

# User's Manual

## For

# DCS303

### Digital Brush DC Servo Driver

Revision 1.0

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Attention: Please read this manual carefully before using the driver!



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**Leadshine Technology Co., Ltd.**

3/F, Block 2, Nanyou Tianan Industrial Park, Nanshan Dist, Shenzhen, China

Tel: (86)755-26434369 Fax: (86)755-26402718

URL: [www.leadshine.com](http://www.leadshine.com) E-Mail: [sales@leadshine.com](mailto:sales@leadshine.com)

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## 1. Introduction, Features and Applications

### Introduction

The DCS303 is a digital DC servo driver developed with DSP and high efficient MOSFET technologies. In position control, it's easy for the end users to change stepping drivers to the DCS303 without changing control systems, because its input command is PUL/DIR signal, which is compatible with that of stepping drivers. In low power motion control applications, performances of DC servo systems using the DCS303 are better than those of digital AC servo systems in velocity, precision, stability, or at least as good as those of digital AC servo systems. However, the cost of the DCS303 stays at the price line of stepping driver, namely far lower than those of AC servo drivers.

The DCS303 is a microsize brush DC servo drive. It is an ideal choice for those applications in which the mounting space for the driver is limited and higher output power is not necessary.

The DCS303 is very easy to tune and all parameters are visible. Handheld and PC based tuning tools, including ProTuner (Windows based setup software) and STU (Small servo tuning unit) can meet different tuning environments or requirements.

### Features

- | Input Voltage: 18-30VDC
- | Output Current: 3 A (Cont.), 15A(Peak), Power range: 5-90W.
- | Based on DSP control technology and high smooth servo control algorithm.
- | Handheld and PC based tuning tools, including Pro Tuner and STU.
- | Feedback resolution  $\times 4$  encoder line count.
- | Position Following error lock range adjustable
- | Position error can be eliminated to 1 count, and velocity error can be eliminated

to the Desired Velocity\*  $\pm 0.3\%$

- | Electronic gear ratio from 1/255 to 255
- | Built-in motion controller for self-test with trapezoidal velocity profile
- | Support PUL/DIR control signals
- | Opto-isolated inputs, support single-ended signals
- | 10 latest errors self-record function
- | Over-current, over-voltage, phase error, encoder error, position following error protections
- | Small size, surface-mount technology

## Applications

Suitable for a wide range of equipments and instruments such as mini type engraving machines, inkjet printers, etc. It performs better in the applications require low noise, high velocity, high precision and high reliability.

## 2. Specifications and Operating Environment

### Mechanical Specifications (unit: mm[inch])

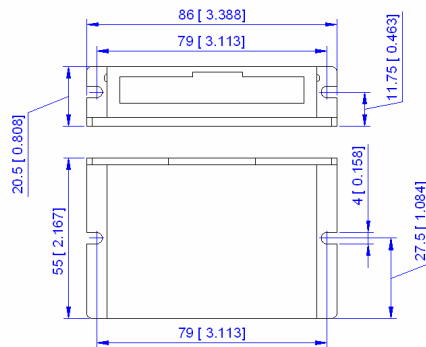


Figure 2-1: Mechanical specifications

## Elimination of Heat

- | Driver's reliable working temperature should be  $< 70^{\circ}\text{C}$  [ $158^{\circ}\text{F}$ ], and motor working temperature should be  $< 80^{\circ}\text{C}$  [ $176^{\circ}\text{F}$ ];
- | It is recommended to mount the driver vertically to maximize heat sink area.

## Electrical Specifications ( $T_j = 25^{\circ}\text{C}/77^{\circ}\text{F}$ )

Parameters	DCS303			
	Min.	Typical	Max.	Unit
Peak output current	0	-	15	A
Supply voltage	+18	+24	+30	VDC
Logic signal current	7	10	15	mA
Pulse input frequency	0	-	200	kHz
Isolation resistance	500			MΩ
Current provided to encoder			50	mA

## Operating Environment and Parameters

Cooling	Natural cooling or forced cooling	
Operating Environment	Environment	Avoid dust, oil fog and corrosive gases
	Ambient Temperature	0 °C – 50 °C
	Humidity	40 – 95%RH
	Vibration	5.9 m/s <sup>2</sup> Max
Storage Temperature	-20 °C – +65 °C	
Weight	Approx. 110 g (3.88 oz)	



### 3. Connections

#### Connector Configuration

##### General information

Control Signal Connector			
Pin	Signal	Description	I/O
1	PUL	Pulse control signal	I
2	DIR	Direction control signal	I
3	OPTO	+5V Opto-isolated power input	I
4	ENA	Enable control signal, can be used to clear position following error	I
5	ERR	Error output signal, HIGH indicates normal, LOW indicates fault.	O
6	EGD	Opto-isolated GND, use for reference when using ERR	GND
Encoder Signal Connector			
Pin	Signal	Description	I/O
1	EB	Encoder channel B input.	I
2	EA	Encoder channel A input.	I
3	E +5V	Positive pole of the auxiliary power supply (50 mA (Max)).	O
4	EGND	Ground of the auxiliary power supply.	GND
Power Connector			
Pin	Signal	Description	I/O
1	Motor+	Motor positive connection.	O
2	Motor-	Motor negative connection.	O
3	+Vdc	+18 TO 30 VDC power input.	I
4	GND	Power Ground.	GND
RS232 Communication Connector			
Pin	Signal	Description	I/O
1	+5V	+5V power only for STU.	O
2	TxD	RS232 transmit.	O
3	GND	Ground.	GND
4	RxD	RS232 receive.	I



#### More about PUL/DIR/ENA Signals

Pin Function	Details
PUL	<u>Pulse signal</u> : This input represents pulse signal; 4-5V when PUL-HIGH, 0-0.5V when PUL-LOW. For reliable response, pulse width should be longer than 2.5μs. Series connect resistors for current-limiting when using +12V or +24V control signals (OPTO). The same as DIR and ENA signals.
DIR	<u>DIR signal</u> : This signal has LOW/HIGH voltage levels, 4-5V when DIR-HIGH, 0-0.5V when DIR-LOW. For reliable motion response, DIR signal should be ahead of PUL signal by 5μs at least. Please note that motion direction is also related to motor-driver wirings and encoder feedback A/B phase signals. Exchanging the connections of two wires of the motor to the driver and A/B phase signals of encoder will reverse motion direction.
ENA	<u>Enable signal</u> : This signal is used for enabling/disabling the driver. High level (NPN control signal, PNP and Differential control signals are on the contrary, namely Low level for enabling.) for enabling the driver and low level for disabling the driver. Usually left <b>UNCONNECTED (ENABLED)</b> .
ERR	<u>Error signal</u> : This pin will be pulled to LOW level (reference to <b>EGD</b> ) when driver goes into faulty status. There is a 10K resistor connected between <b>ERR</b> and <b>OPTO</b> . Please refer to figure 2 in Control Signal Connections for more details.

#### Control Signal Connections

The DCS303 has 3 optically isolated logic inputs to accept control signals. These inputs are isolated to minimize or eliminate electrical noises coupled onto the control signals. In the following figure, connections to open-collector are illustrated.

ERR signal can be used for error detecting and has the same reference (GND) with PUL, DIR and ENA signal.

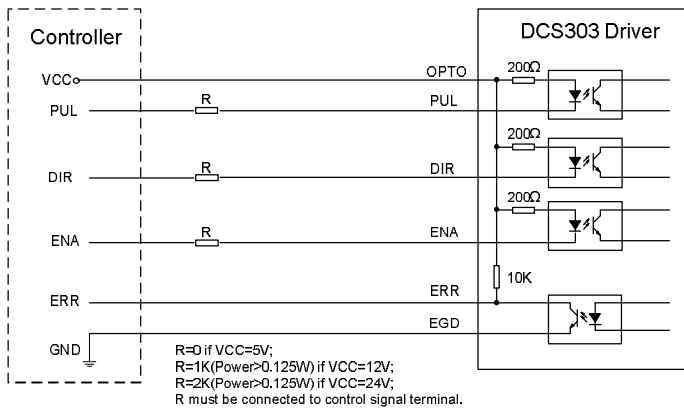


Figure 3-1: Connections to open-collector control signal (common-anode)

### Encoder Connections

If the encoder drains less than 50mA, the DCS303 can supply the encoder directly, and connect it as Figure 3-2. If the encoder drains more than 50mA, use an external DC supply and connect it as Figure 3-3. Note that twisted-pair shielded cabling provides the best immunity in electrically noisy environments.

