CHAPTER 5: TUNING

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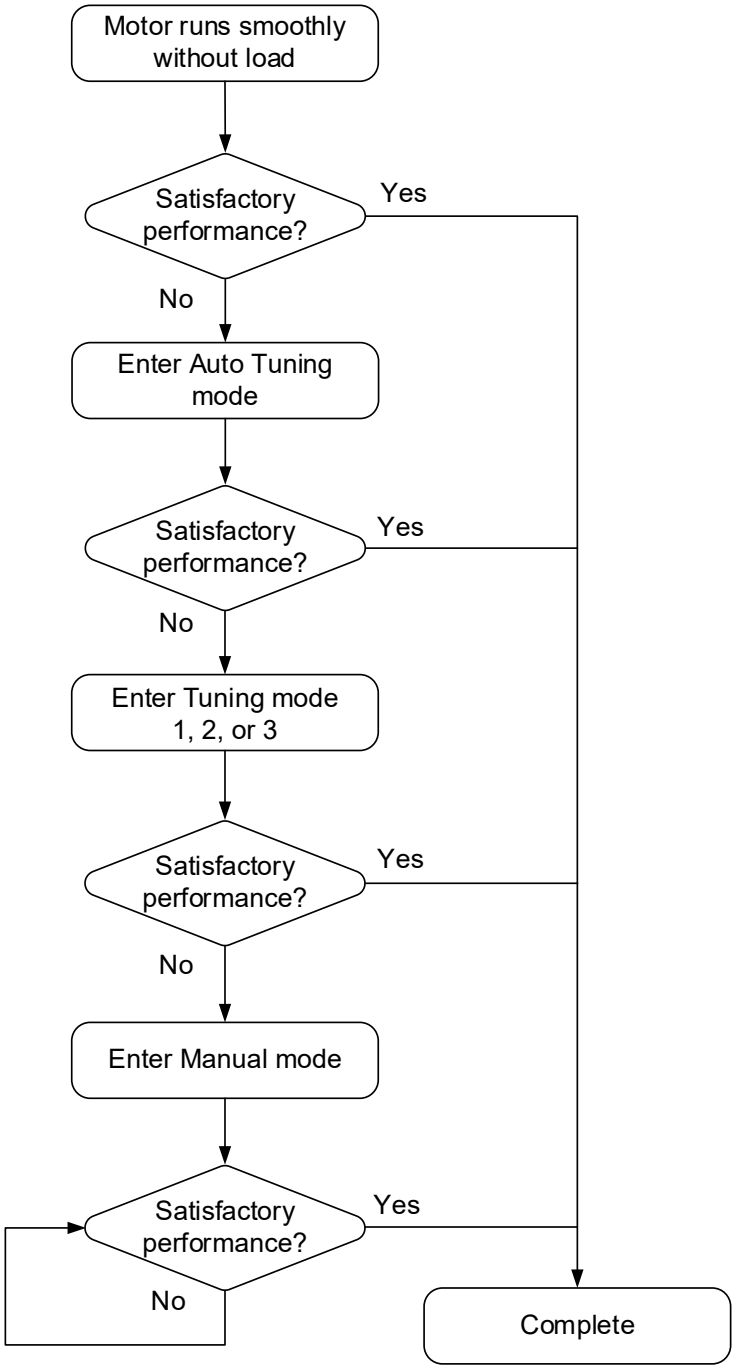
Introduction

This chapter contains information about the auto tuning procedure and the three tuning modes. Advanced users can also tune the servo system using the manual mode.

5.1 - Tuning procedure and the applied mode

5.1.1 - Flow chart for the tuning procedure

You can tune the servo drive by following the flow chart below. First, start from the Auto Tuning mode. If you are not satisfied with the system's performance, you can use Tuning modes 1, 2, 3 or Manual mode for tuning the servo system.



5.1.2 - Tuning Modes

P2.032 Setting Value	Adjustment Mode	Inertia Estimation	Parameter	
			Manually Set	Auto Tuning
0	Manual mode	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	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	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	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	Restore default gain settings	-	-

Note: *Please refer to the parameters list in Section 5.3 Auto tuning.*

5.2 - Auto tuning

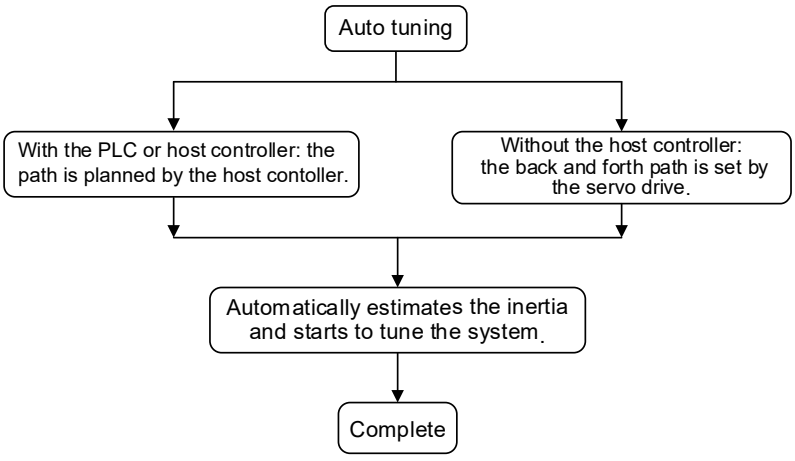
The Auto Tuning function provided by the servo drive enables the system to perform real-time machine inertia estimation and upload the corresponding tuning parameters to the servo drive. You can start auto tuning with SureServo2 Pro (software) or at the drive panel. In general, Auto Tuning works best when the speed is set to at least 200 RPMs (500 preferred) during the tuning process. An inertia ratio of more than 50:1 can very easily cause the auto tuning algorithms to not succeed. It is highly recommended to add some sort of gear reduction between the motor and the load in order to reduce high inertia mismatches. The following table lists the parameters that change according to the results of auto tuning.

Gain Related Parameters	
Parameter #	***Function***
P1.037	Inertia ratio and load weight ratio of servo motor
P2.000	Position control gain
P2.004	Speed control gain
P2.006	Speed integral compensation
P2.031	Level of frequency response
P2.032	Gain adjustment mode
P2.089	Command response gain
-	-
-	-
-	-
-	-
-	-
-	-
-	-
-	-

Filter and Resonance Suppression Parameters	
Parameter #	***Function***
P1.025	Low-frequency vibration suppression (1)
P1.026	Low-frequency vibration suppression gain (1)
P1.027	Low-frequency vibration suppression (2)
P1.028	Low-frequency vibration suppression gain (2)
P2.023	Notch filter frequency (1)
P2.024	Notch filter attenuation level (1)
P2.025	Low-pass filter of resonance suppression
P2.043	Notch filter frequency (2)
P2.044	Notch filter attenuation level (2)
P2.045	Notch filter frequency (3)
P2.046	Notch filter attenuation level (3)
P2.049	Speed detection and jitter suppression
P2.098	Notch filter frequency (4)
P2.099	Notch filter attenuation level (4)
P2.101	Notch filter frequency (5)
P2.102	Notch filter attenuation level (5)

