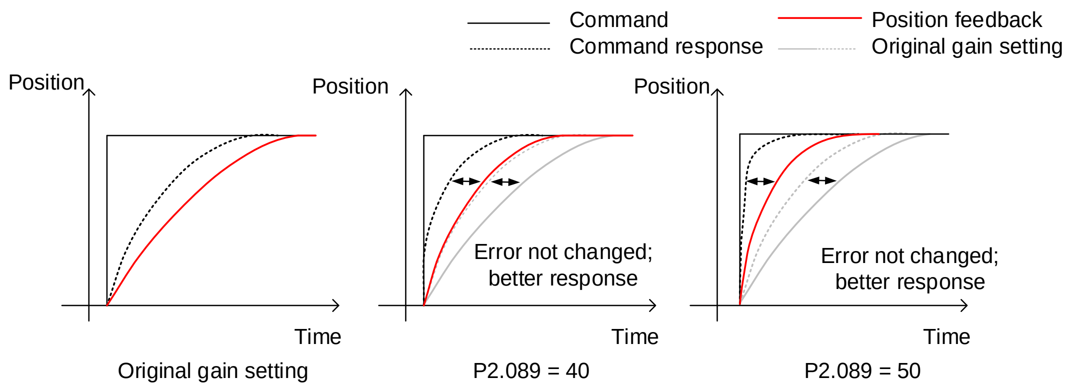
5

5.7.5.2 Function description of two degree of freedom control function

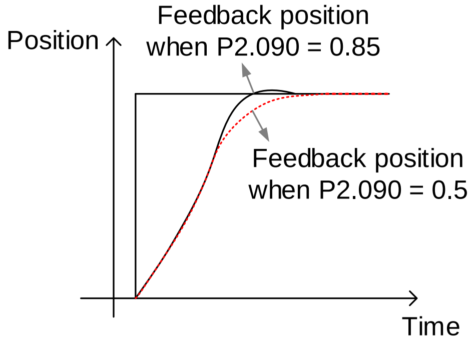
When the two degree of freedom control function is enabled (P2.094 [Bit 12] = 1), set P2.000 and P2.089 for better position response.

Set P2.089 to adjust how well the command response follows the command. Setting P2.089 higher can reduce the transient error between the position command and command response, but the error between the command response and feedback does not change. Thus, P2.089 is valid only when the position command changes. To reduce the difference between the command response and feedback, or to reduce the position jitter when the motor stops, adjust P2.000 or other control gain parameters.





Setting P2.090 (Two degree of freedom mode - anti-interference gain) can adjust the position settling waveform but does not change the command response time. Setting P2.090 to a smaller value lowers the response after the command is complete but reduces the position feedback overshoot.



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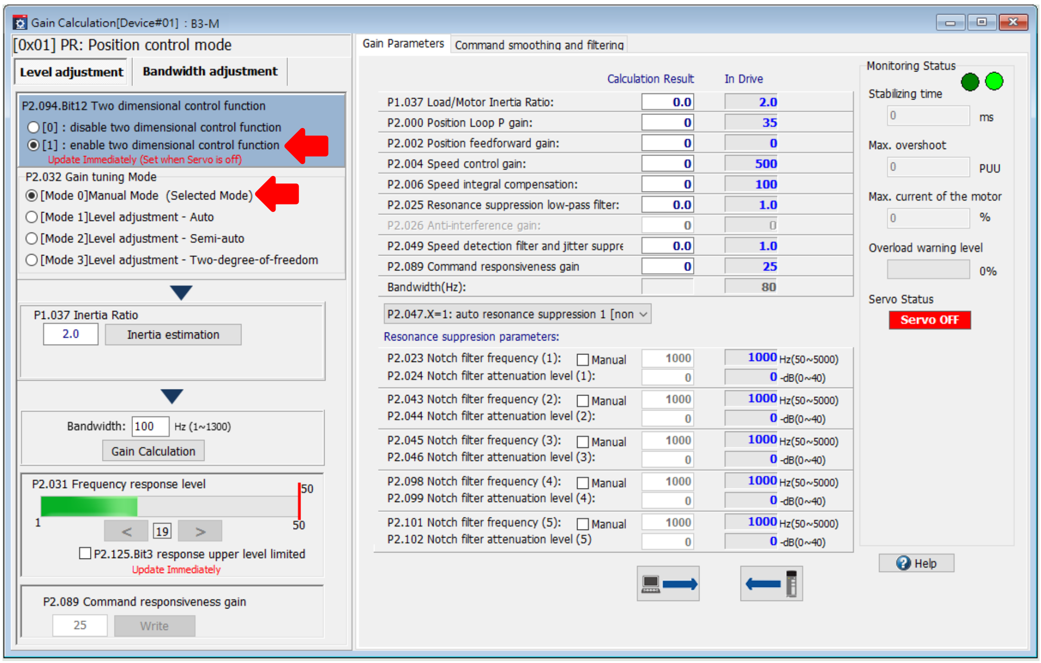
5.7.5.3 Application example of two degree of freedom control function

This section describes the parameter settings when the two degree of freedom control function is used in Manual Mode (P2.032 = 0). Refer to the following steps.



Switch the servo status to Servo ON and then start tuning. Change the parameter settings and at the same time use the Scope function to verify if the settings meet the requirements. It is advisable to increase the bandwidth gradually. To adjust the bandwidth significantly, enable the auto resonance suppression function (P2.047.X ≠ 0), set P2.047.Y and P2.047.Z to auto resonance suppression, and do not set the corresponding resonance parameters.

