servocylinder

Information & User Manual

Electromechanical Linear Actuator with Fully Integrated Phase Index™ Control System

A1 and A2 Series Servo Cylinder Actuators

A1-Series: Standard Servo Cylinder Actuator

A2-Series: Sealed Servo Cylinder Actuator

Safety Information

IMPORTANT: Read this manual before installing and operating the Ultra Motion Servo Cylinder. Failure to read this section can result in personal harm or damage to the product.

Safety Disclaimer

The Servo Cylinder is intended to be a subcomponent of a larger piece of machinery or automated system. This section is not intended to provide the safety guidelines for the entire machine or system that the Servo Cylinder is installed into. It is the responsibility of the purchaser or system designer to assess the risks and safety requirements of the end application they are designing.

If the Servo Cylinder is to be used in a safety critical application, the purchaser or system designer must perform appropriate safety testing to ensure that the product meets the requirements and safety criteria for their application.

Ultra Motion has made all reasonable efforts to present accurate information in this document and is not responsible for unintentional oversights. If, at any time, the purchaser has questions or uncertainty about information in this manual, contact Ultra Motion to speak with an engineer.

Safety Warnings

- Once powered, the Servo Cylinder is capable of rapid motion and can produce large amounts of force. Always ensure that safe clearances from body parts and other equipment are maintained before applying power.
- The Servo Cylinder operates on low voltage (8 to 36 VDC recommended). However, still use caution when handling and working around the actuator to avoid electrical shock.
- At high current draws, motor of the actuator can become very hot. Take adequate time to cool before handling.
- Provide adequate ventilation for cooling of this device.

Safety Notifications

⚠ As you read through the manual, you will notice certain safety notifications that indicate other important safety related information.

Contents

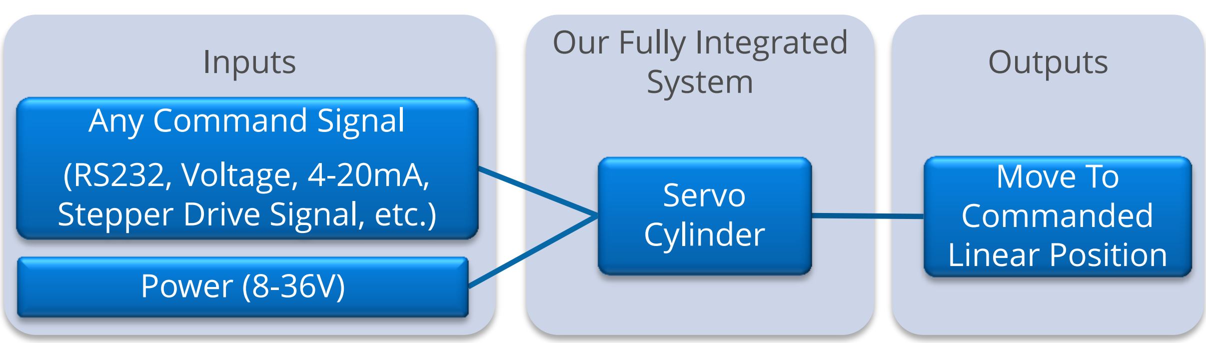
Introduction

The Ultra Motion Servo Cylinder is a high performance linear servo system comprised of a robust rod-style actuator, a configurable brushless DC (BLDC) motor controller, and the cutting edge multi-turn absolute feedback technology Phase Index™. All components of the system have been engineered to seamlessly work together and provide a simple and extremely reliable linear positioning device.

Users must only provide power and a command input and the Servo Cylinder handles the rest. The built in actuator-specific controller can be set to work with many common command inputs including serial, analog, and stepper signals. It includes USB configurable firmware for defining many attributes including performance characteristics, software limits, output information, and much more.