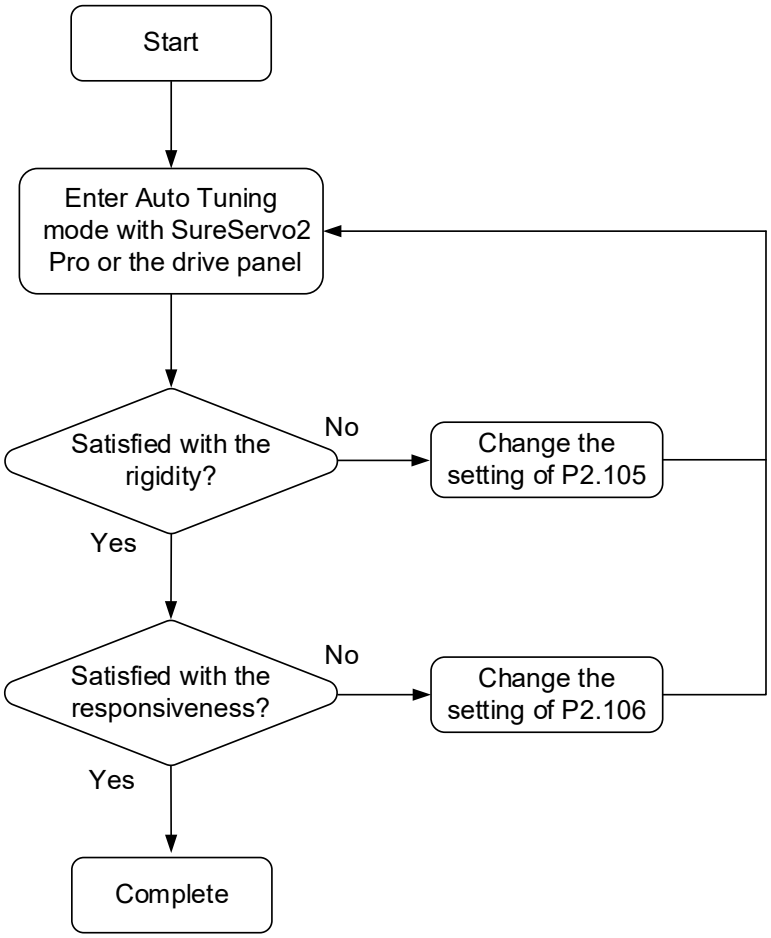
5.2.1 - Flow chart for auto tuning

You can perform the auto tuning using the drive keypad or SureServo2 Pro software. The Auto Tuning function in the SureServo2 servo drive helps you to find the most suitable parameters for your system according to the machine characteristics.



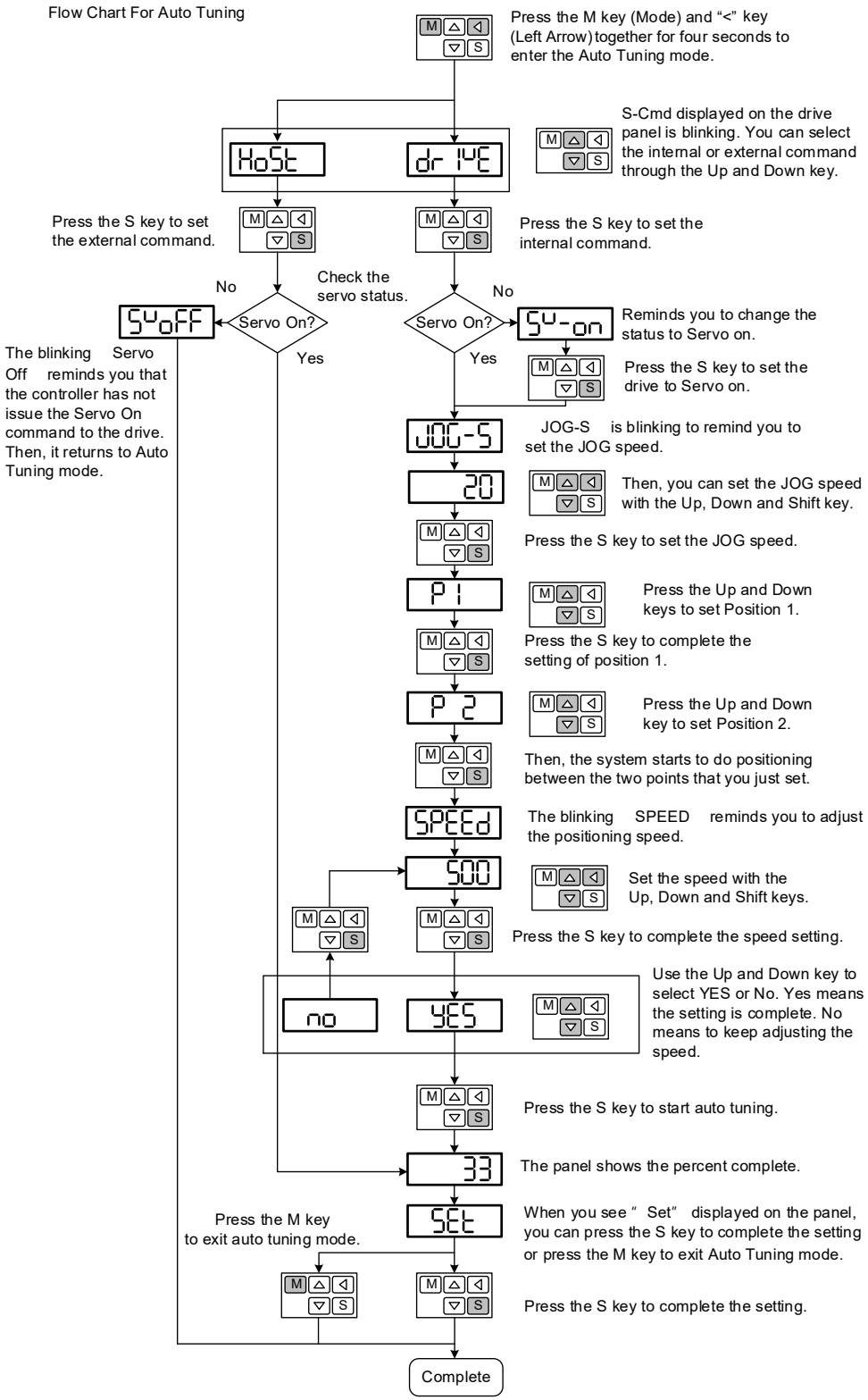
Note: *when the running distance is configured by the host controller, make sure the delay time is added to the operation time. Otherwise, AL08C (Auto-tuning function - Pause time is too short) occurs and the servo drive cannot complete auto tuning.*

You can use P2.105 (Auto-tuning Adjustment Bandwidth Level) and P2.106 (Auto-tuning Adjustment Overshoot Level) to adjust the responsiveness and rigidity in Auto Tuning mode. See the flow chart below.