1. Increase the setting values of P2.000 and P2.089 while maintaining the ratio of P2.000 to P2.089 at approximately 1:1.
2. When the mechanical parts start to vibrate or generate high-frequency sounds, stop increasing P2.000 and decrease P2.000 until the mechanical parts are stable.
3. To increase the servo response, setting P2.089 higher reduces the transient error of command response, but the position overshoot becomes greater. It is recommended that the setting value of P2.089 should be no more than two times the setting value of P2.000.
4. To fine-tune the positioning behavior, you can adjust P2.090.

Relevant parameter

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

Parameter	Function
P2.000	Position control gain
P2.089	Command response gain
P2.090	Two degree of freedom mode - anti-interference gain
P2.091	Two degree of freedom mode - position feed forward gain
P2.092	Two degree of freedom mode - speed feed forward gain
P2.094	Special bit register 3 (enable the two degree of freedom control function)

5

5.7.5.4 Restrictions of vibration elimination

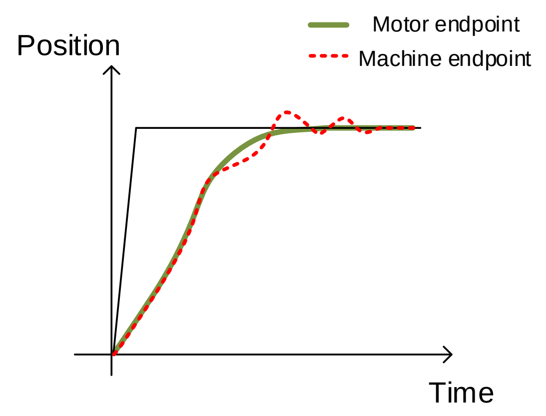
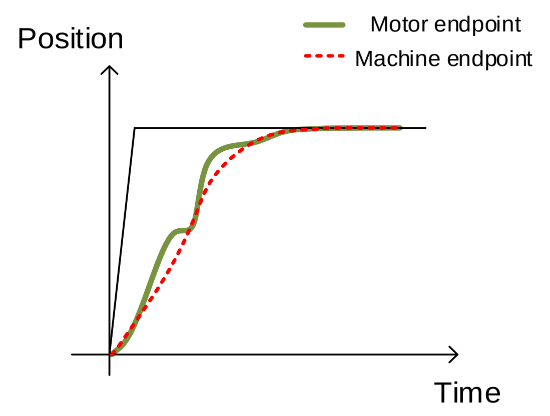
1. The two degree of freedom control function must be enabled (P2.094 [Bit 12] = 1).
2. Frequency range: 1.0 Hz to 400.0 Hz.
3. You can enable two sets of vibration elimination functions simultaneously for -E and -F models, while you can enable only one set of vibration elimination function for -M and -L models.

5.7.5.5 Function description of vibration elimination

The vibration elimination function uses a special algorithm, which can eliminate the vibration in the machine endpoint without slowing down the system response. This function is automatically set during the One Touch Tuning process, or you can set this function in the **System Analysis** window of ASDA-Soft.

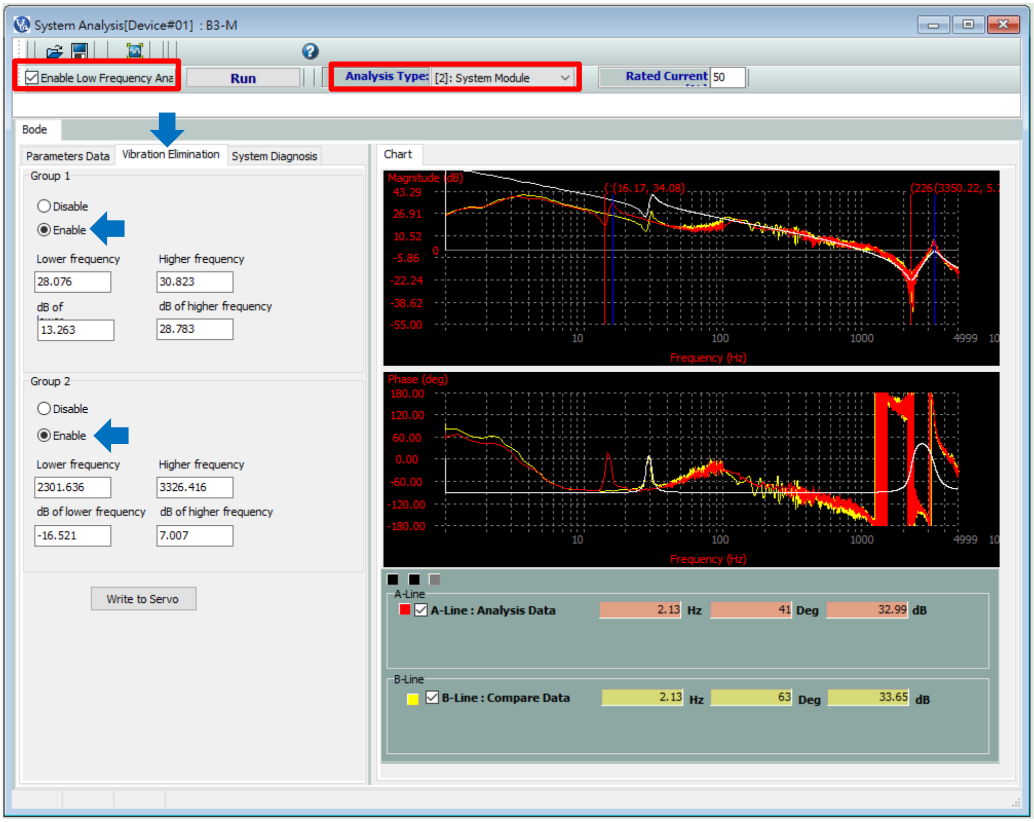
The vibration elimination function builds the flexible mechanical vibration model in the servo drive under the two degree of freedom control mode, so you need to enable the two degree of freedom control function before using the vibration elimination function. When the connection between mechanical parts is not rigid enough, the response between the motor endpoint and the machine endpoint is not consistent, resulting the condition where the motor has stopped but the machine endpoint still vibrates. As for this condition, you can use the **System Analysis** function in ASDA-Soft to provide optimal settings for the vibration elimination parameters, and set P2.097 [Bit 8] and [Bit 9] to enable one or two sets of the vibration elimination functions.