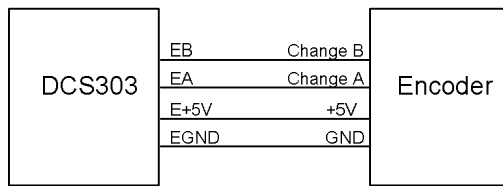


Figure 3-2: The DCS303 supplies the encoder directly

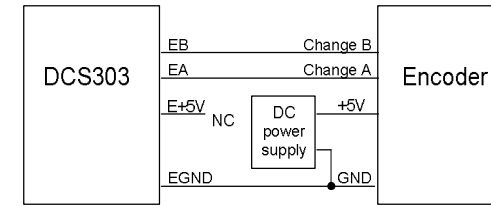


Figure 3-3: Using external DC power supply to supply the encoder

### RS232 Interface Connection

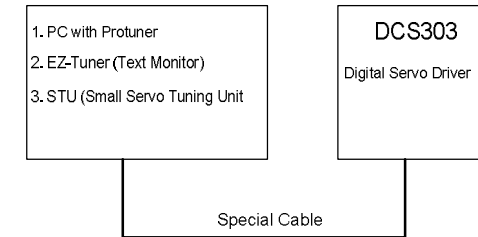


Figure 3-4: RS232 interface connection

### Typical Connections

Two typical connections of the DCS303 are shown as Figure 3-5, 3-6. Please consult “Control Signal Connections” and “Encoder Connections” for more information about controller and encoder connections.

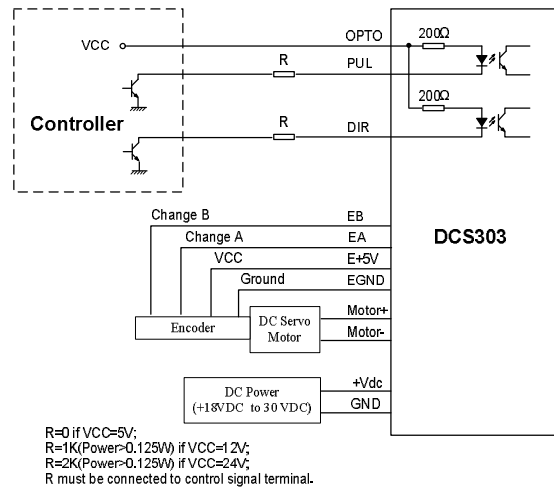


Figure 3-5: Typical connection (Open-collector control signal.)

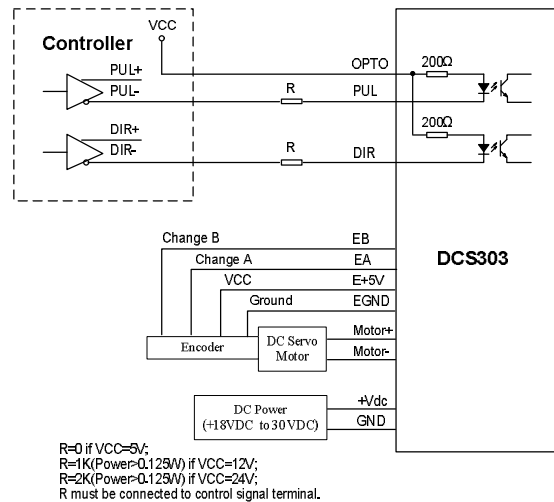


Figure 3-6: Typical connection (Differential control signal)

## 4. Servo Setup

Before you start the servo, you can follow the below steps.

### Install Encoder

If your motor has no encoder, you must have an encoder (more than 200 lines) properly mounted on the motor before you start. And please assemble the encoder according to its factory manual. Please use shielded cables and separate encoder signal cable from interference sources, such as motor wires and power wires at least 5 cm.

### Prepare Power Supply

#### Regulated or Unregulated Power Supply

Both regulated and unregulated power supplies can be used to supply the driver. However, unregulated power supplies are preferred due to their ability to withstand current surge. If regulated power supplies (such as most switching supplies.) are indeed used, it is important to have large current output rating to avoid problems like current clamp, for example using 4A supply for 3A motor-driver operation. On the other hand, if unregulated supply is used, one may use a power supply of lower current rating than that of motor (typically 50% ~70% of motor current). The reason is that the driver draws current from the power supply capacitor of the unregulated supply only during the ON duration of the PWM cycle, but not during the OFF duration. Therefore, the average current withdrawn from power supply is considerably less than motor current. For example, two 3A motors can be well supplied by one power supply of 4A rating.

#### Selecting Supply Voltage

The DCS303 can actually operate within +18V to +30VDC, including power input



fluctuation and back EMF voltage generated by motor coils during motor shaft deceleration. The rated voltage of the motor is an important parameter when selecting supply voltage. Generally speaking, do not use a power supply voltage more than 5 volts of the rated voltage of the motor. Higher voltage may cause bigger motor vibration at lower speed, and it may also cause over-voltage protection or even driver damage.

## Prepare Controller

Prepare a controller with pulse and direction signals. However, the DCS303 has a built-in motion controller for self-test and Servo Tuning. The built-in motion controller can generate control signal with trapezoidal velocity profile.

## System Connections and Noise Prevention

After finishing the above steps, you can connect your servo system. Before you start, make sure that the power is off. Connect your system according to connection diagrams before, and pay attention to the following tips when wiring.

### Wire Gauge

The smaller wire diameter (lower gauge), the higher impedance. Higher impedance wire will broadcast more noise than lower impedance wire. Therefore, when selecting the wire gauge, it is preferable to select lower gauge (i.e. larger diameter) wire. This recommendation becomes more critical as the cable length increases. Use the following table to select the appropriate wire size to use in your application.

Current (A)	Minimum wire size (AWG)
10	#20
15	#18
20	#16



## Cable Routing

All content sensitive signal wires should be routed as far away from motor power wires and driver power wires as possible. Motor power and driver power wires are major sources of noise and can easily corrupt a nearby signal. This issue becomes increasingly important with longer motor power and driver power wires lengths.

## Twisted Wires

Twisted wires effectively increasing noise immunity. The successive twists eliminate noise transients along the length of the cable. Both signal cables and power cables should be of the twisted and shielded type. Differential signal wires should be twisted as a pair. The combination of twisted pair wires and a differential signal significantly adds to noise immunity. Power wires should be twisted as a group along with the ground (or chassis) wire, if available.

## Cable Shielding

All signal wires should be bundled and shielded separately from driver power and motor power wires. Power wires should also be bundled and shielded. When grounding a shield, the rule-of-thumb is to do so at the 'source' of power while leaving the other shield end open. For example, in the case of motor power wires, this would be the drive side. Ideally, twisted pairs should be individually shielded and isolated from the outer shield, which encompasses all wires within the cable. However, since this type of stringent shielding practice is often not required, typical cables do not provide isolation between inner and outer shields.

## System Grounding

Good grounding practices help reduce the majority of noise present in a system. All common grounds within an isolated system should be tied to PE (protective earth) through a 'SINGLE' low resistance point. Avoiding repetitive links to PE creating





ground loops, which are a frequent source of noise. Central point grounding should also be applied to cable shielding; shields should be open on one end and grounded on the other. Close attention should also be given to chassis wires. For example, motors are typically supplied with a chassis wire. If this chassis wire is connected to PE, but the motor chassis itself is attached to the machine frame, which is also connected to PE, a ground loop will be created. Wires used for grounding should be of a heavy gauge and as short as possible. Unused wiring should also be grounded when safe to do so since wires left floating can act as large antennas, which contribute to EMI.