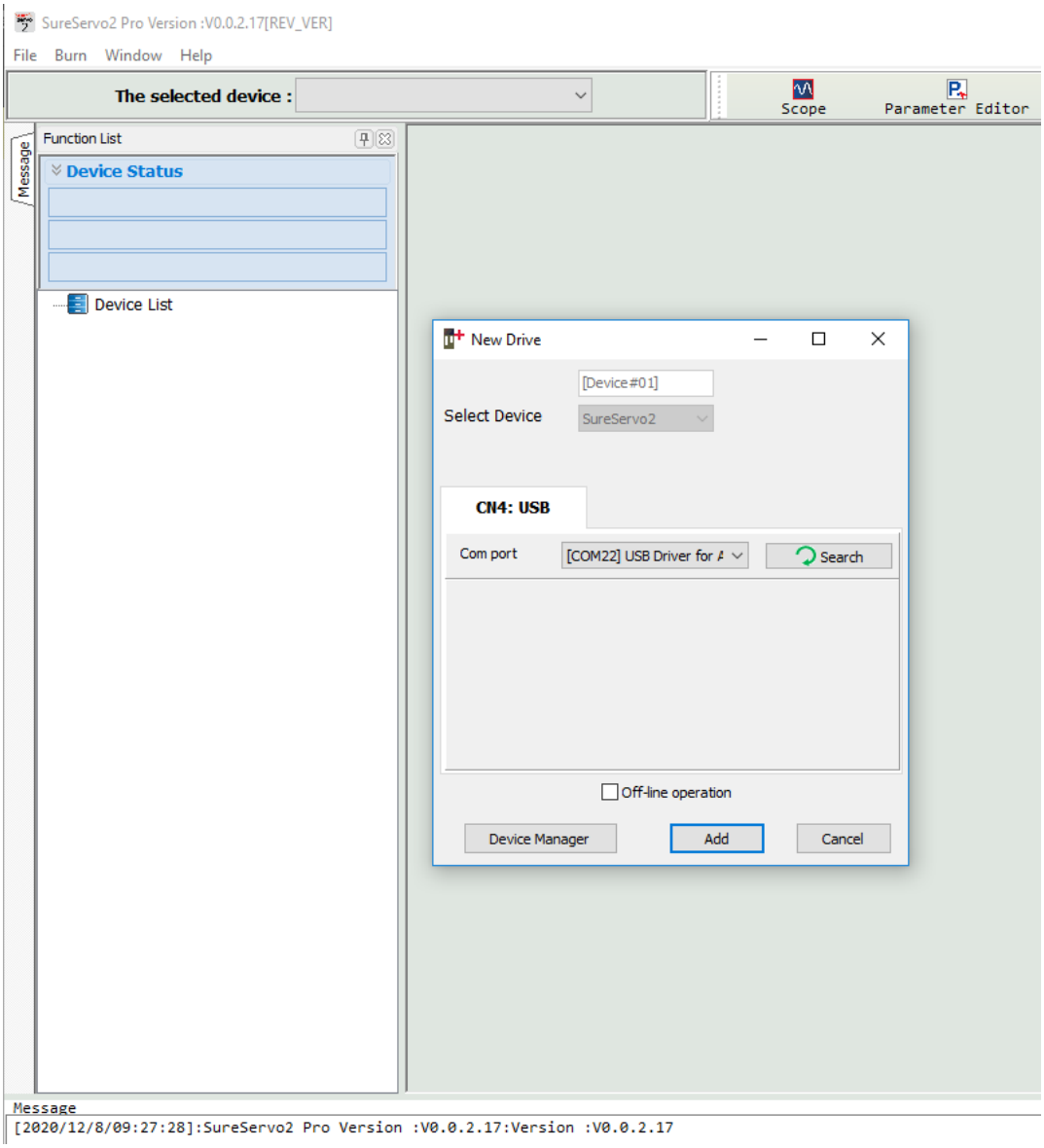
5.2.2 - Auto tuning through the drive keypad

With the tuning procedure below, you can complete auto tuning with the drive keypad (Drive method). Make sure the motor override, positive and negative limit switches work properly before you start to tune the system. Drive must be clear of any faults or warnings.



5.2.3 - Auto tuning with SureServo2 (software)

Instead of using the drive keypad, you can use SureServo2 Pro to complete auto tuning. Please go to go2adc.com/sureservo2 to download SureServo2 Pro for free. Install the software and open the executable file (.exe). You will see the screen shown below.



Make sure the servo drive, servo motor and power are all properly connected. Then click Add to connect to the servo drive with SureServo2.

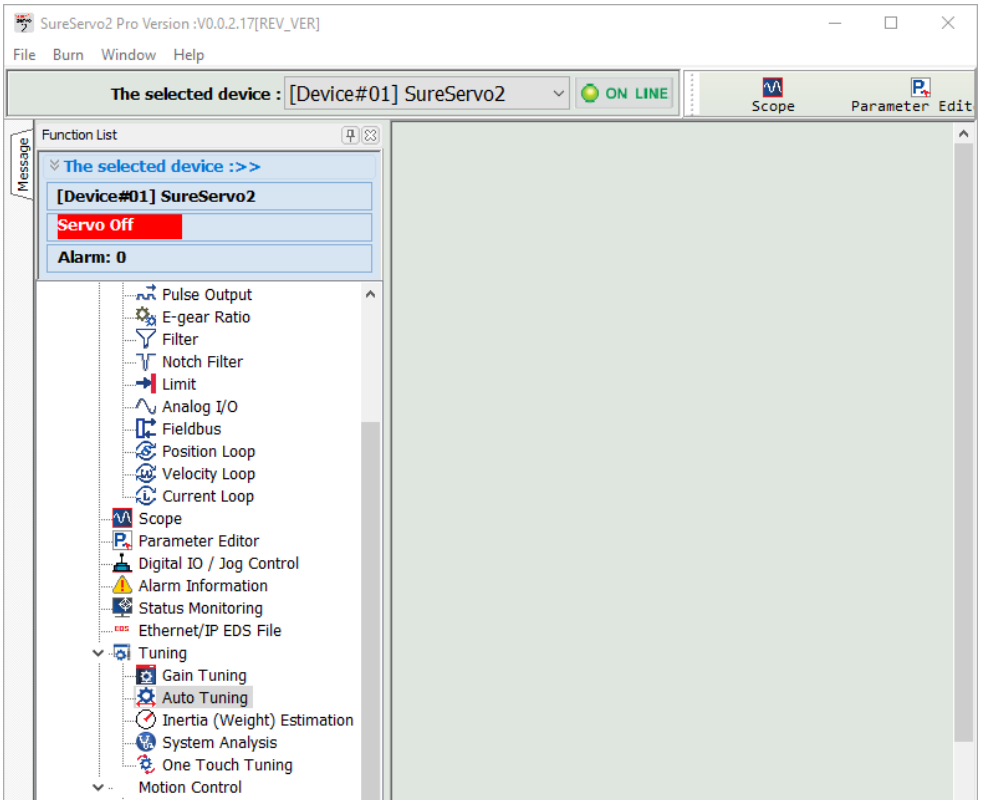
There are two types of auto-tuning procedure, one uses a host controller such as a PLC and one using the servo drive keypad. Both procedures are described below.

Auto-tuning with host controller

The host controller sends the commands to drive the motor.

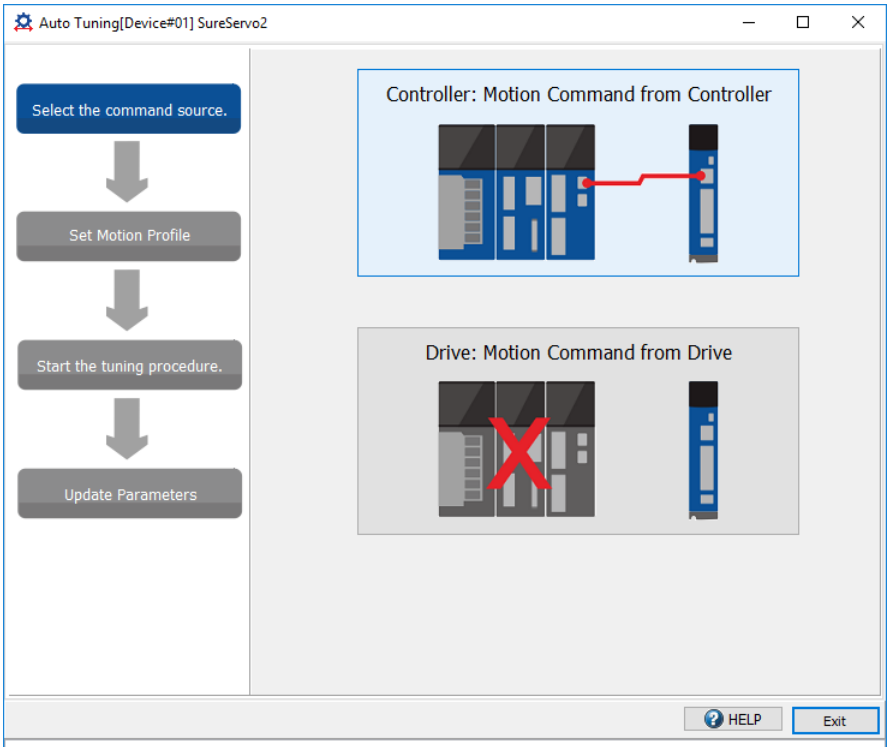
Step 1:

When the computer is connected to the controller, the program window appears as below. Click **Auto Tuning** in the Function List tree view.