After the vibration elimination function is enabled, the servo adjusts the motor command according to the internal model. When you monitor the motor position feedback in the scope, there might be a jitter, but the machine endpoint is stable when settling.

Vibration elimination not enabled	Vibration elimination enabled
	

5.7.5.6 Application example of vibration elimination

1. Start ASDA-Soft and enter the **System Analysis** function window.
2. Select the check box for **Enable Low Frequency Analysis** and select **[2]: System Module** for the Analysis Type, and then click **Run** to start analyzing.
3. After the analysis is complete, go to the Vibration Elimination tab and click the radio button of **Enable** to enable the vibration elimination function. Then, click **Write to Servo** to complete the procedure.



Relevant parameter

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

Parameter	Function
P2.094	Special bit register 3 (enable the two degree of freedom control function)

5

5.7.6 Position command filter

5.7.6.1 Function restriction

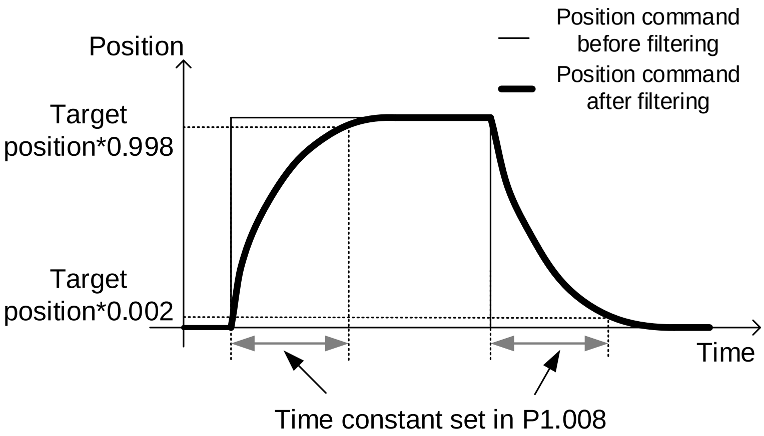
Set the control mode (P1.001.YX) to Position mode (PT or PR).

5.7.6.2 Function description

If the position command changes too drastically, the speed command or current command may become saturated, causing the machine unable to operate according to the expected response. If the resolution of a pulse command is low, it may cause unexpected machine vibration. Adjusting the position command filter can improve the previous two conditions. It is advisable to use the position command filter with P1.008 and P1.068.

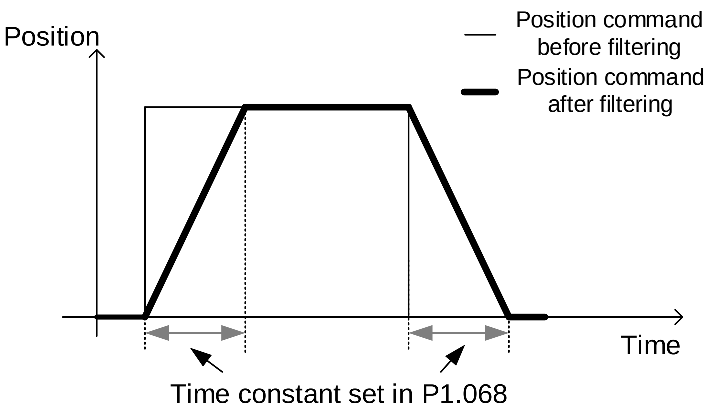
Position command - smoothing constant (low-pass filter) (P1.008)

After the position command is processed with the first-order low-pass filter, the unwanted high-frequency response or noise is attenuated, and the command becomes smoother.



Position command - moving filter (P1.068)

This function distributes the position commands evenly within the set time. When the resolution of the position command is low, using the filter function of P1.068 is recommended. If you use P1.008, it will cause drastic speed changes.



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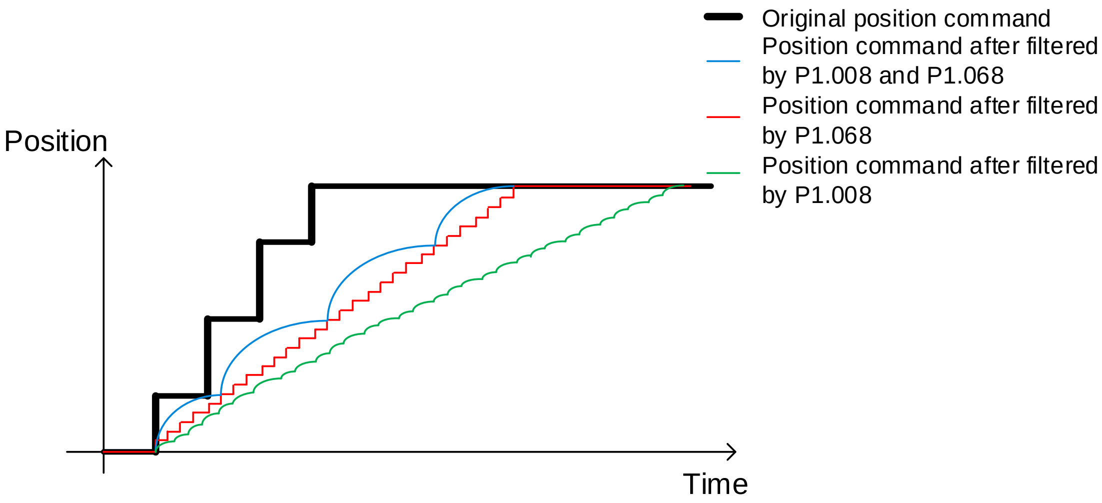
5.7.6.3 Application example