### Power Supply Connection

**NEVER** connect power and ground in the wrong direction, because it will damage the DCS303 driver. The distance between the DC power supply of the drive and the drive itself should be as short as possible since the cable between the two is a source of noise. When the power supply lines are longer than 50 cm, a 1000 $\mu$ F/36V electrolytic capacitor should be connected between the terminal “GND” and the terminal “+VDC”. This capacitor stabilizes the voltage supplied to the drive as well as filters noise on the power supply line. Please note that the polarity can not be reversed.

It is recommended to have multiple drivers to share one power supply to reduce cost if the supply has enough capacity. To avoid cross interference, **DO NOT** daisy-chain the power supply input pins of the drivers. Instead, please connect them to power supply separately.

## 5. Tuning the servo

### Testing the servo

You may wish to secure the motor so it can't jump off the bench. Turn on the power



supply, the green (Power) LED will light. The DCS303 has default parameters stored in the driver. If the system has no hardware and wirings problem, the motor should be locked and the driver should be ready.

If the motor jumps slightly and the red LED immediately turns on (flickers), then either the motor or the encoder is wired in reversal. Open the tuning software ProTuner and check driver status by clicking **Err\_check**. If it's **Phase Error**, then reversal motor wires or exchange encoder inputs and try again. If it's **Encoder Error**, please check encoder and its wirings, and then try again. If it still doesn't work after you followed all of the previous steps, please contact us at [tech@leadshine.com](mailto:tech@leadshine.com).

If the red LED is off and the motor is normal, then you can start to tune the servo with selected tool. **ProTuner** and **STU** are available for the DCS303.

### Tuning the Servo

A servo system is error-driven. The “Gain” of the system determines how hard the servo tries to reduce the error. A high-gain system can produce large correcting torques when the error is very small. A high gain is required if the output is required to follow the input faithfully with minimal error.

A servo motor and its load both have inertia, which the servo amplifier must accelerate and decelerate while attempting to follow a change at the input. The presence of the inertia will tend to result in over-correction, with the system oscillating beyond either side of its target. It's called UNDER DAMPED status. See Figure 5-1. This oscillation must be damped, but too much damping will cause the response to be sluggish, namely cause the system to get into an OVER DAMPED state. When we tune a servo, we are trying to achieve the fastest response with little or no overshoot, namely get a CRITICALLY DAMPED response.

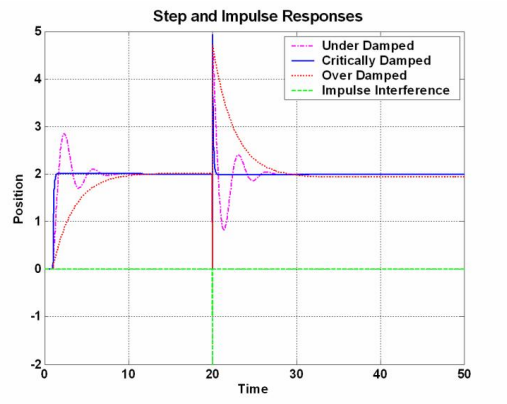


Figure 5-1: Step and impulse responses

As mentioned in previous contents, the DCS303 is a digital servo driver and its input command is PUL/DIR signal. In other words, step response just exists in each step command signal. For each step command signal is a very small movement, so OVER SHOOT and SETTLING TIME between each step are very small, causing you hardly can see a step response such as Figure 8, even if the SET POINT is a very large quantity and the acceleration is very high.

However, if you try to evaluate performances of the digital servo by investigating its position tracking-error or position following error, you may find it's much easier than investigating its step response. The easiest way to get a tracking-error or position following error response is to induce an impulse load on the motor. See Figure 5-1 at "time 20".

Leadshine offer a Windows based setup software **ProTuner** to its customers for evaluating servo performances. Small servo tuning unit **STU** (optional) is available too, and it's for field tuning without PC.

Tuning servo systems formed by DCS303 drivers can be summarized as the following rules:

1. If servo system is UNSTABLE, then the first thing of tuning is to stabilize the system. You can increase **Derivative Gain** of **Position Loop** ( $K_d$ ) or decrease **Proportional Gain** of Position Loop ( $K_p$ ) or **Integral Gain** of Position Loop ( $K_i$ ).
2. If servo system is **UNDER DAMPED**, then increase  $K_d$  or decrease  $K_p$  or  $K_i$ .
3. If servo system is **CRITICALLY DAMPED**, then stop tuning and download the parameter settings to the driver's EEPROM.
4. If servo system is **OVER DAMPED**, then decrease  $K_d$  or increase  $K_p$  or  $K_i$ .

## 6. PC window based Tuning Using ProTuner

### Introduction

This manual will provide an overview of connection and basic setup instructions for Leadshine's digital servo driver DCS303 using the **ProTuner** software. The basic setup of a digital driver is designed to be analogous to the setup and tuning of an analog amplifier. These instructions will walk you through the following steps necessary to start up your driver and motor. This document is intended for setting up the driver with the **ProTuner**.

### Software Installation

The ProTuner is windows based setup software for tuning Leadshine's digital drivers. It can run in windows systems, including Win95/Win98/WindowsNT/ Windows 2000/Windows XP. And the selected PC should have 1 serial port at least for communicating with the driver.

Double click "**ProTuner\_All\_Setup\_V1.0.exe**" to begin installing the **ProTuner**. See Figure 6-1. Click **Next** to enter the "License Agreement" window. See Figure 6-2.

**Note:** ProTuner\_All\_Setup\_V1.0.exe can be used for all Leadshine digital drives. User can get it from either Leadshine CD or website. Please get the latest version from <http://www.leadshine.com>.



Figure 6-1: Begin to install the ProTuner



Figure 6-2: License agreement

Choose “I agree to the terms of this license agreement” and click **Next** to continue installation. The user can enter user’s information in the following window. See

Figure 6-3. After entering the user’s information, click **Next** to select installation folder, where you would like to install the **ProTuner**. See Figure 6-4.

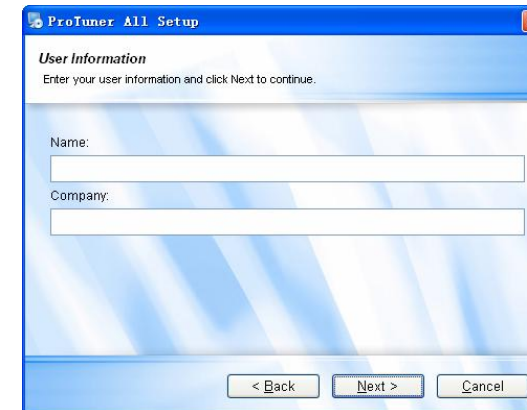


Figure 6-3: User’s information settings

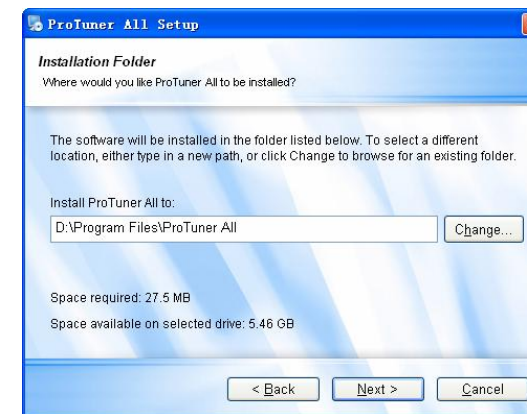


Figure 6-4: Installation folder settings

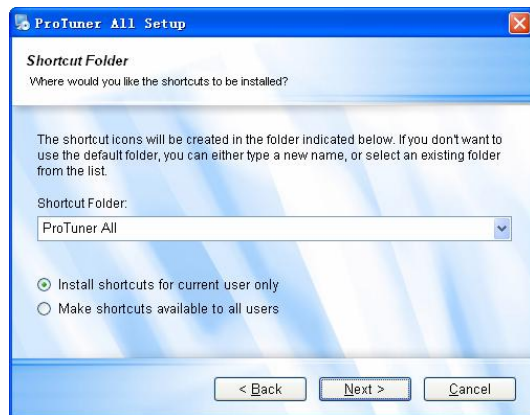


Figure 6-5: Shortcut folder setting

Set the “Shortcut Folder” in Figure 6-5 and continue to install the **ProTuner** by following Figure 6-6 and Figure 6-7. An **Installation Successful** window will appear if the **ProTuner** is installed successfully. See Figure 6-8.