Step 2:

Click **Controller: Motion Command From Controller** and make sure the motion/machining path is set correctly.

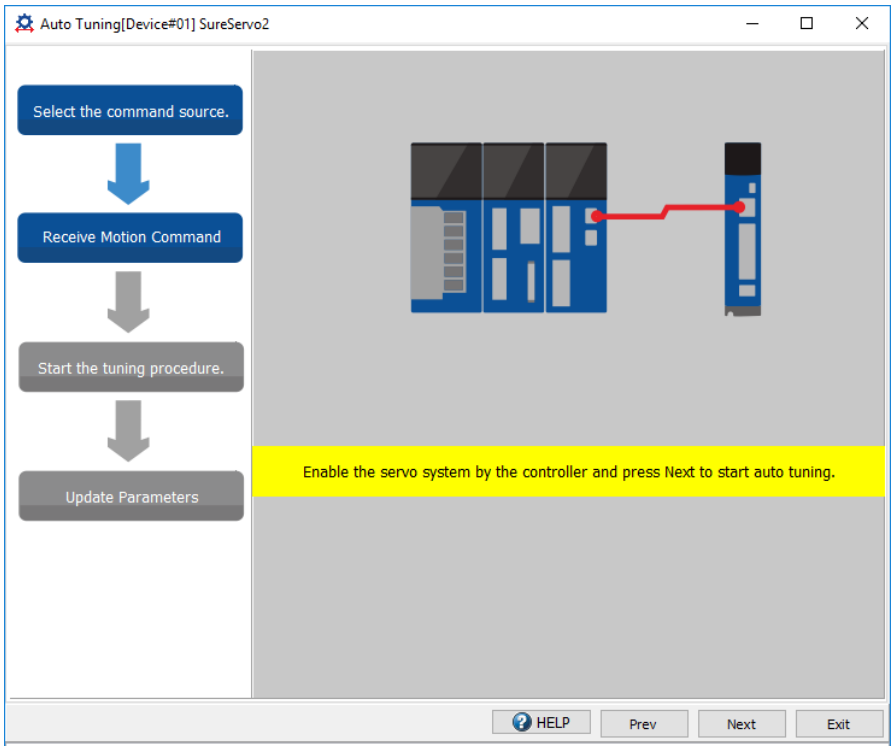


Suggestions: you should set the motor to operate at least one cycle in both forward and backward directions. It should reach the positions (in both forward and backward directions) in 1000 ms or less with the running speed not less than 500 rpm.

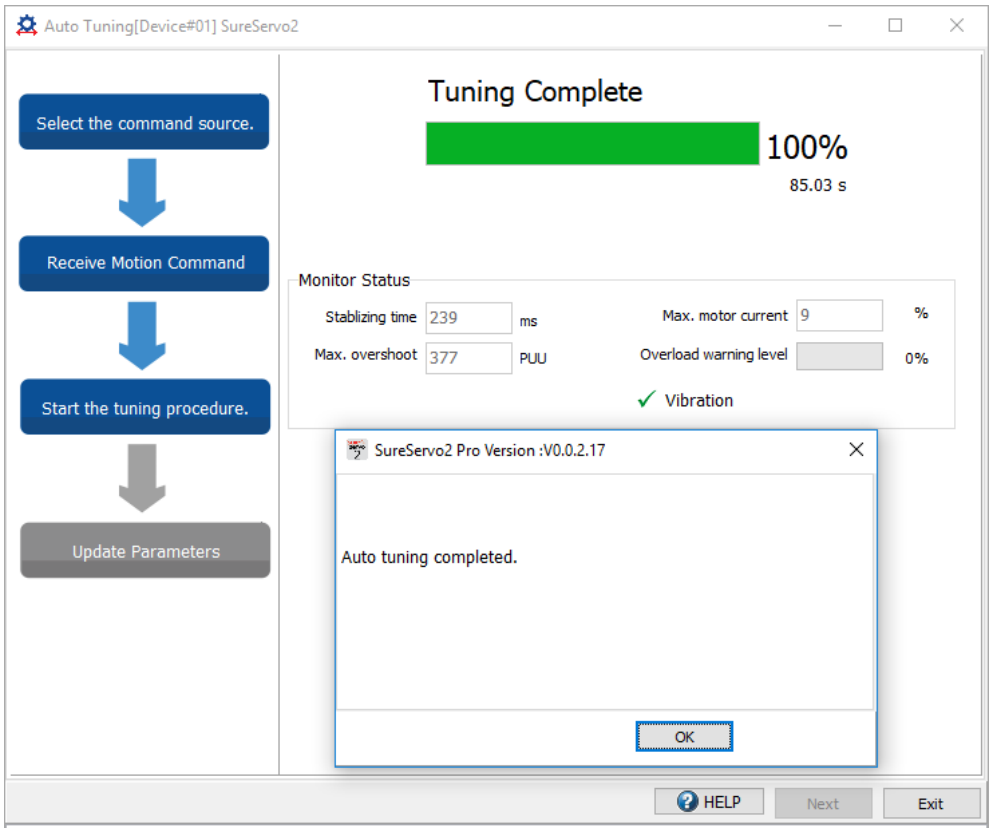
Step 3:

Enable the servo (Servo ON), then repeatedly start and run the motor with the path you just set. Before running the motor, make sure no one is standing close to the machinery.

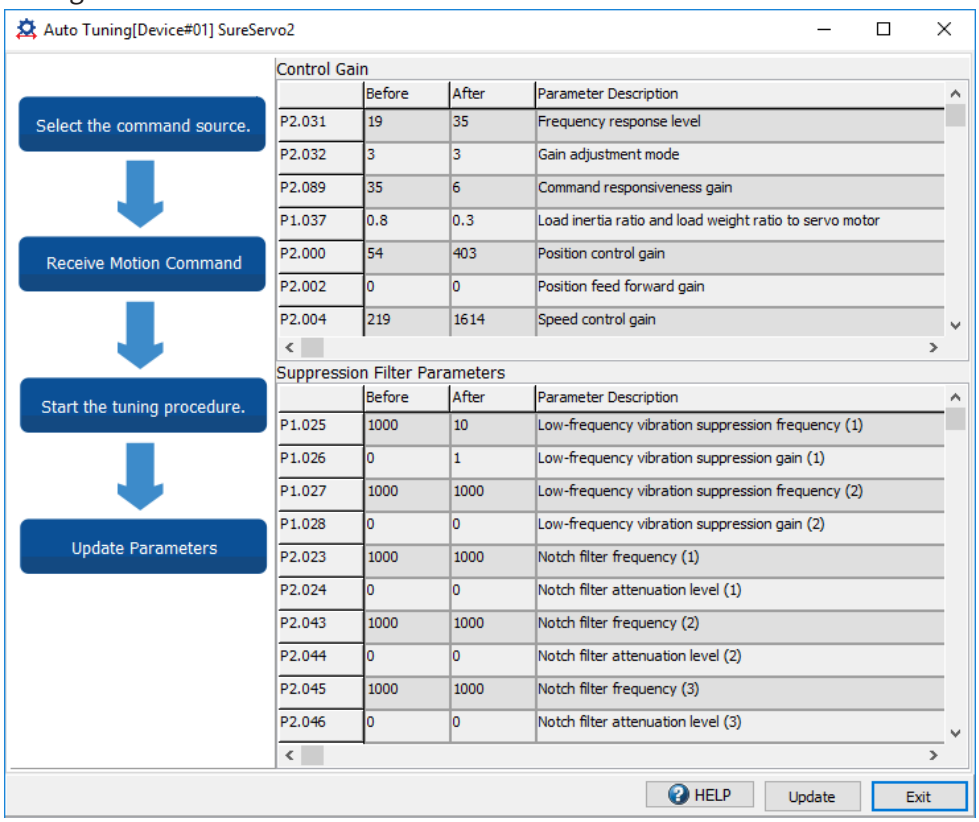
Then, click **Next**.



