

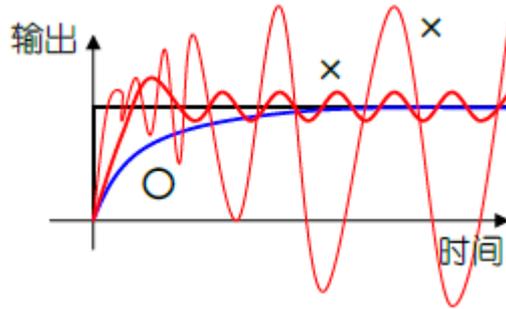
# **Instruction for ESTUN Servo System Gain Tuning**

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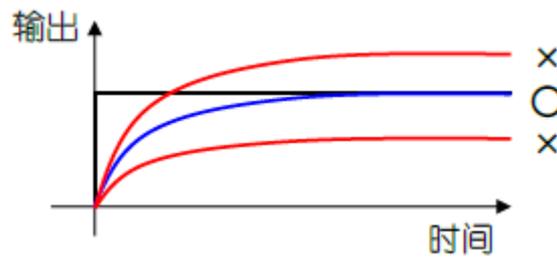
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1. **What is the ideal gain tuning**

a. Stability, No oscillation and continuous oscillation

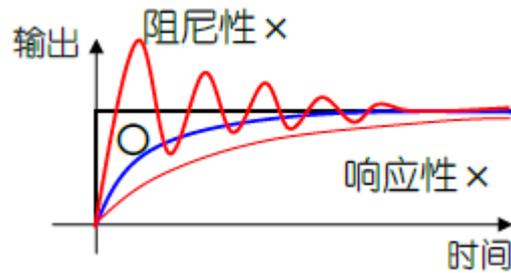


b. Accuracy, Target value is the same as actual output value



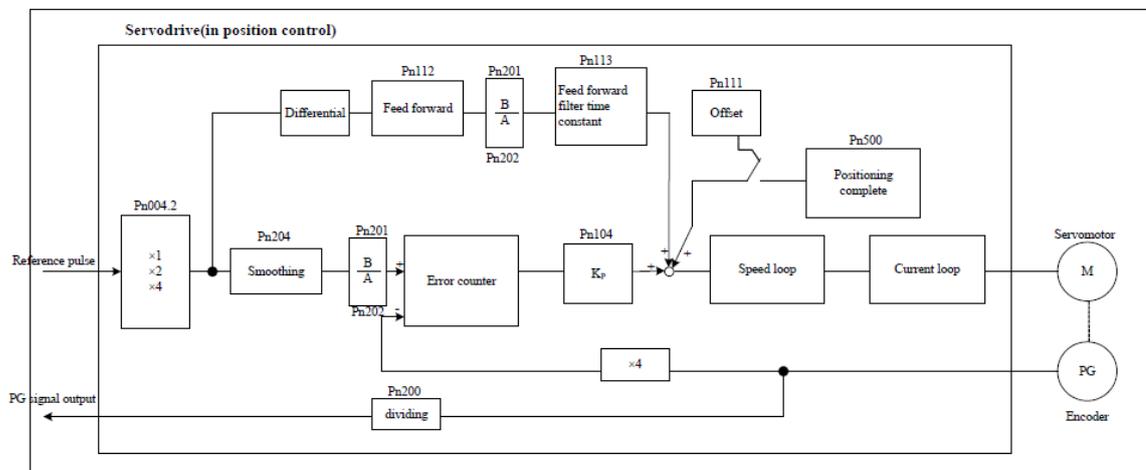
i.

c. Correspondence, Quick response and No overshooting



## 2. The structure for ESTUN servo control loops

A block diagram for position control is shown as below.



### Speed control loop gain (Pn102):

Speed loop gain is mainly used to decide the responsiveness of speed loop. Under the precondition of no vibration of mechanical system, the bigger the value of this parameter is, the higher the responsiveness is.

If the setting value of the load inertia ratio is correct, speed loop gain can reach designed value range. It consequently ensures the high responsiveness of speed loop.

Increase the ratio of speed loop gain can enhance the robustness of servo system. However, in real application, the value of speed loop gain cannot be too large. Otherwise, it will cause the whole servo system to vibrate.