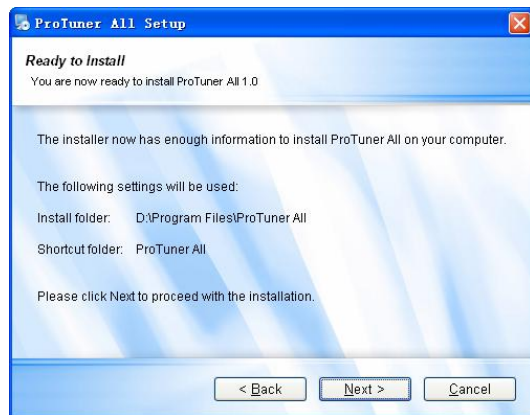


Figure 6-6: Installation information summarization

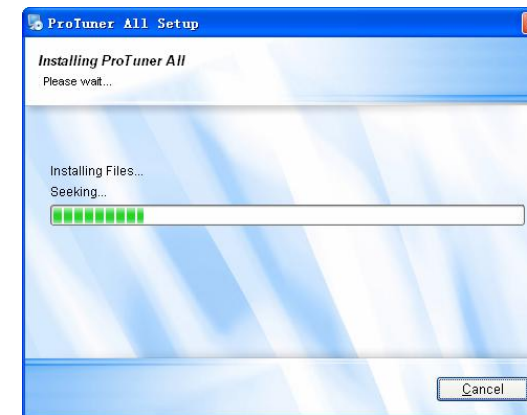


Figure 6-7: Installing the ProTuner

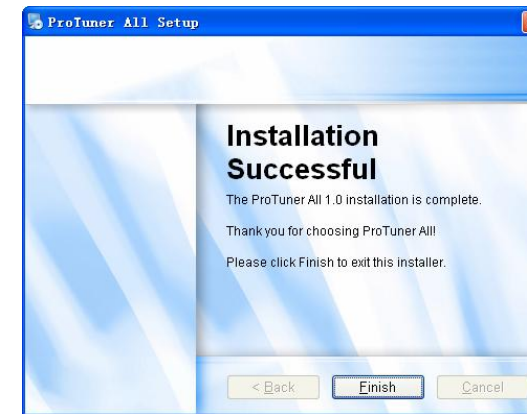


Figure 6-8: Finish installation

**Note:** Leadshine also offers special version ProTuner which does not need installation. Please visit our website [www.leadshine.com](http://www.leadshine.com) for latest ProTuner.

### RS232 Interface Connection

Connect the servo system according to chapter “**Connections**” and connect the PC to the driver as the following figure.

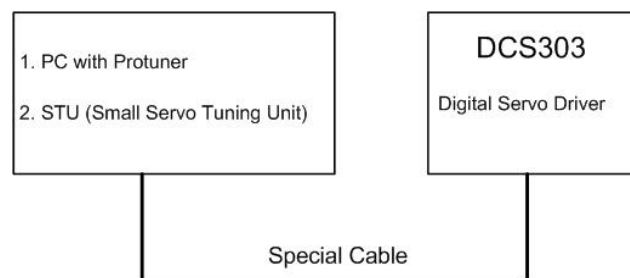


Figure 6-9: RS232 interface connection

### Testing the servo

You may wish to secure the motor so it can't jump off the bench. Turn on the power supply, the green (Power) LED will light. The DCS303 has default parameters stored in the driver. If the system has no hardware and wirings problem, the motor should be locked and the driver should be ready.

If the motor jumps slightly and the red LED immediately turns on (flickers), then either the motor or the encoder is wired in reversal. Open the tuning software ProTuner and check driver status by clicking **Err\_check**. If it's **Phase Error**, then reversal motor wires or exchange encoder inputs and try again. If it's **Encoder Error**, please check encoder and its wirings, and then try again. If it still doesn't work after you followed all of the previous steps, please contact us at [tech@leadshine.com](mailto:tech@leadshine.com).

If the red LED is off and the motor is normal, then you can start to tune the servo with **ProTuner**. However, we recommend you see the following contents before starting tuning.

## Software Introduction

### ProTuner Main Window



Figure 6-10: ProTuner

#### Ø Option

The user can choose three drop-down menus by clicking “**Option**”, including **Com Config**, **SaveToDriver** and **Exit**.

- I **Com Config**: Configure Com communication interface.
- I **SaveToDriver**: Download the current parameter settings to the driver.
- I **Exit**: Exit the **ProTuner**.

Com Config Window



Figure 6-11: RS232 communication configuration window

**Serial Port:** Select the serial communication port to which the driver is connected. The factory default setting is COM1.

**Baud Rate:** Select the communication baud rate. The factory default setting is 38400.

Click **Open** button to establish a connection with the specified settings. When connecting, you can choose **SaveToDrive** to download the current parameter settings to the driver, or to upload the stored driver settings into the **ProTuner** by clicking **Tuning > Position Loop** on the menu bar.

Ø Tuning

The user can choose one or two drop-down menu(s) by clicking **Tuning**, including **CurrentLoop (Only exist in special version.)** and **PositionLoop**.

l **PositionLoop:** There are three tabs in **Position Loop Tuning** window, including **P\_parameter**, **T\_Speed\_Par**, and **CurveSetting** tabs.

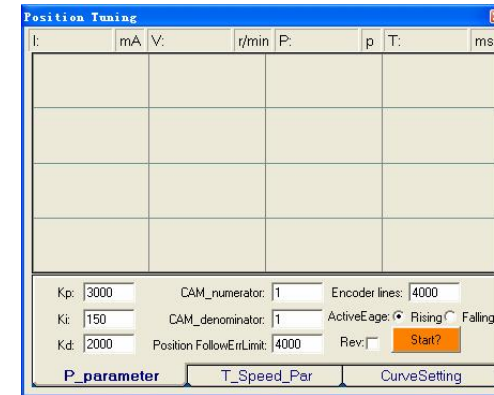


Figure 6-12: P\_parameter tab

In **P\_parameter** tab, the user can set **Position Loop** PID parameters, **Electronic Gear Ratio**, **Position Following Error Limit**, etc.

**Kp: Proportional Gain.** Proportional Gain determines the response of the system to position errors. Low Proportional Gain provides a stable system (doesn't oscillate), has low stiffness, and large position errors under load. Too large Proportional Gain values will cause oscillations and unstable systems.

**Ki: Integral Gain.** Integral Gain helps the control system overcome static position errors caused by friction or loading. The integrator increases the output value as a function of the position error summation over time. A low or zero value for the Integral Gain may have position errors at rest (that depend on the static or frictional loads and the Proportional Gain). Increasing the Integral Gain can reduce these errors. If the Integral Gain is too large, the systems may "hunt" (oscillate at low frequency) about the desired position.

**Kd: Derivative Gain.** Derivative Gain provides damping by adjusting the output value as a function of the rate of change of error. A low value provides very little damping, which may cause overshoot after a step change in position. Large values

have slower step response but may allow higher Proportional Gain to be used without oscillation.

**CAM\_numerator: Numerator of Electronic Gear.** Can be set from 1 to 255.

**CAM\_denominator: Denominator of Electronic Gear.** Can be set from 1 to 255.

**Position FollowErrLimit: Position Following Error Limit.** The limit of the difference between commanded position and the actual measured position. When position following error reaches Position Following Error Limit parameter setting in the driver, the protection will be activated.