Wait until the tuning progress bar reaches 100%, after which a window with "Auto tuning completed" appears. Click **OK** to continue.



The screen shows a table comparing the parameters before and after being changed by auto tuning.



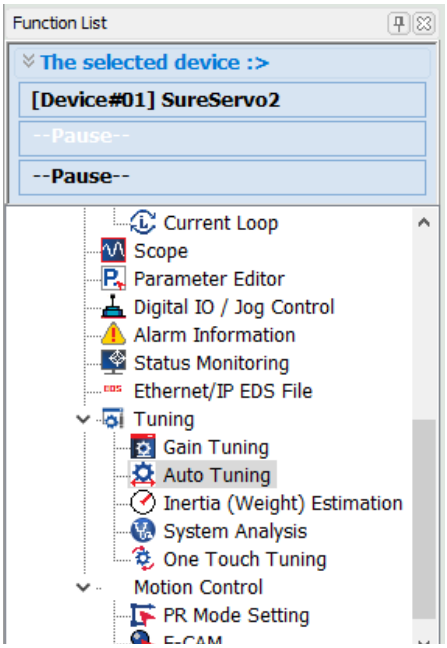
Click **Update** to save the new tuning parameters and complete auto tuning.

AUTO-TUNING WITH SERVO DRIVE

The servo drive sends the commands to drive the motor.

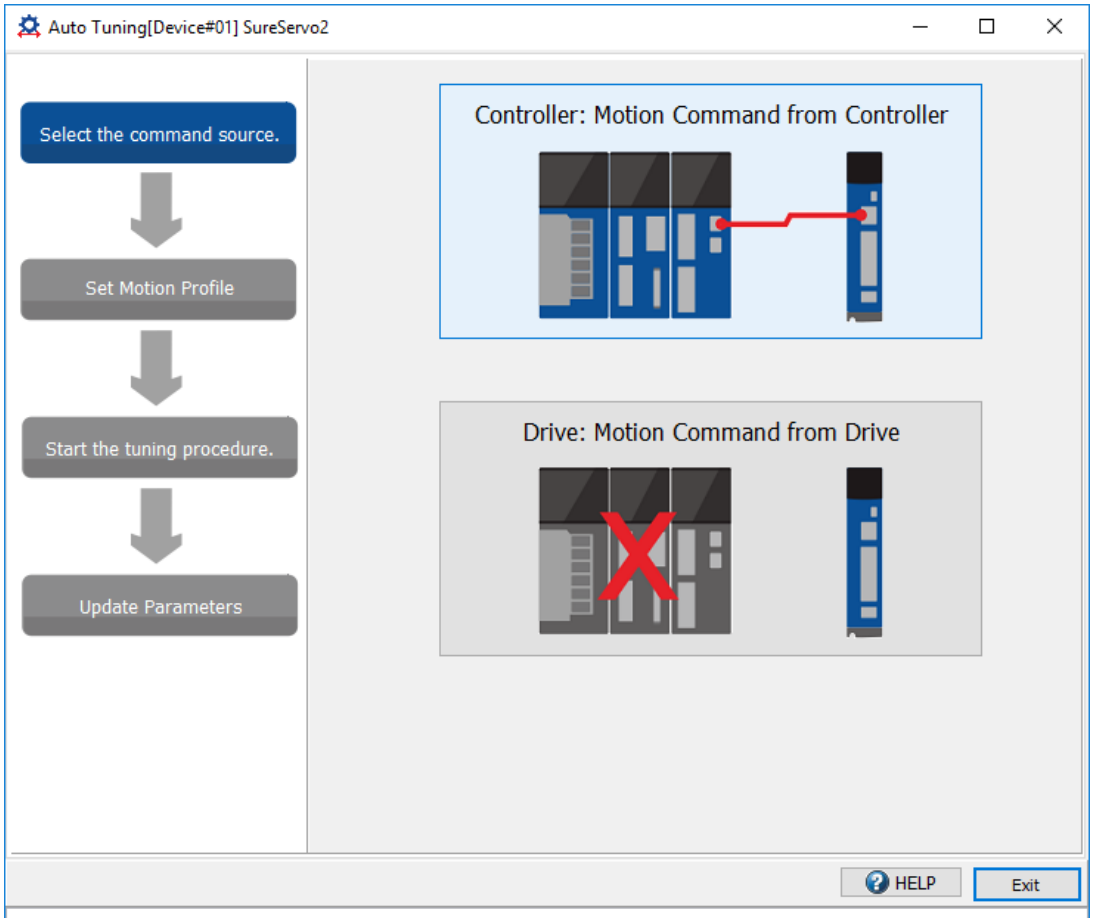
Step 1:

When the computer is connected to the servo drive, the program window appears as below. Click **Auto Tuning** in the Function List tree view.



Step 2:

Click **Drive: Motion Command From Drive** to start the Auto Tuning procedure.



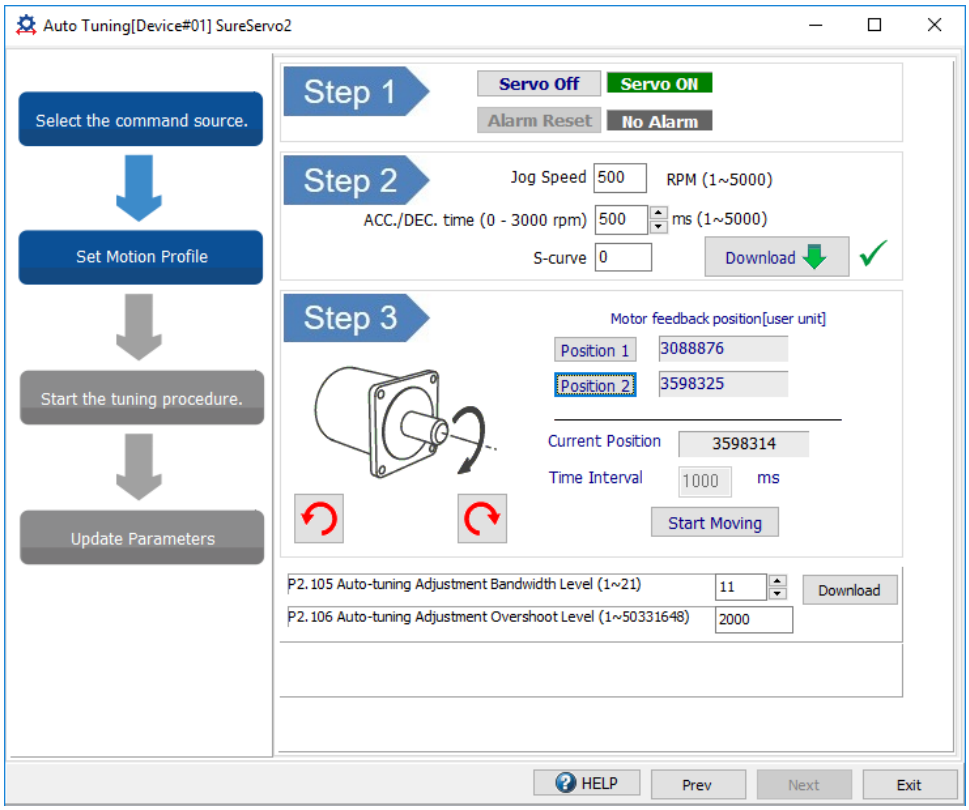
Please follow the steps below to set the motor running path on the screen below:

1) Set the system to Servo On state.
2) Set the acceleration/deceleration time and jog speed. The default setting for acceleration/deceleration time is 200 ms. Set the jog speed to no less than 500 rpm. The Jog speed in this field is also the tuning speed. Then click Download.
3) After you set the motor's jog definition parameters, you can use the Left or Right button to jog the motor to position 1 and 2 (example: jog to the pick point and the place point on a pick and place application). Click on the **Left** or **Right** buttons to jog the motor into the machine's starting position and click the **Position 1** button. If the motor is connected to a belt or there is no "machine starting position", simply click **Position 1**. Next, use the **Left** and **Right** buttons to move to the machine's end-of-move position and press the **Position 2** button. If there is no defined end-of-move position, simply move the motor some distance from position 1 so the Auto Tune feature can properly function. Then, click **Start Moving** to run between two positions. The motor moves to position 1 and 2 in the forward and backward directions.