### **Speed loop integration time constant (Pn103):**

Parameter Pn103 (Speed loop integration time constant) can reduce the ripple of motor speed. However, it will also reduce the responsiveness of the servo system. Therefore, when increase the time constant, the drive' s reaction time will be slowed and it needs more time for positioning.

When the load inertia is high or mechanical system is likely to vibrate, it is a must to increase speed loop integration time constant.

### **Position control loop gain (Pn104):**

Position loop gain is one of the fundamental index of AC servo system and has close relation to Servo motor & mechanical load. Generally speaking, higher position loop gain will cause:

1. Higher responsiveness of motor speed
2. Smaller position tracing error
3. Shorter positioning time

However, it requires higher relevant mechanical system robustness and natural frequency.

### 3. **The adjusting principle between three control loops**

Servo driver has three feedback loops which are Position loop, speed loop and current loop. Current loop has the highest responsiveness. Meanwhile, speed loop must have a higher responsiveness than position loop.

If we do not abide by this principle, the motor will be caused to vibration or undesired reaction. While designing the servo drive, Estun has ensured the highest responsiveness of current loop. Therefore, users only need to adjust the gain of position and speed loop.

Generally speaking, the responsiveness of position loop cannot be faster than speed loop. Hence, it is strongly recommended to increase the gain of speed loop first.

When you want to tune the servo gain parameters, in case you only increase the gain of position loop, the motor is likely caused to vibrate. This will cause the increase of speed adjusting time and positioning time rather than desired decrease.

#### 4. **Typical transmission mechanism and parameter setting**

##### a) Ball screw

The ball screw is a kind of transmission that converts rotary motion into linear motion. It is a high-rigidity connection by the rolling of balls instead of the sliding of the screw.

Motor and the ball screw are connected by a coupling, for short-distance high-precision positioning. Normally the stroke does not exceed 10 meters. It has high transmission efficiency, and stable transmission; high positioning accuracy and high transmission rigidity; good synchronization performance. And it can be used for high-speed reference application.



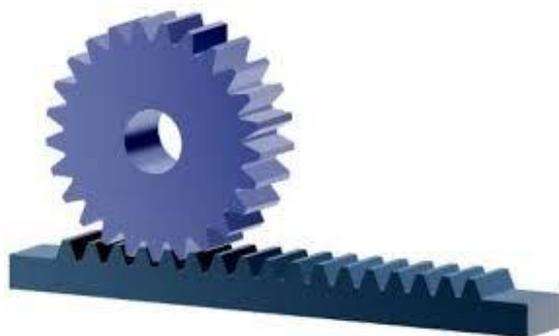
Recommended parameter setting range:

Pn102 Hz	Pn103 [ms]	Pn104 [1/s]
600-800	100-200	50-70

## b) Gear-rack Drive

The Gear-rack Drive is one kind of transmission that the gear is for the rotary motion, and the rack is for linear movement. The rack can be considered as a part of a gear with an infinite number of teeth. So every circle of the gear becomes a straight line which is the involute of the tooth profile curve. It becomes a linear motion and also is a highly rigid motion.

The Gear-rack Drive has a large bearing capacity and high transmission precision. It is suitable for large stroke, high precision and high torque transmission. In the long-distance heavy-load linear motion, the ball screw may have an insufficient strength, which may cause vibration, jitter, etc., which may cause the screw to bend, deform, or even break. The rack will not have such issues. Technically the Gear-rack drive can be connected infinitely long distance and run at high speed without affecting the accuracy.



Recommended parameter setting range:

Pn102 [Hz]	Pn103 [ms]	Pn104 [1/s]
500-700	150-250	40-60

### c) Pulley Drive

The pulley drive is the kind of low rigidity transmission motion. It transmits the motion by the friction between the belt and the wheels.

The pulley drive is suitable for the occasion that there is a large center distance between two shafts. The transmission is smooth and noiseless, which can reduce and absorb vibration. If there is overload during work, the belt will slip on the pulley to prevent damage to the machine; The Pulley drive can't guarantee the accurate of the transmission. The pulley material is generally made by cast iron; the cost is low, lubrication is not required; and the maintenance is easy.