**Encoder Lines: Encoder Line Count.** The DCS303 supports single-ended and differential-ended incremental encoders. Here, one thing should explained is that the Encoder Lines parameter in this tab is just for self-test motion controller during tuning, and will not affect the driver to interpret the encoder feedback signal. With regard to the DCS303, feedback resolution is  $\times 4$  encoder line count.

**ActiveEdge: Active Edge.** The user can set the triggered edge of pulse command signal in this panel. When the driver works in CW/CCW mode, no matter what level is at fixed level terminal, the driver can works properly.

**Rev: Reverse Direction :** Change the default direction to the same input level in DIR. For example, the motor run CW at default setting and will run CCW if **Rev** is selected.

**Start/Stop button:** The user can start or stop self-test by clicking this button.

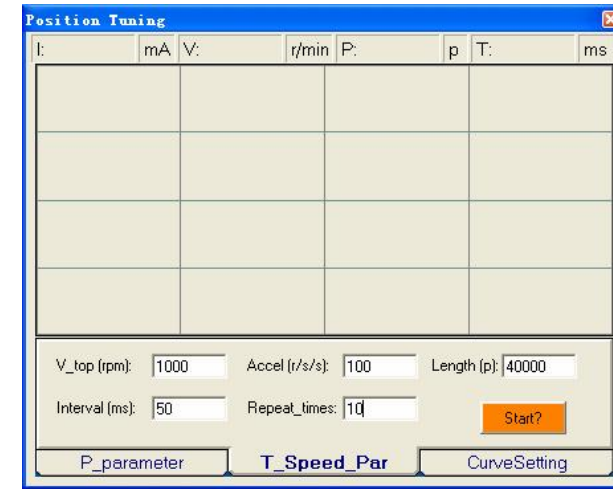


Figure 6-13: T\_Speed\_Par tab

In **T\_Speed\_Par** tab, the user can set velocity profile for self motion test and tuning, including Maximum Speed, Acceleration, position move Distance of trapezoidal velocity profile, and Interval, Repeat Times of self motion test.

**V\_top: Maximum Speed.** The maximum speed of trapezoidal velocity profile. Its unit is RPM.

**Accel: Acceleration.** The acceleration of trapezoidal velocity profile. Its unit is (r/s)/s.

**Length: Distance.** The distance required to move. Its unit is pulse (count).

**Interval:** The interval between positive rotation and negative movement.

**Repeat\_times:** The repeat times of positive and negative movement.

**Start/Stop button:** The user can start or stop self-test by clicking this button.

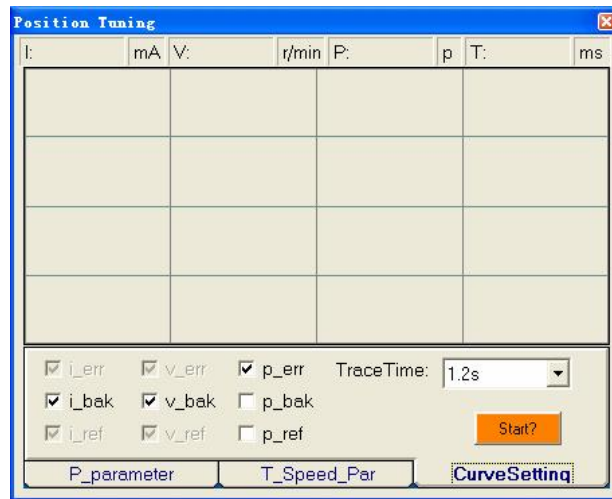


Figure 6-14: CurveSetting tab

In **CurveSetting** tab, the user can choose curves displayed in digital scope of **Position Loop Tuning** window and **DigitalMonitor** window, and set their **Trace Time**. These curves includes **Current Following Error** (i\_err), **Velocity Following Error** (v\_err), **Position Following Error** (p\_err), **Current Feedback** (i\_bak), **Velocity Feedback** (v\_bak), **Position Feedback** (p\_bak), **Current Command** (i\_ref), **Velocity Command** (v\_ref), **Position Command** (p\_ref).

**i\_err: Current Following Error.** The difference between commanded current and the actual measured current.

**v\_err: Velocity Following Error.** The difference between commanded velocity and the actual measured velocity.

**p\_err: Position Following Error.** The difference between commanded position and the actual measured position.

**i\_bak: Current Feedback.** This is the actual measured current in motor coil. Ideally,

this value should be as close as possible to the commanded current.

**v\_bak: Velocity Feedback.** This is the actual measured velocity measured by the encoder. Ideally, this value should be as close as possible to the commanded velocity.

**p\_bak: Position Feedback.** This is the actual measured position measured by the encoder. Ideally, this value should be as close as possible to the commanded position.

**i\_ref: Current Command.** This is the commanded current.

**v\_ref: Velocity Command.** This is the commanded velocity.

**p\_ref: Position Command.** This is the commanded position.

**Trace Time: Trace Time.** This is the trace time of the digital scope.

**Start/Stop button:** The user can start or stop self-test by clicking this button.

Ø **Digital\_monitor**

1 **Digital Monitor:** Displays curves and dynamic values of different point of different curves.



Figure 6-15: Digital scope window



**I: Current.** Displays dynamic values for Current related curve(s). Dynamic value will change with mouse focus changes. Its unit is mA.

**V: Velocity.** Displays dynamic values for Velocity related curve(s). Dynamic value will change with mouse focus changes. Its unit is r/min.

**P: Position.** Displays dynamic values for Position related curve(s). Dynamic value will change with mouse focus changes. Its unit is pulse (count).

**T: Time.** Displays dynamic values for Time. Dynamic value will change with mouse focus changes. Its unit is ms.

Ø **Err\_check**

**I Error Check:** This window shows both the present status of each error event and their history. Current error event(s) can be reset by clicking **Erase Current Err!** button, and all error events can be reset by clicking **Erase All!** button.

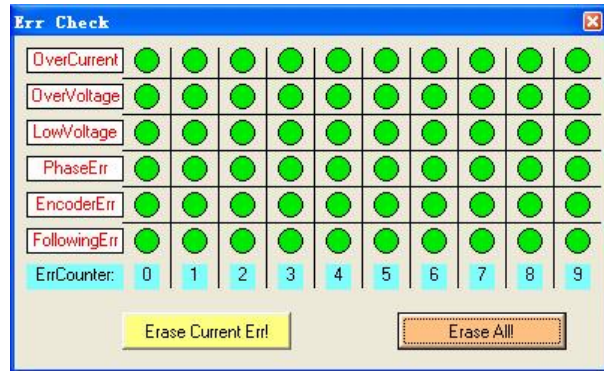


Figure 6-16: Error check window

**OverCurrent: Over-current Protection.** Protection will be activated when continuous current exceeds 20A.

**OverVoltage: Over-voltage Protection.** When power supply voltage exceeds 36.5

± 1.5 VDC, protection will be activated.

**PhaseErr: Phase Error Protection.** Motor power lines wrong & not connected and encoder feedback signals A/B phases wrong connected will activate this protection.

**EncoderErr: Encoder Error Protection.** No encoder feedback signals or wrong encoder feedback signals will activate this protection.

**FollowingErr: Position Following Error Limit Protection.** When position following error reaches **Position Following Error Limit** parameter setting in the driver, this protection will be activated.

**ErrCounter:** Displays current error(s) and current error history.

**Erase Current Err!: Erase Current Err** button. The user can clear current error(s) by clicking this button.

**Erase All!: Erase All!** button. The user can clear all error(s) including error history by clicking this button.

Ø **About**

The user can choose two drop-down menus by clicking “**About**”, including **Product Information** and **Contact Us**.