Before running the motor, make sure no one is standing close to the machinery.

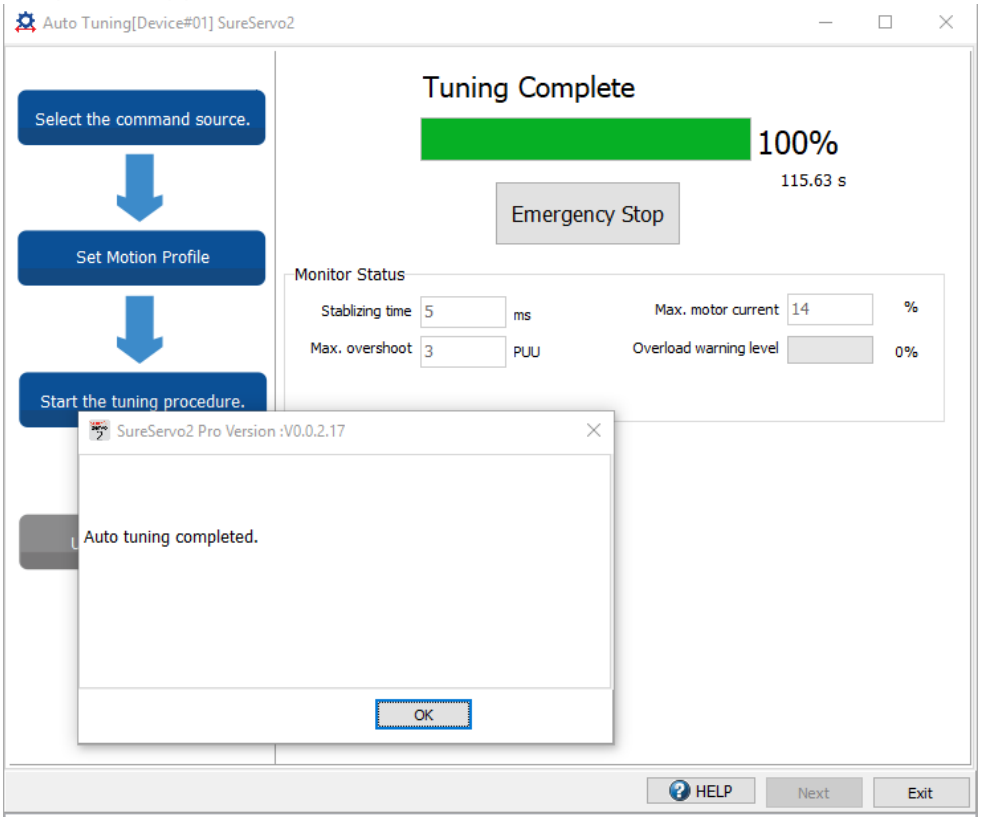
After ensuring the motor is cycling back and forth between position 1 and position 2, press **Next** to start the Auto Tuning process.

Note: *If AL007 (Position Deviation) appears when you attempt to jog the motor, you will need to increase the ACC/DEC time and/or decrease the Jog Speed. Press the Prev button to return to the previous screen and restart the procedure (this will re-Enable the servo).*

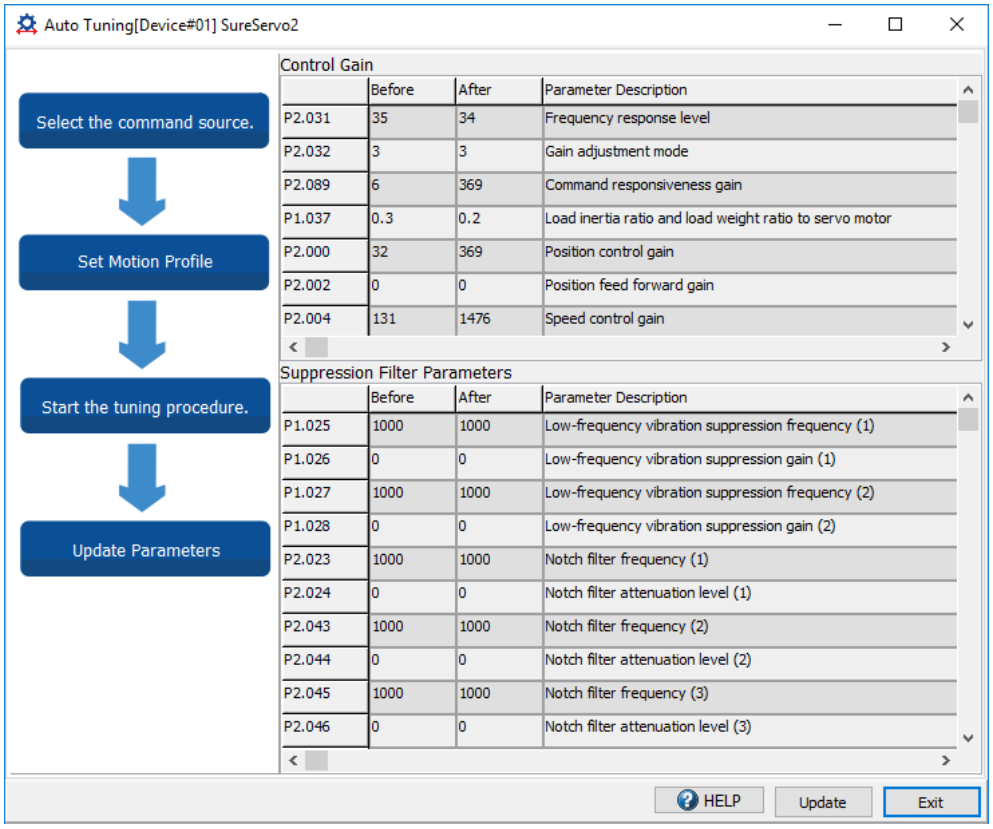


Step 3:

Wait until the tuning progress bar reaches 100%, after which a window with "Auto tuning completed" appears. Click **OK** to continue.



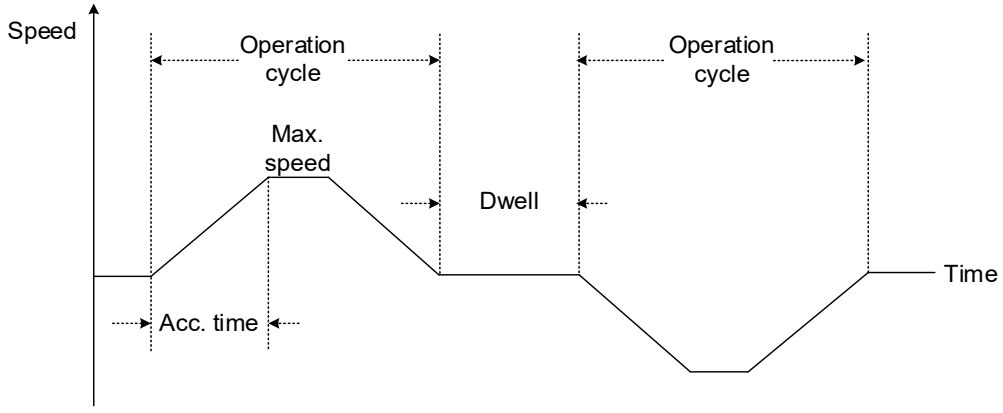
The screen shows a table comparing the parameters before and after being changed by auto tuning.