Recommended parameter setting range:

Pn102 [rad/s]	Pn103 [ms]	Pn104 [1/s]
300-500	200-300	30-50

Notice:

The above recommend parameter setting is without setting of Pn106 ,

Pn106 is the default setting;

If the Load inertia ratio (Pn106) is bigger than 10 times, normally the setting value of Pn102 and Pn104 need to be reduced and with bigger value of Pn103;

## 5. **The basic procedure for tuning**

The basic principle of gain tuning is to make the servo system have a minimum delay time, and also has the minimum following error when positioning. So it needs to be adjusted according to the actual motion of the motor to optimize system' s performance.

### **The top-priority operation:** Static Inertia Ratio Detection Operation

The correct inertia ratio setting is the foundation of the gain setting. So the load inertia ratio detection operation is the first step of gain tuning, and after that customer can know the selection of the motor is suitable or not.

Specific steps:

- a) Detecting the static inertia ratio by Fn009;
- b) Checking the result of Un015. It shows the static inertia ratio directly. Set this value on Pn106.(Normally this value is smaller than 500, it means the static inertia ratio is smaller than 5 times)

The importance of a suitable inertia ratio:

Big inertia ratio:	Small inertia ratio:
With the fixed gain setting, bigger inertia ratio, the slower speed response	With the fixed gain setting, smaller inertia ratio, the quicker speed response
With stronger gain setting, it can improve the speed response. But it can easily cause vibration.	With softer gain setting, the speed response can meet the requirement and no vibration.
Overload alarm occurs easily.	There will be no overload alarm.
Regenerative circuit error easily.	Not easy to cause Regenerative circuit error

1) Adjusting of Speed loop gain

Under the precondition of no vibration of mechanical system, the bigger the value of Pn102 is, the higher the responsiveness is.

The principle of adjusting Pn103: If the static inertia ratio is bigger and the setting of Pn103 is bigger. But with bigger value of Pn103, the response time of the speed loop is longer. During this situation, customer can try bigger Pn102 but without causing the vibration of the machine.

The adjustment of these two parameters is an iterative process.

## 2) Solutions when vibration occurs

### a) When there is vibration or abnormal sound in the system.

Firstly make sure there is no problem with the machine itself (coupling, belt' s installation). After make sure the machine itself has no problem, then adjusting drive' s parameters. When vibrates or abnormally sounds occurs, normally we suggest to reduce the speed loop gain. If customer do not want to reduce the gain, try increasing the constant value of the torque filter (Pn105) or decreasing Pn127 (low speed detection filter) up to 0. The last solution is setting the notch filter (high risk, not recommended), because the machine' s rigidity will be changing due to time changes. It will cause the notch filter to fail.

### b) Set the notch filter.

In some cases, the system has a long stroke. In different stroke ranges, the resonance point may be different. But we need to pay attention to the misalignment of the resonance frequency (when using notch filter function to remove one mechanical resonance point, but this notch filter setting is possible to cause another mechanical vibrations at other locations. If resonance frequency

misalignment issue occurs, do not use the notch filter function.

The mechanical resonance point can be obtained by the FFT function in Eview. The notch filter function has better effect if the resonance point frequency is above 200HZ. FFT function will get more accurate result when Pn407-Pn410 are set as factory value.

The resonance point measured by the FFT may deviate from the actual mechanical resonance point. If directly set the resonance point measured by the FFT to the driver (Pn407, Pn409), the system vibration may not be eliminated. During this situation, we can try modify the result of FFT function. (Frequency Value can be up or down). See if the system resonance point can be eliminated. The Pn408 and Pn410 filter depths are generally set to 3.

### 3) Adjusting of Position loop gain

The position loop proportional gain is only valid when the drive is operating in position mode. When servo motor is holding the position, increasing the position loop proportional gain can improve the locking stiffness of the motor. When servo system is running under position mode, increasing or decreasing the value of Pn104 will affect the following error value. Under the premise that the position loop system is stable and the actual position is not overshooting. It's better to increase the position loop proportional gain to reduce the position lag.

For the application that requires multi-axis simultaneous interpolation movement, the position loop gain Pn104 of each axis should be adjusted to be the same.