**I Product Information** window: Shows some product information about ProTuner.

**I Contact Us** window: Shows some contact information about Leadshine.

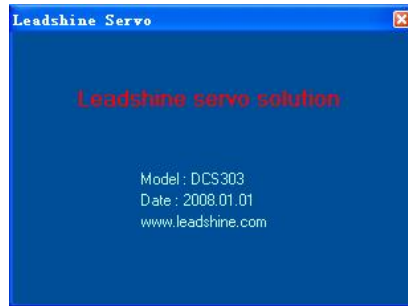


Figure 6-17: Product information



Figure 6-18: Contact information

## Servo Tuning

### Position Loop Introduction

Position loop tuning is dependant on the mechanical load, and therefore will change with any mechanical system changes. Position loop tuning should be performed with the motor installed in the system. The position loop can be closed around velocity or torque mode (depending on whether the velocity loop is enabled or disabled). If it is closed around velocity mode, the position loop algorithm output becomes the new velocity set point. If it is closed around torque mode, the position loop algorithm output becomes the new torque set point. There are some important differences in the

tuning process and application of these two approaches:

**Position around Velocity:** This mode is most common in "contouring" application, where a position trajectory must be tracked very closely. The velocity loop provides additional "stiffness", and keeps the dynamic position errors minimal, since the system now reacts to not just position errors, but also velocity errors (which can be interpreted as position error changes). It is important to start with a stable yet responsive velocity loop. Typically, it is sufficient to just use the position loop proportional gain. Feedforward gain can be added to improve tracking performance (i.e. minimize the difference between commanded and actual position). The velocity loop is disabled in current version DCS303, and it adopts **Position around Current** (Torque) mode.

**Position around Torque:** This mode is most common in point-to-point applications, where actual motion between start and end point is not very critical. In this case, velocity loop tuning can be avoided. This can be advantageous if the velocity feedback is poor (e.g. low resolution encoder, poor encoder quadrature.). **In this case, the tuning process requires that the position loop proportional and derivative gain are increased simultaneously, unless the system has sufficient friction, in which case no derivative gain is necessary. Once a stable response is achieved, integral gain can be added to improve stiffness.** It is best to use a step command with the profiler enabled as a reference signal during tuning.

Driver tuning is a multi-step process that involves proper tuning of up to three different servo loops, namely current loop, velocity loop and position loop. You can either tune the position loop around the velocity loop, or around the current loop. Generally, it is much easier to tune a position loop around a velocity loop because only the proportional gain is needed. When tuning position around the current loop, a high derivative gain may be necessary on top of both proportional and integral gains.

For most of the DCS303 drivers have been being sold to the customers with

Leadshine's DCM5xxxx DC servo motors, Leadshine will tune the current loop before sending drivers out of the factory. **Leadshine just offer a special version ProTuner to some customers for tuning current loop**, while most of customers just need to tune the position loop parameters with the standard version if they use the drivers with Leadshine's DCM5xxxx DC servo motors. If you use the DCS303 with DC servo motors from other manufacturers and current loop tuning is needed. Please contact Leadshine for special version ProTuner to tune the current loop.

Follow the steps below for tuning the driver with the standard version **ProTuner**.

### Position Loop Tuning

Set the parameters and select the curves displayed in **Digital Monitor** before starting self-test and tuning. See Figure 6-19 and Figure 6-20 for the parameters for the tuning in this paper. When we tune a servo, we are trying to achieve the fastest response with little or no overshoot, namely get a Critically Damped response.

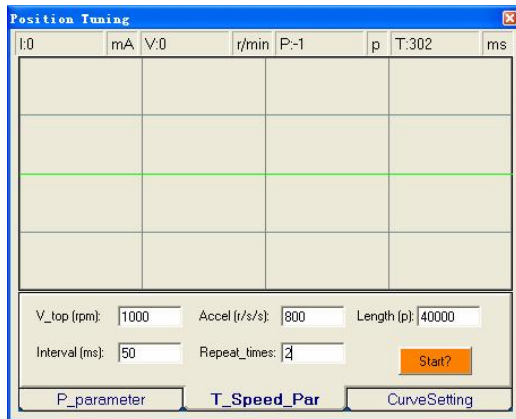


Figure 6-19: Self-test motion settings for the tuning



Figure 6-20: Digital Scope settings for the tuning

As mentioned above, the DCS303 adopts position around current (torque) mode, and when tuning position around the current loop, a high derivative gain may be necessary on top of both proportional and integral gains. Here, we set  $K_p=1200$ ,  $K_i=0$ ,  $K_d=400$  first, and the self-test result is shown in Figure 6-21.

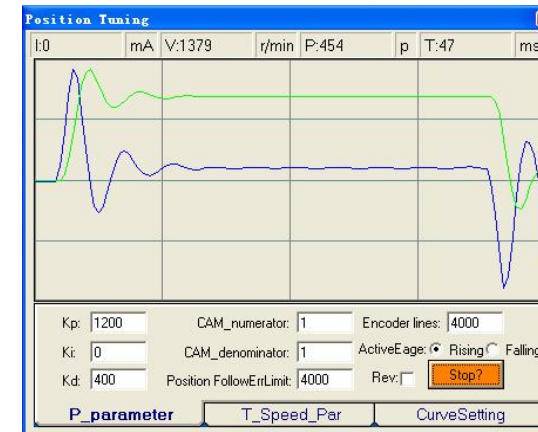


Figure 6-21: Position following error curve and velocity curve ( $K_p=1200$ ,  $K_i=0$  and  $K_d=400$ )

It's very easy to see from the velocity curve (Green line) that the system is under damped. This will cause system oscillating beyond either side of its target, so it must be damped. Figure 6-22 shows the result after increasing Kd to 800. In the Figure 6-22, the oscillation is much smaller than that of Figure 6-21. You can get even smaller oscillation when increasing Kd to 1500. See Figure 6-23.

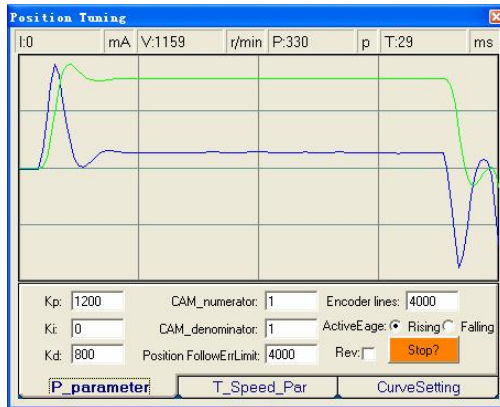


Figure 6-22: Position following error curve and velocity curve (Kp=1200, Ki=0 and Kd=800)

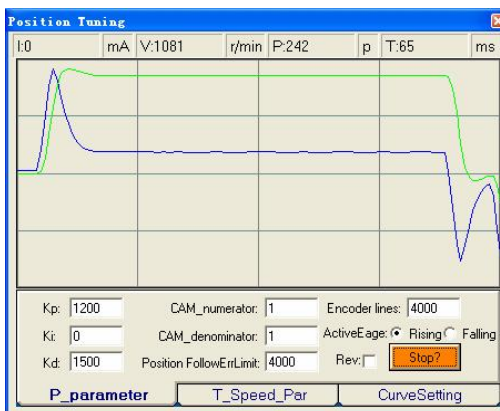


Figure 6-23: Position following error curve and velocity curve (Kp=1200, Ki=0 and Kd=1500)

Although very smooth velocity curve had been gotten in Figure 6-23, we can see that the position following error is still too large to accept. And this can be improved by increasing Ki value. See Figure 6-24. However, we can see the system response in Figure 6-25 is already Over Damped, namely too much damping has caused the response to be sluggish. This can be improved by increasing Kp or reducing Kd. See Figure 6-25 and Figure 6-26. Here we try to improve the performances by increasing Kp.