Please click **Update** to complete auto tuning or **Exit** to discard the new settings.

5.2.4 - Alarms related to auto tuning

In Auto Tuning mode, it is vital that you program the command path, including the operation cycle (such as acceleration, constant speed and deceleration) and dwell time. See the figure below. When any of the settings are incorrect, the servo drive stops and displays an alarm. Please check the alarm causes and take corrective action.

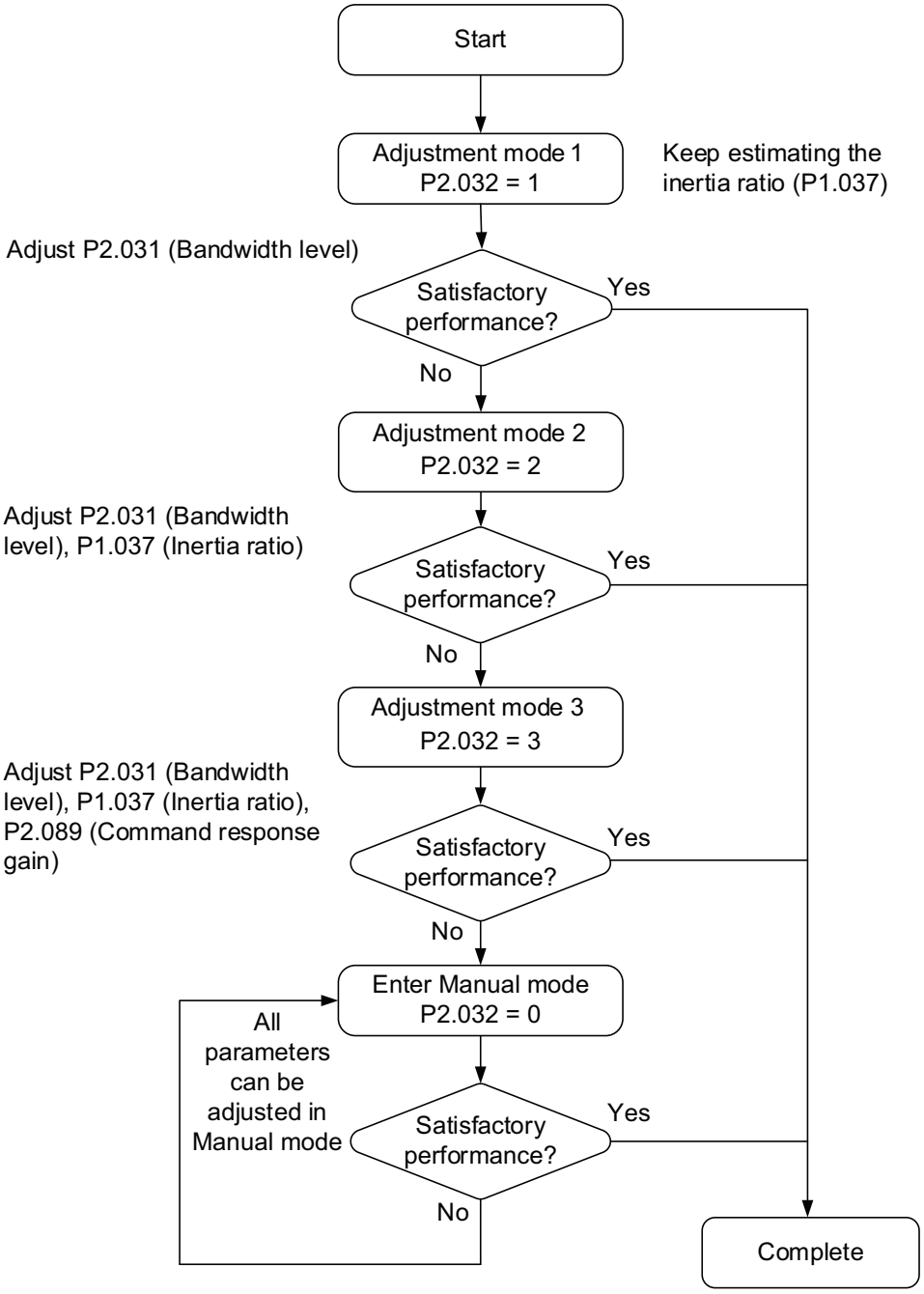


Display	*Alarm name*
AL007	Excessive Position Deviation
AL08A	Auto-tuning function - Command error
AL08B	Auto-tuning function - Inertia estimation error
AL08C	Auto-tuning function - Pause time is too short

5.3 - Tuning mode

Apart from the Auto Tuning function described above, there are three other tuning modes you can use to fine tune the system. You can then easily complete tuning by increasing or decreasing the frequency response bandwidth level (P2.031). Please follow the tuning procedure in Section 5.1.

5.3.1 - Flow chart of Tuning mode



5.3.2 - Gain Adjustment mode 1

In this mode, the servo drive continues to estimate the system's inertia and updates the value of parameter P1.037.

P2.032 Setting Value	Adjustment Mode	Inertia Estimation	Parameter	
			Manual Tuning	Auto Tuning
1	Gain adjustment mode 1	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

Requirements for inertia estimation:

1) Motor speed increases from 0 rpm to 3000 rpm within 1.5 seconds.
2) It is suggested to set the speed to 500 rpm or higher. The lowest speed should be no less than 200 rpm.
3) The load inertia should be less than 50 times the motor inertia.
4) The change in the external force or inertia ratio cannot be too great.

5.3.3 - Gain Adjustment mode 2

When gain adjustment mode 1 cannot meet your need, you can try gain adjustment mode 2 to tune the servo system. In gain adjustment mode 2, the system does not automatically estimate the inertia. You must set the correct mechanical inertia in parameter P1.037.

P2.032 Setting Value	Adjustment Mode	Inertia Estimation	Parameter	
			Manual Tuning	Auto Tuning
2	Gain adjustment mode 2	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

Inertia estimation is applicable to most applications. However, when the machine does not comply with the requirements for inertia estimation, you have to set the correct inertia ratio in parameter P1.037.

5.3.4 - Gain Adjustment mode 3

If your need cannot be met by gain adjustment mode 1 or 2, please select gain adjustment mode 3. Parameter P2.089 (Command Response Gain) is available 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 overshoot and machinery vibration. This function is only available when changing the command, such as the acceleration / deceleration application.

P2.032 Setting Value	Adjustment Mode	Inertia Estimation	Parameter	
			Manual Tuning	Auto Tuning
3	Gain adjustment mode 3	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

5.3.5 - Setting the frequency response bandwidth (stiffness)

You can use parameter P2.031 (frequency response bandwidth level) to tune the servo system in an easier and user-friendly way. With a fixed inertia ratio, when increasing the bandwidth level (P2.031), the servo's bandwidth increases as well. If resonance occurs, please lower the parameter value by one or two bandwidth levels (you should adjust the bandwidth level according to the actual situation). For instance, if the value of P2.031 is 30, you can reduce the bandwidth level to 28. When adjusting the value of this parameter, the servo system automatically adjusts the corresponding parameters, such as P2.000 and P2.004.