Servo Cylinder advantages include:

- Closed Loop position, force, and speed control directly out of the box
- Complete command language optimized for linear motion applications
- Full-time absolute position – never requires homing, even with loss of power.
- Extreme fault tolerance
- Precision in rugged package – extremely long life
- Completely configurable
- Drop-in Replacement for many existing systems including stepper-motor driven actuators



Product Features

- Type: Electromechanical Linear Actuator with Fully Integrated Phase Index™ Control System
  - Integrated controller operates a Brushless DC Motor with Field-Oriented Control (FOC)
  - Controller is fully absolute, requires no homing, and has a wide variety operating modes including RS232 Serial CLI, Analog Voltage or Current, 1-2ms Pulse, Stepper Signal, Toggle, or Preset Position.
- Operating Voltage: 8 to 36 VDC
- Force: Up to 530 lbf *(For standard models)*
- Stroke: Up to 7.75 in of travel *(For standard models)*
- Speed: Up to 14 in/s *(For standard models)*
- Linear Resolution: Up to 0.000061 in (*1.55 µm)*
- Ingress Protection Rating: IP65 *(For A2 Series only)*
- 100% RoHS Compliant
- Simple configuration, editable text file in USB Mass Storage *(Compatible with Windows and Linux)*
- Two (2) Optically Isolated Digital Inputs, for reliable, low noise signal transmission
- Two (2) modular General Purpose Input / Outputs (GPIOs) with several functions *(see page 14)*
- Semi-Custom and custom models available. Contact Ultra Motion engineering for details.

Operating Modes

There are 9 available operating modes, each of which may be used out of the box on *any* Servo Cylinder actuator.

Command Line Interface (CLI) RS232 Serial	**Analog Voltage** -10 to +10V (Configurable)	**Analog Current** 4-20mA (Configurable)
1-2ms Pulse (PWM) PWM Servo Control (Configurable)	**Step & Direction** Stepper Motor Control Signal	**A/B Quadrature** Stepper Motor Control Signal
CW/CCW Stepper Motor Control Signal	**Toggle** Digital I/0 for Extension and Retraction	**Preset Position** Digital I/0 to travel between up to 4 programmed positions

Note that the serial connection may be used in Command Line Interface mode for direct control of the actuator, or in any of the other operating modes for non-motion commands, including status and diagnostic information.

Command Line Interface (CLI) RS232 Serial Mode

The Servo Cylinder's Command Line Interface (CLI) offers the user complete control over all performance parameters, motion commands, and diagnostic information through a direct connection to a programmable logic controller (PLC), a computer with any terminal program such as PuTTY (using a serial-to-USB adapter), or any platform that operates an RS232 serial communication port such as LabVIEW, MATLAB, Python, Arduino, etc.

The Servo Cylinder can be configured to operate in "Human mode" (where detailed information regarding commands and asynchronous error messages are output to the terminal window) or "Machine Mode" (where asynchronous messages are turned off, and checksums are sent to ensure communication integrity). The CLI may also be used in any other operating mode for non-motion commands.

Analog Voltage

In Analog Voltage mode, the actuator extends to a position proportional to a range of input voltages. The limits of the input voltage are from -10 to +10V, however these values may be configured to any desired voltage range within -10 to +10V.

For example, the user can program the actuator by setting inputs from 0 to 5V to correlate to outputs from minimum to maximum stroke, or set -10 to +10V to correlate between 1 in and 3.5 in.

Analog Current

In Analog Current mode, the actuator extends to a position proportional to a range of input currents. The limits of the input current are from 4-20mA, and configurable similarly to Analog Voltage mode. Additionally, this mode enables the actuator to respond gracefully to a total loss of signal (0 mA).

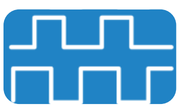
1-2ms Pulse (PWM)

In 1 to 2 ms Pulse (PWM) mode, the actuator can be easily configured to respond to a standard RC PWM signal with 50 Hz or 333 Hz update rate.