Under position control mode, it requires to adjust the speed loop first (Keep Pn104 as the factory setting). After the adjusting of speed loop has been done, then adjusting the position loop gain.

The adjusting of position loop should be done step by step. If the value of Pn104 is too big, it will also cause vibration.

#### **To sum up:**

There are no fixed values for Pn102, Pn103 and Pn104. They are depending on the mechanical transmission connection type, the movement type of the load, the load inertia, the running speed,

the acceleration/deceleration, and the rotor inertia and etc. The simple method of adjustment is to adjust the gain parameter from small value to large value in the range of general experience according to the external load. The value of Pn103 is from a large value to a small one. The best setting value is that the machine has no vibration overshoot.

#### 4) Adjusting of some other utility parameters

##### a. Pn105 Torque reference filter time constant

It can eliminate or lighten mechanical vibration, but incorrect setting will result to mechanical vibration. Normally with smaller setting value of Pn105, the better responsiveness of the control, but it is depending on the mechanical conditions. For example, when the belt is connected (the system rigidity is low), the setting of Pn105 cannot be set too low; if the screw is connected (the system rigidity is relatively high), the Pn105 setting value can be lower.

##### b. Pn127 Low speed detection filter

Normally it should be set as 0. To reducing the speed lag and ensure the accuracy when motor running at low speed.

6. **How to use the ESVIEW to make the job more efficient**

a. Description of the sampling setting time on ESVIEW

If the sampling time is set as 1, the sampling interval is 0.1ms. So the whole sampling time is 0.1s (1000 data).

If the sampling time is set as 100, the sampling interval is 10ms. So the whole sampling time is 10s (1000 data).

The maximum sample time for Esview is 10s, and the sampling time should be set as 100.

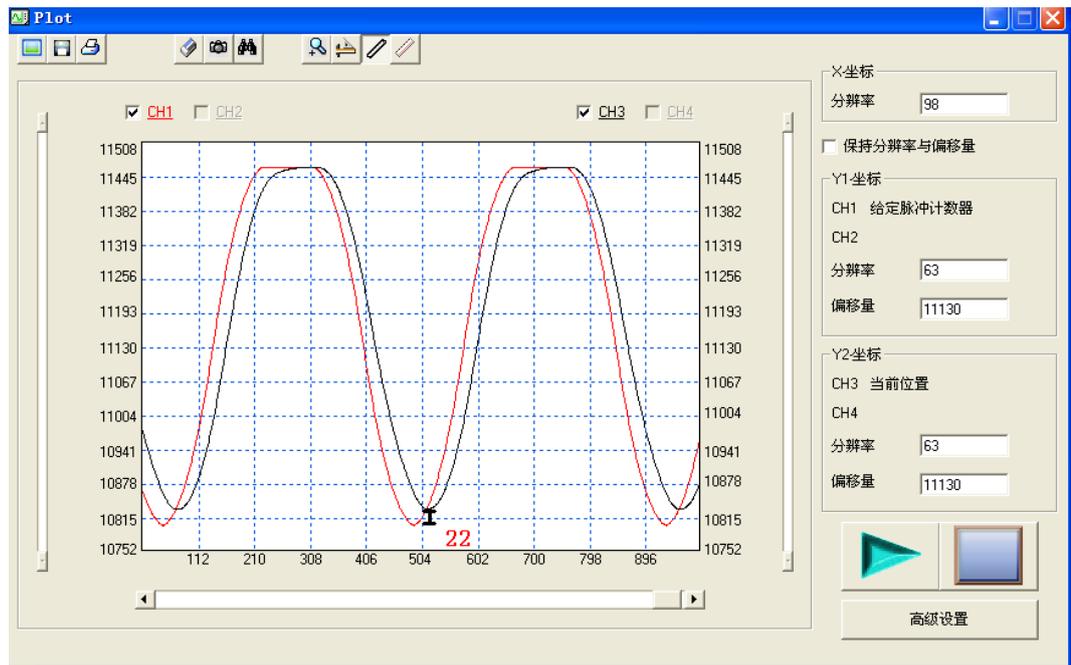
If sampling time set as 10s, the sampling data interval is large. Some data may not be observed, but the whole graph can be observed;

If sampling time set as 0.1s, sampling interval is the smallest, sampling data can be dense.