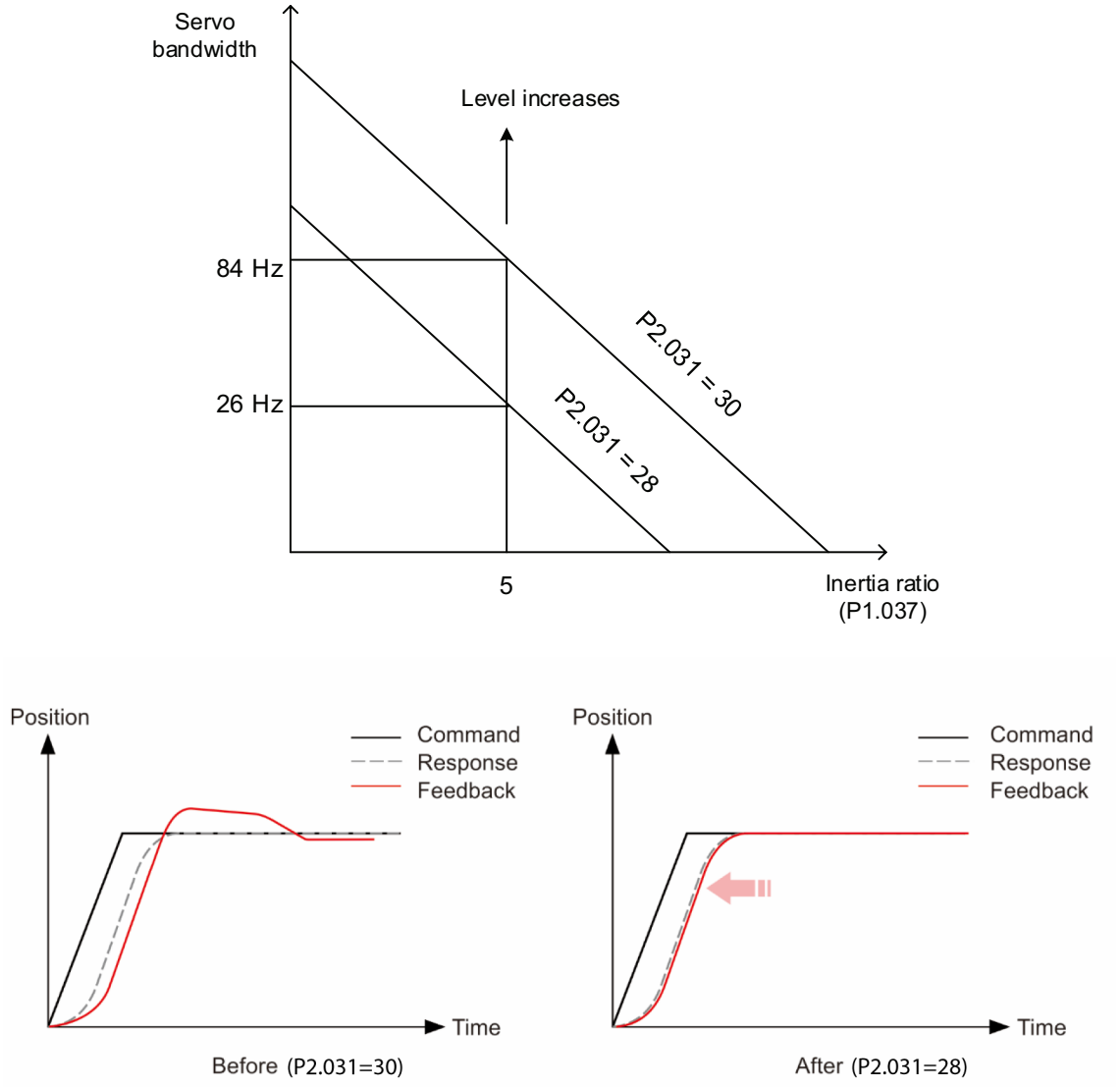


Figure 5-1 Adjust the bandwidth level

5.3.6 - Gain response

You can use parameter P2.089 (Command responsiveness gain) to adjust the response. Increasing the gain can minimize the deviation between the position command and command response in intermittent duty zone. When adjusting the value of P2.089, please enable the function for two degrees of freedom (two dimensional control)(set P2.094 to 0x1000).

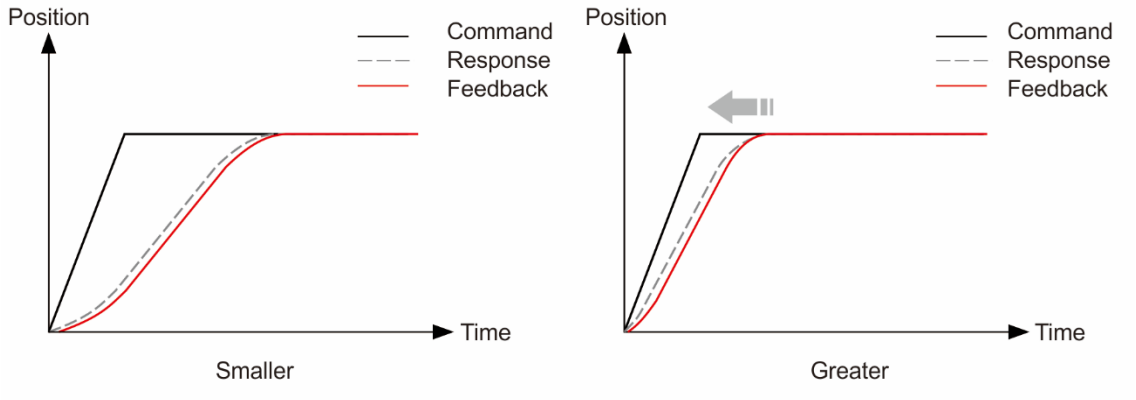


Figure 5-2 Adjust the gain response

5.4 - Tuning in Manual mode

The selection of the position and speed response frequency should be determined by the machinery stiffness and the application. Generally, for applications or machines that require high speed and high precision, higher frequency response bandwidth is required. However, increasing the response bandwidth might cause resonance. Thus, machinery with higher stiffness is used to solve this problem. When the resonance frequency is unknown, you can gradually increase the gain parameter values to increase the frequency resonance 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, parameter P2.000)

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

$$\text{Frequency response bandwidth of position loop (Hz)} = \frac{\text{KPP}}{2\pi}$$

Speed control gain (KVP, parameter P2.004)

This parameter determines the response of speed loop. The bigger the KVP value, the higher the response frequency of the speed loop and the lower the following error. However, if you set the value too high, it could cause machinery resonance. The response frequency of the speed loop must be 4–6 times higher than the response frequency of the position loop; otherwise, the machinery might vibrate or it might cause overshoot when positioning. The calculation of speed loop frequency response is as follows:

$$\text{Frequency response bandwidth of speed loop}$$

$$\text{fv} = \left(\frac{\text{KVP}}{2\pi}\right) \times \left[\frac{(1 + \text{P1} - 37/10)}{(1 + \text{JL/JM})}\right] \text{Hz}$$

JM: Motor Inertia; JL: Load Inertia; P1.037: 0.1 (times)

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

$$\text{fv} = \left(\frac{\text{KVP}}{2\pi}\right) \text{Hz}$$

Speed integral compensation (KVI, parameter 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 the machinery to vibrate. It is suggested that you set the value as follows:

$$\text{KVI (P2.006)} \leq 1.5 \times \text{Speed loop frequency response}$$

Low-pass filter for resonance suppression (NLP, parameter P2.025)

A high inertial value ratio reduces the frequency response of the speed loop. Therefore, you must increase the KVP value to maintain the response frequency. Increasing KVP value might cause machinery resonance. Please use this parameter to eliminate the noise from resonance. The higher the value, the better the capability for reducing high-frequency noise. However, if you set the value too high, it can cause instability in the speed loop and overshoot in positioning. It is suggested that you set the value as follows:

$$\text{NLP (P2.025)} \leq \frac{10000}{6 \times \text{Speed loop frequency response (Hz)}}$$

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

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

Position feed forward gain (PFG, parameter 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 in positioning. If the setting of the e-gear ratio is larger than 10, it might cause noise as well.

5.5 - Mechanical resonance suppression

Five sets of notch filters are provided to suppress mechanical resonance. You can set all five to the auto resonance suppression parameter (P2.047) with manual adjustment.

Please see the following flowchart for manual adjustment.