Step & Direction

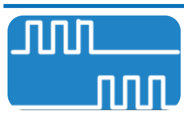
A Servo Cylinder in this mode operates with a direction signal and step pulses. This allows the Servo Cylinder to replace a stepper motor that operates under this command signal.

A/B Quadrature



A Servo Cylinder in this mode operates with A/B Quadrature, which consists of two square wave code signals spaced 90° out of phase, allowing for both speed and direction to be tracked. This allows the Servo Cylinder to replace a stepper motor that operates under this command signal.

CW/CCW

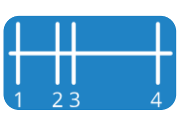


A Servo Cylinder in this mode operates with stepper motor CW/CCW control mode. This allows the Servo Cylinder to replace a stepper motor that operates under this command signal.

Toggle Mode

In Toggle mode, the Servo Cylinder operates with the simplicity of a brushed DC control system with the added performance and long-life of a BLDC motor. In this mode, the actuator simply extends for as long as it is given an extend signal to its digital input, and retracts likewise.The absolute position capability of the Servo Cylinder eliminates the need for external limit switches, and also allows for configurable acceleration and velocity for smooth, controlled motion. Output speed and torque can either be preset, or controlled by using analog inputs.

Preset Position Mode



Preset position mode provides the user with an easy way to perform a wide variety of positioning tasks. This mode is especially useful for replacing pneumatic pistons.

The user selects one of up to four (4) pre-programmed positions by toggling the state (00, 01, 10, or 11) of the two digital inputs (IN1/IN2), causing the actuator to move to the selected position at a defined speed and acceleration using the Servo Cylinder's built-in trajectory generator. .

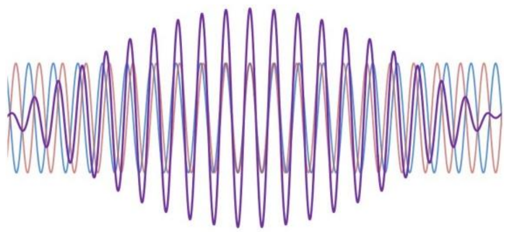
Integrated Field-Oriented (FOC) Motor Control System with Phase Index™ Feedback

What is Phase Index™?

Phase Index is Ultra Motion's innovative position sensor technology for electromechanical actuators. The Phase Index™ position sensor is a digital, high-speed, high-resolution, non-contacting actuator position sensor that works over a wide temperature range and is resistant to vibration, shock, particulate debris, and condensing moisture. The sensor is self-calibrating, and retains absolute position with full accuracy without power or backup power. No homing routine is needed to establish an accurate absolute position.

phase index™

The Phase Index™ position sensor works by using the phase relationship between two cyclical signals with different periods to determine absolute position within a larger interference cycle of the combined signals. When implemented with state-of-the-art magnetic sensor technology, this technique allows for a high-speed, high-resolution, digital actuator position sensor that is always accurate and that works across a range of harsh environmental conditions.



The first implementation of Ultra Motion's Phase Index™ position sensor technology, used in a highly demanding space application, has performed flawlessly through extensive and rigorous environmental testing and field operations. It is now implemented in a wide variety of applications, from high-performance aerospace actuators to low-cost industrial motion control systems.

How is Phase Index™ used in Servo Cylinder?

Phase Index is seamlessly integrated into the Field-Oriented Control system used to operate the Servo Cylinder's Brushless DC (BLDC) motor. Specifically, it provides reliable absolute position of the BLDC rotor for commutation and the absolute linear position of the actuator shaft. The onboard digital signal processor (DSP) handles all user inputs, configuration, trajectory generation, Field-Oriented Control, and position control loop calculations.

Advantages of Field-Oriented (FOC) Motor Commutation

Field-Oriented Control (also known as Vector Control) is generally considered to be the best performing method of BLDC motor commutation when compared to other common methods of BLDC commutation such as trapezoidal or sinusoidal commutation.