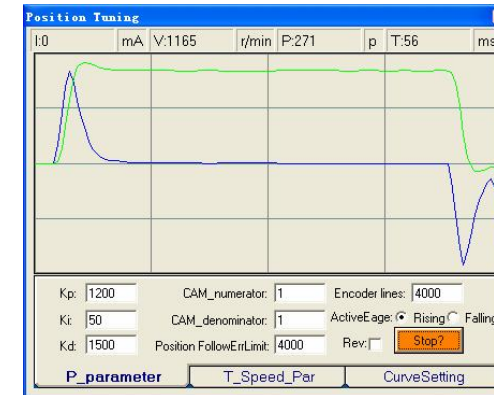


Figure 6-24: Position following error curve and velocity curve (Kp=1200, Ki=50 and Kd=1500)

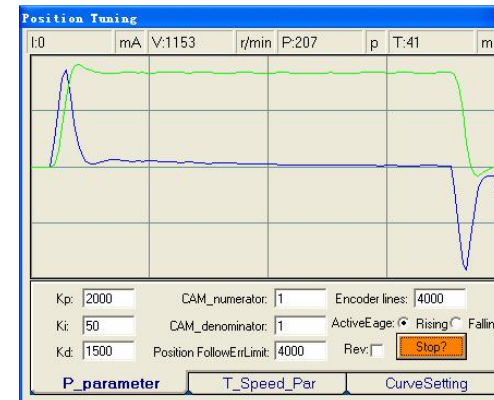


Figure 6-25: Position following error curve and velocity curve (Kp=1500, Ki=50 and Kd=1500)

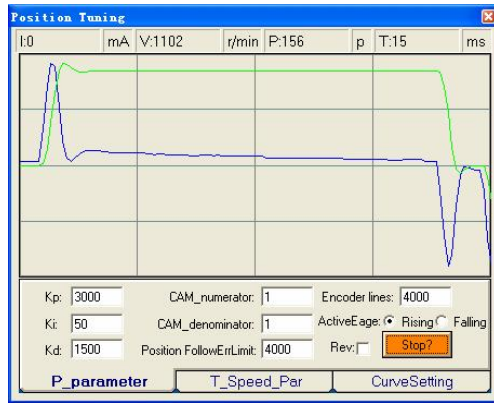


Figure 6-26: Position following error curve and velocity curve (Kp=3000, Ki=50 and Kd=1500)

Increase Kd can reduce velocity overshoot, and get a better velocity curve in as shown in Figure 6-27.

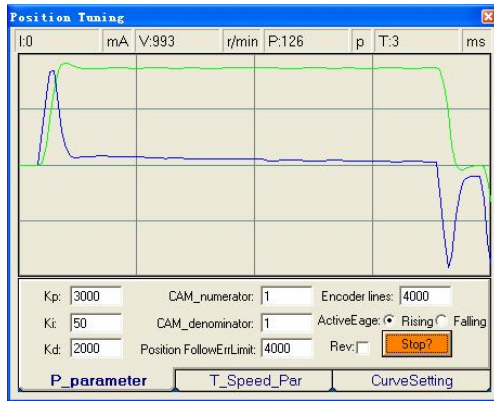


Figure 6-27: Position following error curve and velocity curve (Kp=3000, Ki=50 and Kd=2000)

Since position following error is still large during constant speed period in Figure 6-27, we try to increase Ki to improve system's performances. Figure 6-28, Figure 6-29, and Figure 6-30 show the result after increasing Ki. From Figure 6-30, we can

see that too much Ki will cause position curve over shoot.

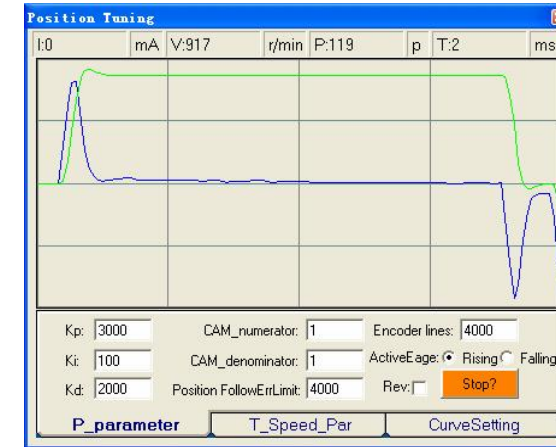


Figure 6-28: Position following error curve and velocity curve (Kp=3000, Ki=100 and Kd=2000)

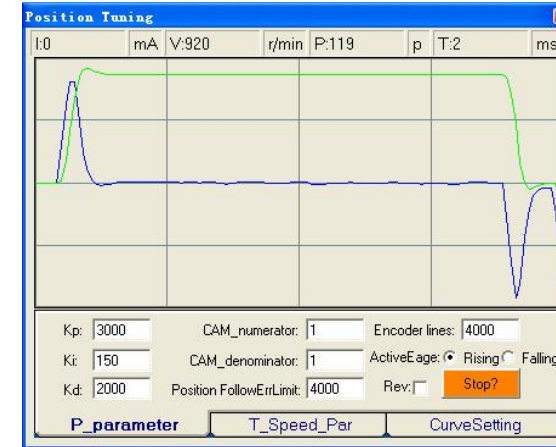


Figure 6-29: Position following error curve and velocity curve (Kp=3000, Ki=150 and Kd=2000)

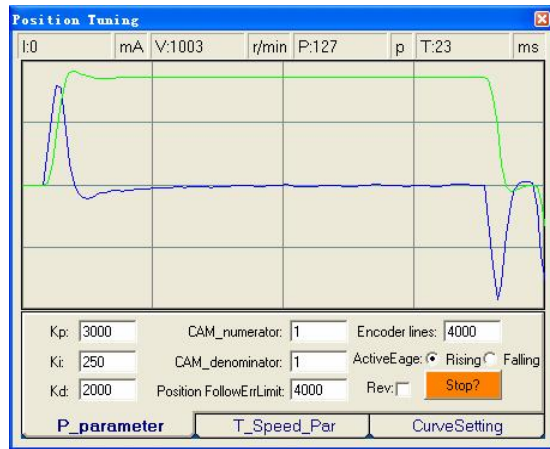


Figure 6-30: Position following error curve and velocity curve (Kp=3000, Ki=250 and Kd=2000)

Increasing Kp a little and reducing Ki to 150 can achieve a faster response with little overshoot, namely get a response close to Critically Damped response. See Figure 6-31. Remember to download the parameter settings to the driver’s EEPROM when you get satisfying performances.

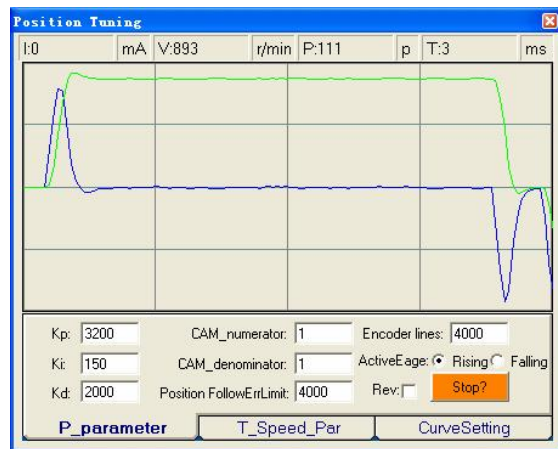


Figure 6-31: Position following error curve and velocity curve (Kp=3200, Ki=600 and Kd=4000)

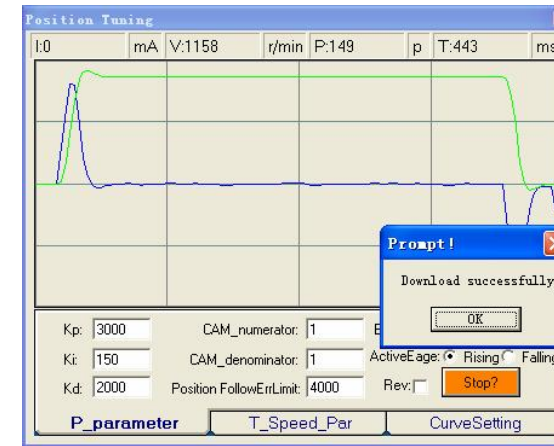


Figure 6-32: Position following error curve and velocity curve (Kp=3000, Ki=150 and Kd=2000)

Tuning servo systems formed by DCS303 drivers can be summarized as the following rules:

1. If servo system is UNSTABLE, then the first thing of tuning is to stabilize the system. You can increase **Derivative Gain** of **Position Loop** (Kd) or decrease **Proportional Gain** of Position Loop (Kp) or **Integral Gain** of Position Loop (Ki).
2. If servo system is UNDER DAMPED, then increase Kd or decrease Kp or Ki.
3. If servo system is CRITICALLY DAMPED, then stop tuning and download the parameter settings to the driver’s EEPROM.
4. If servo system is OVER DAMPED, then decrease Kd or increase Kp or Ki.