When the resolution of the position command is low (for example, the command resolution is lower than 10000 pulse/rev), using the position command filter reduces the jitter in the command feedback caused by low resolution.



Relevant parameter

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

Parameter	Function
P1.008	Position command - smoothing constant (low-pass filter)
P1.068	Position command - moving filter

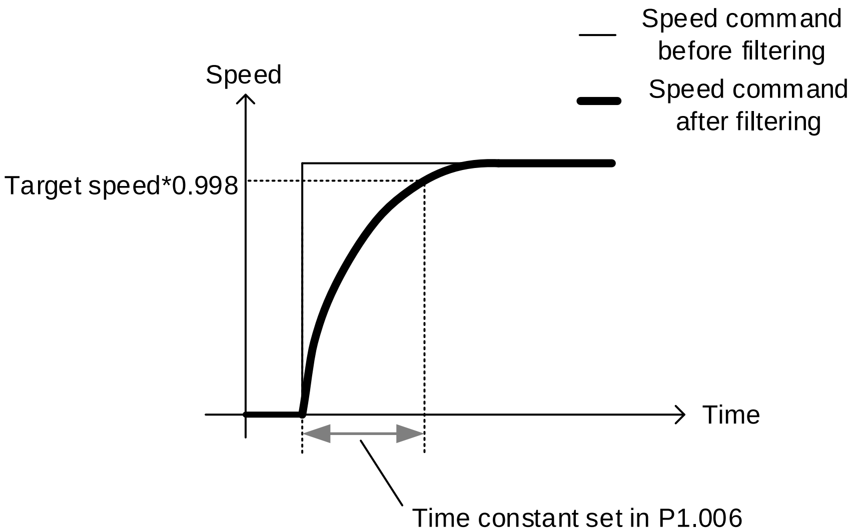
5.7.7 Speed command filter

5.7.7.1 Function restriction

Set the control mode (P1.001.YX) to Speed mode (S or Sz).

5.7.7.2 Function description

After the speed command is processed with the first-order low-pass filter, the unwanted high-frequency response or noise is attenuated, and the command becomes smoother.



5.7.7.3 Application example

When the position control circuit of the machine is built in the controller, the servo is in analog Speed mode (S) and receives the external analog voltage speed command issued by the controller. To reduce the analog voltage noise, which can be detected by setting the channel to **Speed command: Voltage [Volt]** in the Scope function of ASDA-Soft, increase the setting value of P1.006. However, if the filter time is set too long, the position control response of the controller becomes slower. If desiring to keep the position control response stable, set the filter bandwidth 8 times (or more) the position bandwidth of the controller.

Relevant parameter

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

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

5

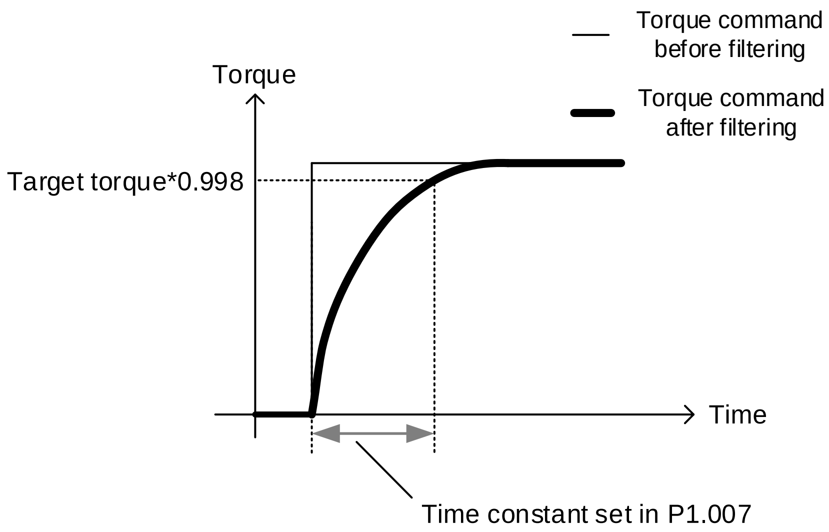
5.7.8 Torque command filter

5.7.8.1 Function restriction

Set the control mode (P1.001.YX) to Torque mode (T or Tz).

5.7.8.2 Function description

After the torque command is processed with the first-order low-pass filter, the unwanted high-frequency response or noise is attenuated, and the command becomes smoother.



5.7.8.3 Application example

When the servo is in analog Torque mode (T) to perform force control (such as tension or pressure control), the command value is usually a constant which changes slowly. Since the bandwidth of the servo current loop is much higher than that of the position loop and speed loop, it is highly responsive but is subject to noise interference. Properly adjust P1.007 to reduce the high-frequency noise and increase the control accuracy.