FOC provides smooth movement at all speeds, as opposed to trapezoidal commutation which is subject to significant torque ripple (which gets magnified at lower rotor speeds). FOC also provides efficient operation at all speeds, as opposed to sinusoidal commutation which has limited efficiency at high speeds due to limitations in bandwidth of P.I.D. controllers. Additionally, FOC provides increased acceleration performance, and allows for direct user control of torque and actuator force.

High Performance Electronics

Modern automotive grade components used in the motor control system allow for robust operation over a wide range of supply voltages and temperatures. The Servo Cylinder's low on-state resistance, high current capacity, and rapid switching time results in cool and efficient control over the load. High-speed current feedback from all three phases allows for maximum flexibility of Field-Oriented Control.

Mechanical Design

- Direct-Coupled drivetrain for zero backlash and maximum accuracy
- Compatible with a wide variety of screw types, including highly efficient ballscrews, self-locking Acme screws, and zero backlash screw designs

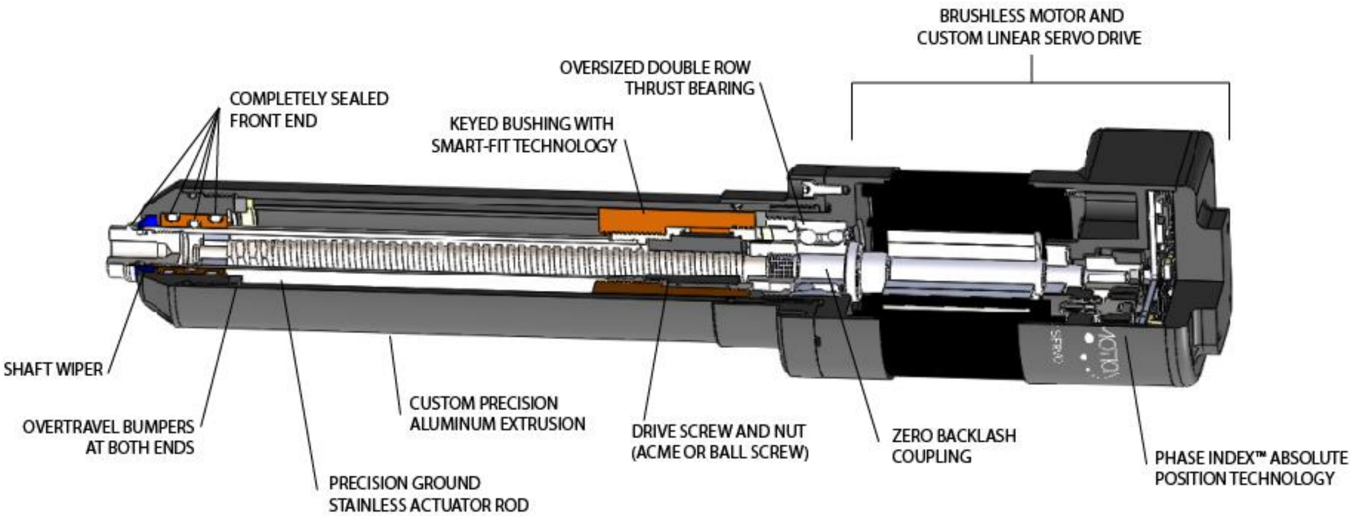
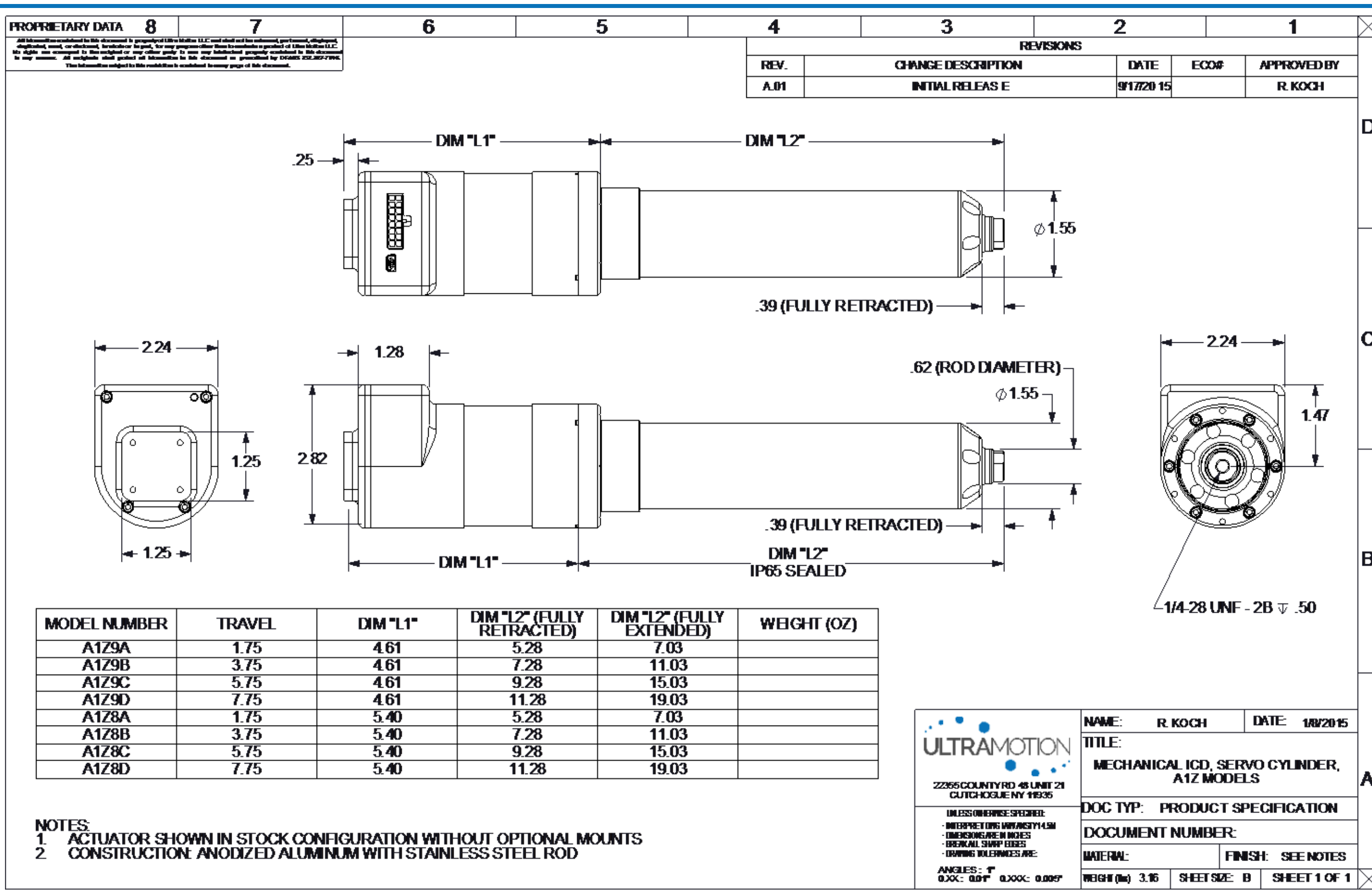


Figure 1: Anatomy of Servo Cylinder

Mechanical Interface & Dimensions



MODEL NUMBER	TRAVEL	DIM "L1"	DIM "L2" (FULLY RETRACTED)	DIM "L2" (FULLY EXTENDED)	WEIGHT (OZ)
A1Z9A	1.75	4.61	5.28	7.03	
A1Z9B	3.75	4.61	7.28	11.03	
A1Z9C	5.75	4.61	9.28	15.03	
A1Z9D	7.75	4.61	11.28	19.03	
A1Z8A	1.75	5.40	5.28	7.03	
A1Z8B	3.75	5.40	7.28	11.03	
A1Z8C	5.75	5.40	9.28	15.03	
A1Z8D	7.75	5.40	11.28	19.03	