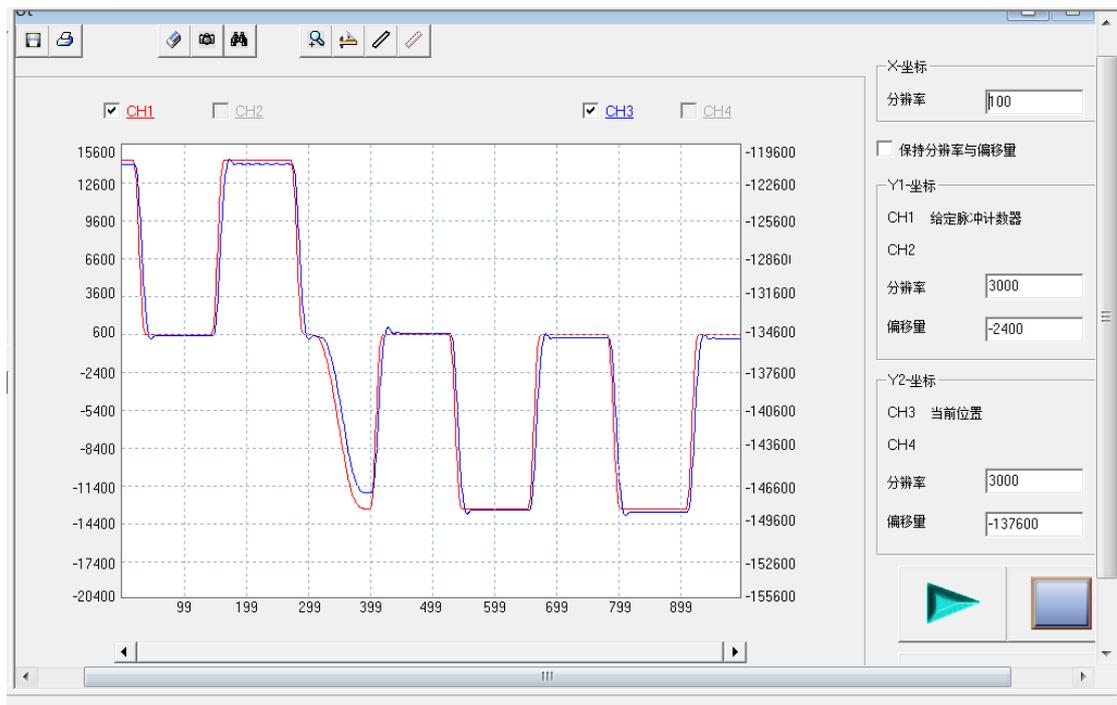
b. How to check the tuning result

Under position control mode:

The position response lag time can be compared by the given pulse and the current position (motor feedback position) (red is the given pulse counter, black is the current position).



On the following picture, red line is the given pulse, and blue line is the current position.



7. **Parameter setting values for some typical machines**

a) Wood cutting CNC machine

Configurations: Pronet-E-10A , EMG-10APA22

Pn100	0
Pn102	600
Pn103	200
Pn104	80
Pn127	0

b) CNC machine

Configurations: Pronet-50AMA, EMG-50ASA22

Pn100	0
Pn102	800
Pn103	200
Pn104	60
Pn127	0

c) Knitting machine

Configuration: PRONET-04AEA-EC, EMJ-04ASB22

Pn100	0
Pn102	600
Pn103	700
Pn104	70
Pn127	0

d) Plasma cutting machine

Configuration: Pronet-E-08A, EMJ-08APB22

Pn100	0
Pn102	500
Pn103	200
Pn104	40
Pn127	0

e) Glass cutting machine

Configuration: PRONET-08AMF & EMJ-08AFB22 (X axis)

PRONET-15AMF & EMG-15AFB22 (Y axis)

Pn100	0
Pn102	1000
Pn103	1000
Pn104	80
Pn127	0

f) 4D entertainment chair

Configuration: ProNet-E-08A, EMJ-08APB22

Pn100	0
Pn102	800
Pn103	1000
Pn104	30
Pn127	0