Relevant parameter

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

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

5

5.8 Application function adjustment

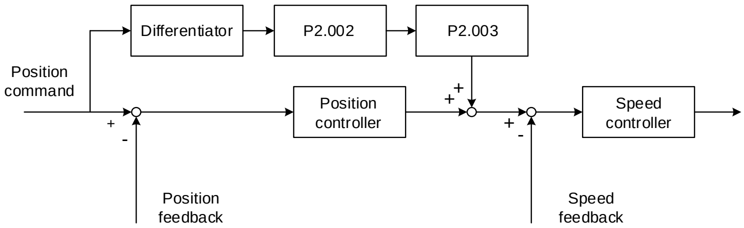
5.8.1 Adjusting position error in constant speed zone

5.8.1.1 Function restriction

1. When using P2.002 and P2.003, set the control mode (P1.001.YX) to Position mode (PT, PR).
2. When using P2.007, set the control mode (P1.001.YX) to Position or Speed mode (PT, PR, S, Sz).

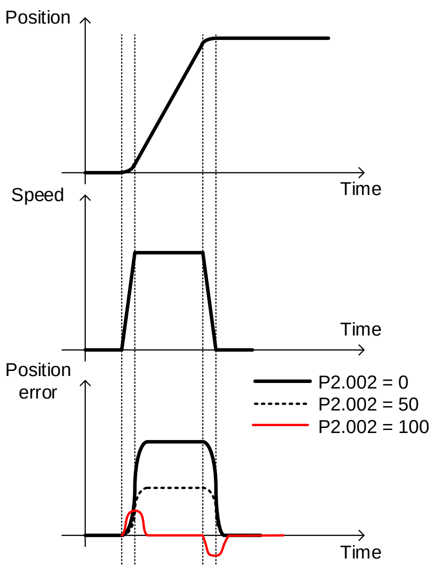
5.8.1.2 Function description

In Position mode, this function uses the Position command to calculate an ideal speed value and applies this value to the Speed command. This function reduces the position error in the constant speed zone during position control. Therefore, you can use this function to shorten the settling time or reduce the following error.



Position feed forward gain (P2.002)

This parameter converts the changes between position commands into an ideal speed value and applies this value to the Speed command. The higher the value of P2.002, the smaller the error in the constant speed zone, and thus the error reduces when the system performs dynamic following. When this parameter is set to 100, it completely eliminates the position error in the constant speed zone but causes a greater position overshoot. When this parameter is set to 0, the position feed forward gain function is disabled.



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Position feed forward gain smoothing constant (P2.003)

The ideal speed is calculated by the position command with a differentiator, so the discontinued noise of the position command is also magnified. The lower the position command resolution, the more severe the noise. In this case, you can set a higher constant value to reduce the interference from the noise. Please note that the overshoot is greater during the position settling process if you set a higher value for the filter.

Speed feed forward gain (P2.007)

In Speed mode, this parameter calculates the ideal current using the speed command and applies this result to the electric current command. Using this function can reduce the speed error that occurs during uniform acceleration and deceleration. In Position mode, using this function is not recommended because it causes a rather poor settling performance.

5.8.1.3 Application example

In the application of contour control, to reduce the geometric error caused by the servo following error (e.g., the actual feedback radius is shorter than the command radius when a circular path is executed), you can increase the setting of P2.002. In the point-to-point positioning application, you can also set a higher value for P2.002 to reduce the transient position error during acceleration. However, using the position feed forward gain function is more likely to cause position overshoot and a longer settling time.

Important: do not use P2.002 (Position feed forward gain) for applications that do not allow overshoot. Use P1.061 (Viscous friction compensation) instead.

Relevant parameter

Refer to Chapter 8 for detailed descriptions.

Parameter	Function
P1.061	Viscous friction compensation
P1.062	Percentage of friction compensation
P1.063	Constant of friction compensation
P2.002	Position feed forward gain
P2.003	Position feed forward gain smoothing constant
P2.007	Speed feed forward gain

5.8.2 Position overshoot adjustment

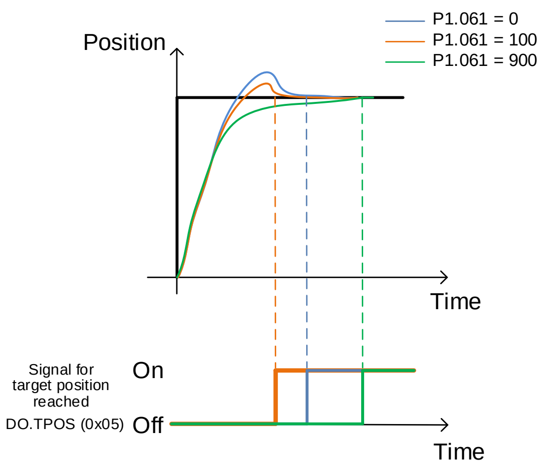
5.8.2.1 Function restriction

When using this function, set the control mode (P1.001.YX) to Position or Speed mode (PT, PR, S, or Sz).

5.8.2.2 Function description

The position overshoot occurred during positioning may be caused by the high value of P2.002 or a great change in the system friction. Lowering the setting of P2.002 or properly setting the viscous friction compensation can reduce the position overshoot.

When using P1.061 (Viscous friction compensation), set P1.062 (Percentage of friction compensation) to a non-zero value. P1.061 is the torque compensation amount based on the speed change, which unit is 0.1%/1000 rpm. When adjusting P1.061, it is recommended that you first set it to 100, 200, then gradually increase the value. Setting the value too high may cause an increased overshoot or a longer settling time with an unchanged overshoot.



5.8.2.3 Application example

For applications that do not allow overshoot, using this function can reduce the position overshoot; however, a high value of P1.061 can cause a longer positioning time.

Relevant parameter

Refer to Chapter 8 for detailed descriptions.