Remember that tuning the servo is to get satisfying performances, getting the best performances of the servo is a time consuming work. So if the servo performance can meet your application requirements, then the easier tuning way the better. Just like if the performances of the products can meet your application requirements, then the cheaper the better.

## 7. Using Tips

### Sequence Chart of Control Signals

In order to avoid some fault operations and deviations, PUL, DIR and EN should abide by some rules, shown as the following figure:

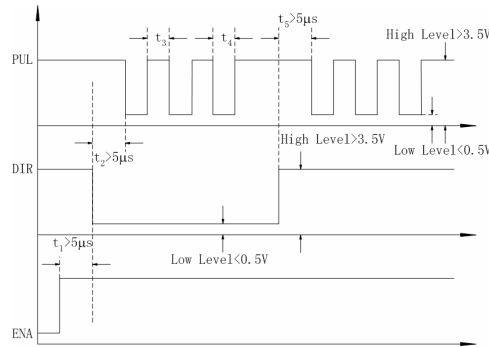


Figure14: Sequence chart of control signals

#### Notes:

- $t_1$ : EN must be ahead of DIR by at least  $5\mu s$ . Usually, ENA is NC (not connected). See **Connections** section for more information.
- $t_2$ : DIR must be ahead of PUL effective edge by at least  $5\mu s$  to ensure correct direction.
- $t_3$ : Pulse width not less than 2.5s;
- $t_4$ : Low level width not less than 2.5s.

### Protection Functions

To improve reliability, the driver incorporates some built-in protection functions. The DCS303 uses one RED LED to indicate what protection has been activated. The periodic time of RED is 5 s (seconds), and how many times the RED turns on indicates what protection has been activated. Because only one protection can be

displayed by RED LED, so the driver will decide what error to display according to their priorities. See the following **Protection Indications** table for displaying priorities.

#### Over-current Protection

Protection will be activated when continuous current exceeds 20A, and RED LED will turn on once within each periodic time (5 s).

#### Over-voltage Protection

When power supply voltage exceeds  $36.5 \pm 1.5$  VDC, protection will be activated and RED LED will turn on twice within each periodic time (5 s).

#### Phase Error Protection

Motor power lines wrong & not connected and encoder feedback signals A/B phases wrong connected will activate this protection. RED LED will turn on four times within each periodic time (5 s).

#### Encoder Error Protection

No encoder feedback signals or wrong encoder feedback signals will activate this protection. RED LED will turn on five times within each periodic time (5 s).

#### Position Following Error Protection

When position following error reaches Position Following Error Limit parameter setting in the driver, this protection will be activated. RED LED will turn on seven times within each periodic time (5 s).

**Attention:** Since there is no protection against power leads (+, -) reversal, it is critical to make sure that power supply leads correctly connected to driver. Otherwise, the driver will be damaged instantly.



## Protection Indications

Priority	Time(s) of ON	Sequence wave of RED LED	Description
1 <sup>st</sup>	1		Over-current protection
2 <sup>nd</sup>	2		Over-voltage protection
3 <sup>rd</sup>	4		Phase error protection
4 <sup>th</sup>	5		Encoder error protection
5 <sup>th</sup>	7		Position following error protection

## Changing Default Motor Direction

The DCS303 will turn the motor in the CW direction when the direction input is “high” (logical “1”). If instead CCW is preferred, then:

- 1) Reverse the “motor +” and “motor -” leads.
- 2) Reverse the encoder “Channel A” and “Channel B” leads.

## Maximum Pulse Input Frequency

Maximum Pulse Input Frequency is the highest frequency that the driver can accept. To convert this frequency to RPM, use the following formula:

$$RPM(\max) = \frac{(\text{Max Pulse Input Frequency}) \times 60}{(\text{Encoder Line Count}) \times 4} \times \frac{CAM\_numerator}{CAM\_denominator}$$

## APPENDIX

### TWELVE MONTH LIMITED WARRANTY

Leadshine Technology Co., Ltd. warrants its products against defects in materials and workmanship for a period of 12 months from shipping date. During the warranty period, Leadshine will either, at its option, repair or replace products which proved to be defective.

### EXCLUSIONS

The above warranty shall not apply to defects resulting from: improper or inadequate handling by customer; improper or inadequate customer wiring; unauthorized modification or misuse; or operation beyond the electrical specifications of the product and/or operation beyond environmental specifications for the product.

### OBTAINING WARRANTY SERVICE

To obtain warranty service, a returned material authorization number (RMA) must be obtained from customer service at e-mail: [tech@leadshine.com](mailto:tech@leadshine.com) before returning product for service. Customer shall prepay shipping charges for products returned to Leadshine for warranty service, and Leadshine shall pay for return of products to customer.

### WARRANTY LIMITATIONS

Leadshine makes no other warranty, either expressed or implied, with respect to the product. Leadshine specifically disclaims the implied warranties of merchantability and fitness for a particular purpose. Some jurisdictions do not allow limitations on how long and implied warranty lasts, so the above limitation or exclusion may not apply to you. However, any implied warranty of merchantability or fitness is limited to the 12-month duration of this written warranty.





## SHIPPING FAILED PRODUCT

If your product should fail during the warranty period, e-mail customer service at [tech@leadshine.com](mailto:tech@leadshine.com) to obtain a returned material authorization number (RMA) before returning product for service. Please include a written description of the problem along with contact name and address. Send failed product to distributor in your area or: Leadshine Technology Co., Ltd. Floor 3, Block 2, Tianan Industrial Park, Nanshan Dist, Shenzhen, China. Also enclose information regarding the circumstances prior to product failure.



## Contact Us

### China Headquarters

**Address:** 3/F, Block 2, Nanyou Tianan Industrial Park, Nanshan District Shenzhen, China

**Web:** <http://www.leadshine.com>

### Sales Hot Line:

**Tel:** 86-755-2643 4369 (for All)

86-755-2641-7674 (for Asia, Australia, Africa areas)

86-755-2640-9254 (for Europe, America areas)

**Fax:** 86-755-2640-2718

**Email:** [sales@leadshine.com](mailto:sales@leadshine.com).

### Technical Support:

**Tel:** 86 755-2641-8447 and 86-755-2647-1129

**Fax:** 86-755-2640-2718

**Email:** [tech@leadshine.com](mailto:tech@leadshine.com) and [vic@leadshine.com](mailto:vic@leadshine.com).

### Leadshine U.S.A

**Address:** 25 Mauchly, Suite 318 Irvine, California 92618

**Tel:** 1-949-608-7270

**Fax:** 1-949-608-7298

**Web:** <http://www.leadshineUSA.com>

**Email:** [sales@leadshineUSA.com](mailto:sales@leadshineUSA.com) and [support@leadshineUSA.com](mailto:support@leadshineUSA.com).

### Leadshine Hong Kong

**Address:** Rm 3, 9/F, Block E, Wah Lok Industrial Center, 31-41 Shan Mei St., Fo Tan, Shatin, Hong Kong

**Tel:** 852-2952-9114

**Fax:** 852-2952-9395

**Email:** [hk\\_sales@leadshine.com](mailto:hk_sales@leadshine.com).