Parameter	Function
P1.061	Viscous friction compensation
P1.062	Percentage of friction compensation
P2.002	Position feed forward gain

5

5.8.3 Multi-axis contour control

5.8.3.1 Function restriction

1. In the communication mode, settings for P1.034 - P1.036, P2.068, and P1.017 for each axis have to be consistent.
2. The settings of the two degree of freedom control function (P2.094 [Bit 12]) for each axis have to be consistent.
   - When the two degree of freedom control function is enabled (P2.094 [Bit 12] = 1), settings of P2.002, P2.089, P1.008, and P1.068 for each axis must be consistent.
   - When the two degree of freedom control function is disabled (P2.094 [Bit 12] = 0), settings of P2.000, P2.002, P1.008, and P1.068 for each axis must be consistent.
3. Setting the same speed loop bandwidth (P2.004 / 2π) for each axis is recommended.

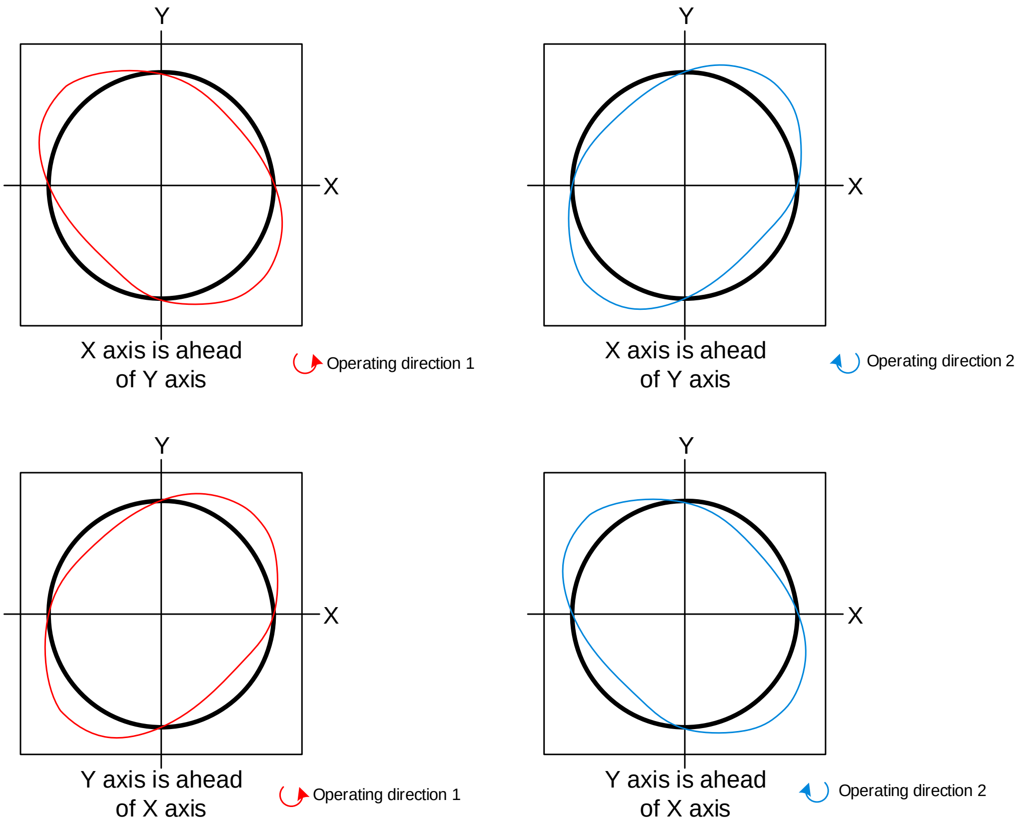
5.8.3.2 Function description

For the application of multi-axis contour control, make sure the servo parameter settings among all axes are consistent. If the response settings among each axis do not match, the contour distorts.

1. When the filter parameter settings (P1.008, P1.068) of each axis are inconsistent, the response of the axis with a lower filter parameter setting goes ahead of the other axes.
2. When the position gain parameter settings (P2.000, P2.002, P2.089) of each axis are inconsistent, the response of the axis set with a higher position gain goes ahead of the other axes.
3. After all axes are tuned, if their speed loop bandwidth settings (P2.004 / 2π) are inconsistent but the contours remain undistorted, you can apply the position gain parameter settings of the axis with the lowest bandwidth to the other axes.

Note: it is recommended that you set the Analysis Type to **Speed Open-loop** in the System Analysis of ASDA-Soft; the zero-crossing frequency is the speed loop bandwidth.

The contours in black indicate that the response settings of each axis are consistent. The distorted contours in red and blue are generated due to the inconsistent response settings.



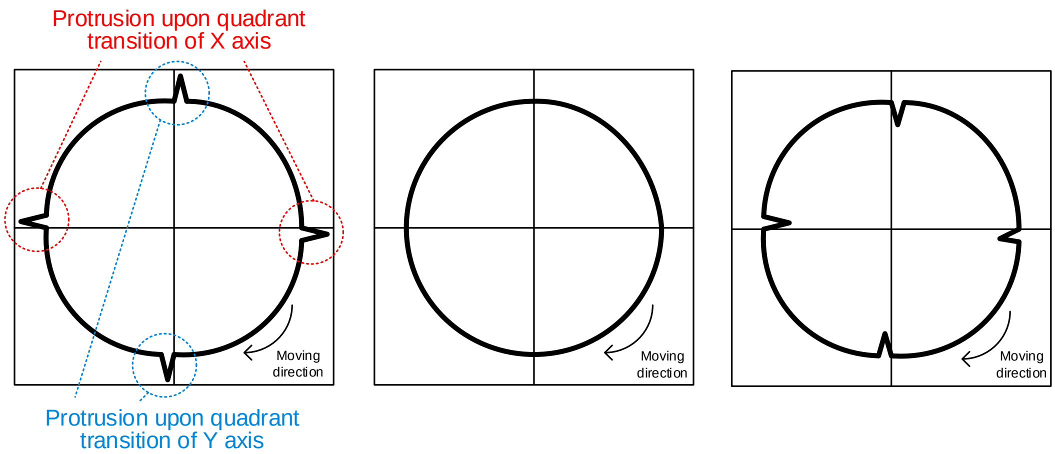
5.8.3.3 Application example

Adjusting the contour errors:

If the contour becomes unsmooth when transiting from one quadrant to another, it is caused by insufficient friction compensation of the servo. Descriptions for manually and automatically adjusting the friction compensation are as follows.

Manual adjustment:

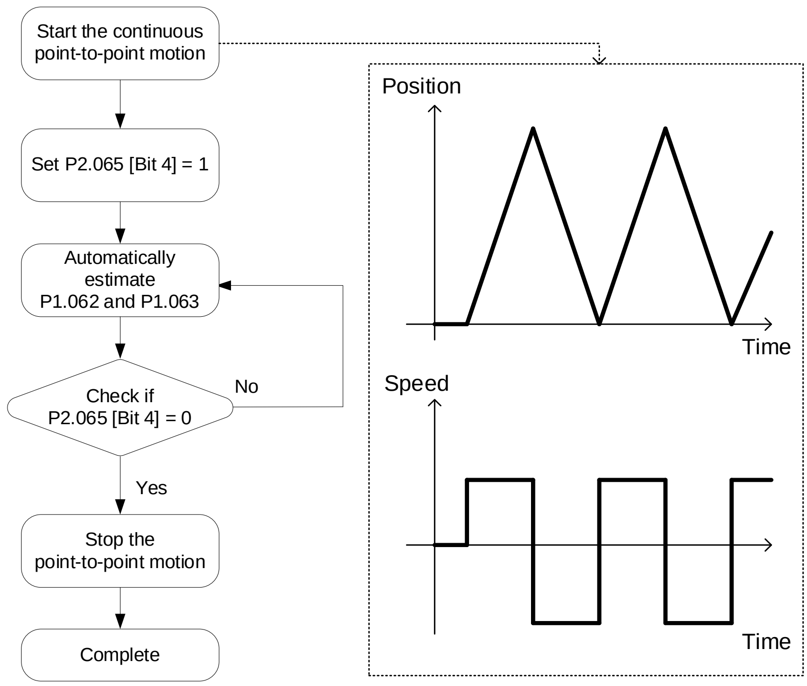
Take the circular motion for example. You can gradually increase the value of P1.062 until the quadrant protrusion disappears and the quadrant becomes concave, and then start adjusting P1.063. On the basis of the default 100% of P1.063, the lower the value of P1.063, the sooner the system reaches the setting of P1.062; the higher the value of P1.063, the slower the system reaches the setting of P1.062. When the contour (error) upon quadrant transition slightly becomes concave, you can increase the setting of P1.063 to speed up the compensation. If the contour slightly becomes convex, reduce the setting of P1.063 to slow down the compensation.



Insufficient friction compensation | Proper friction compensation | Over friction compensation

Auto adjustment:

The switch for automatic friction estimation is P2.065 [Bit 4]. Set P2.065 [Bit 4] to 1 to enable the automatic friction estimation. Use the controller or PR command and set a continuous point-to-point motion (do not set the delay time) to maintain the estimation performance. Once the estimation is complete, the servo automatically sets P2.065 [Bit 4] to 0.



Relevant parameter

Refer to Chapter 8 for detailed descriptions.

Parameter	Function
P1.062	Percentage of friction compensation
P1.063	Constant of friction compensation
P2.065 [Bit 4]	Special bit register 1 (Automatic friction estimation)

5

5.8.4 Gain switching

5.8.4.1 Function restriction

1. When P2.027.X is set to 0, 1, 2, 4, 5, 6, or 8, P1.078 (Gain switching delay time) is not supported.
2. When P2.027.X is set to 3 or 7, P1.078 (Gain switching delay time) is supported.

5.8.4.2 Function description

Increasing the gain during operation can achieve a better command following and shorter settling time. Reducing the gain when the servo motor is in a stop state can reduce the high frequency noise and vibration.
During the gain switching process, if the servo motor operation is not smooth, increasing the gain switching time constant (P2.028) can smooth the gain switching process.
The servo automatically switches the relevant control parameters based on the value set for P2.027.X (Gain switching condition); however, you need to additionally set the change rate of the parameter (refer to the “After switching” columns in the following page).

5.8.4.3 Application example

The control mode and whether P1.078 is supported are determined by the gain switching conditions. Refer to the following descriptions.

P2.027.X: gain switching condition

X	Condition	Control mode	P1.078 Gain switching delay time
0	Disable gain switching function.	-	-
1	Signal of gain switching (DI.GAINUP: 0x03) is on.	All	-
2	In Position control mode, position error is larger than P2.029.	PT / PR	-
3	Frequency of Position command is larger than P2.029.	PT / PR	Supported
4	Speed of servo motor is faster than P2.029.	All	-
5	Signal of gain switching (DI.GAINUP: 0x03) is off.	All	-
6	In Position control mode, position error is smaller than P2.029.	PT / PR	-
7	Frequency of Position command is smaller than P2.029.	PT / PR	Supported
8	Speed of servo motor is slower than P2.029.	All	-

P2.027.Y: gain switching method

0: gain rate switching

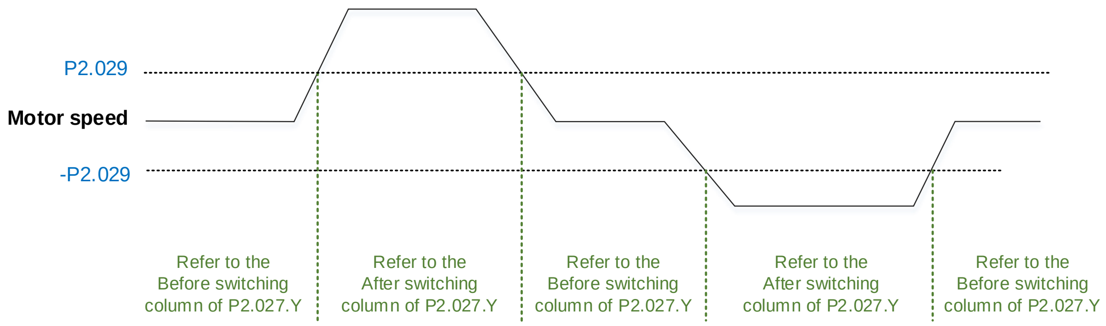
1: integrator switching (switch from P controller to PI controller)

PT / PR			
Y = 0		Y = 1	
Before switching	After switching	Before switching	After switching
P2.000 x 100%	P2.000 x P2.001	P2.000 x 100%	P2.000 x P2.001
P2.004 x 100%	P2.004 x P2.005	P2.004 x 100%	P2.004 x 100%
P2.025 x 100%	P2.025 x P2.107	P2.025 x 100%	P2.025 x P2.107
P2.026 x 100%	P2.026 x 100%	P2.026 x 0%	P2.026 x 100%
P2.049 x 100%	P2.049 x P1.080	P2.049 x 100%	P2.049 x P1.080

S / Sz			
Y = 0		Y = 1	
Before switching	After switching	Before switching	After switching
P2.004 x 100%	P2.004 x P2.005	P2.004 x 100%	P2.004 x 100%
P2.025 x 100%	P2.025 x P2.107	P2.025 x 100%	P2.025 x P2.107
P2.026 x 100%	P2.026 x 100%	P2.026 x 0%	P2.026 x 100%
P2.049 x 100%	P2.049 x P1.080	P2.049 x 100%	P2.049 x P1.080

When **P2.027.X is set to 0, 1, 2, 4, 5, 6, or 8**, P1.078 (Gain switching delay time) is not supported. P2.027.X = 4 is taken as the example in the following figure.

P2.027.X = 4



When P2.027.X is set to 3 or 7 and P1.078 (Gain switching delay time) is set, the gain parameter during the delay time is adjusted as follows.

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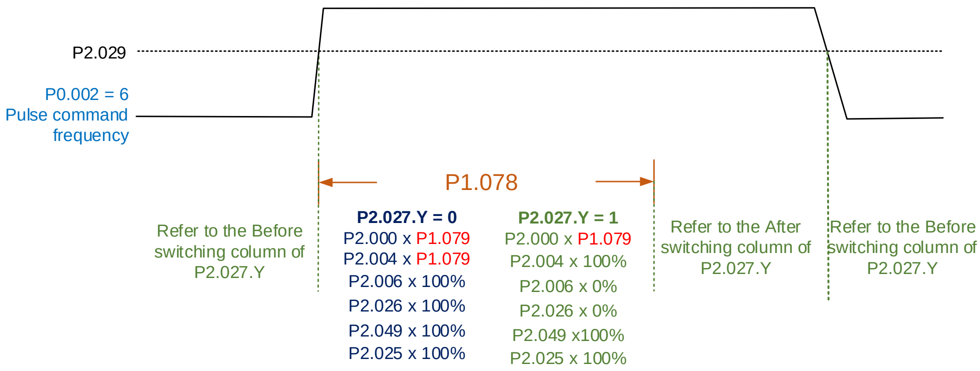
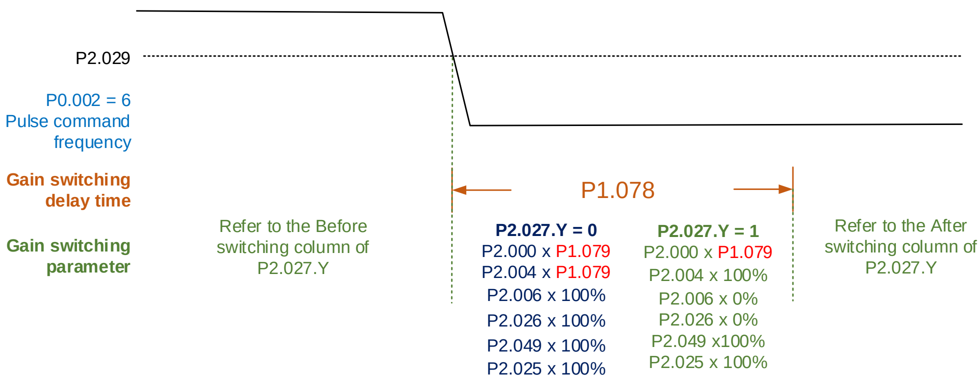
P2.027.X = 3



P2.027.X = 7



Relevant parameter

Refer to Chapter 8 for detailed descriptions.

Parameter	Function
P1.078	Gain switching delay time
P2.027	Gain switching condition and method selection
P2.028	Gain switching time constant
P2.029	Gain switching condition