NOTES:
1. ACTUATOR SHOWN IN STOCK CONFIGURATION WITHOUT OPTIONAL MOUNTS
2. CONSTRUCTION: ANODIZED ALUMINUM WITH STAINLESS STEEL ROD

Figure 2: Mechanical Interface Control Drawing for A1Z series actuators

Design Guidelines and Best Practices for Electromechanical Actuators

This section aims to provide some helpful advice for implementing Servo Cylinder and electromechanical linear actuators in general. The information on this page will help get the most out of your Servo Cylinder while also avoiding the most common pitfalls seen by the application engineers at Ultra Motion.

Include Dynamic Forces in Specified Load Rating

If using an actuator to lift a specific amount of weight, remember that the forces being exerted by the actuator will be in excess of that weight, due the dynamic force required to accelerate the mass.

Would a "Self-Locking" actuator be better for you?

"Self-Locking" is a characteristic of a screw system where the thread pitch and friction force is such that no amount of actuator load will cause the screw to rotate. This characteristic is due to friction force exceeding screw torque and is utilized in machine screws and in linear actuators for certain applications.

An actuator powered by a self-locking leadscrew has the following performance tradeoffs:

Pros	**Cons**
• No power necessary to statically support a large load indefinitely. • Lower Cost (For Acme screws).	• Generally lower performance: Lower force, max speed, and efficiency. • Increased stiction, micro-motions more difficult to achieve

Increase Maximum Speed with a Higher Bus Voltage

In DC motors, torque/force is independent of bus voltage. However, maximum actuator speed *is* proportional to bus voltage.

Use an Unregulated Power Supply if Possible

For the reasons outlined in Power Supply Requirements and Wiring Details (Page 11), unregulated supplies are generally superior to regulated supplies for motion control applications.

Motor Back-EMF Causes Unstable Bus Voltage

For the reasons outlined in Back-EMF (Voltage Spikes) (Page 11), motors will inject energy into a power bus and cause spikes in bus voltage. Use a Power Shunt (Page 11), and be wary of any equipment that shares a power bus with an actuator.

Shield All Signal Inputs and Outputs

Wires leading to the actuator (especially analog inputs and GPIOs) should be shielded to prevent electromagnetic interference (EMI) and cross-talk. This is the most common cause for unexpected behavior in Proportional mode.

Never "Side-Load" an Actuator Not Rated For Side-Load

Side loads often occur inadvertently by over-constraining actuator mounts. Rod style linear actuators such as Servo Cylinder are typically not rated for "side-load" (force which is perpendicular to the direction of travel of the shaft). We suggest mounting methods which have rotational degrees of freedom such as pivoting joints (like a clevis or trunnion), even if rotation is not expected during operation.

Beware Running an Actuator into a Hard-Stop

When using an actuator with a DC motor, take care that you do not run the actuator into a physical "hard-stop", such as a machine element or any physical body which the actuator impacts on its travel and which disallows movement. If this happens, the control system will attempt to obey position commands by powering through the physical block. Often, this results in the motor over-heating and burning out.

Servo Cylinder is programmed to prevent collision with its own internal hard-stops, however care must be taken to protect the actuator from external hard-stops. It also features errMode – Error Mode (Actuator Hardware Protection Feature) which will prevent the actuator from exerting damaging amounts of force or torque. This is especially useful when training and testing out an application.

Requirements and Specifications

Read this section to learn about all requirements for operating the Servo Cylinder.

Electrical Interface

A1 Series Actuator Pinout

Pin No.	Pin	Color
1	ANI	Green
2	GND	Black
3	TX	Green (DB-9 Connector)
4	DIO1	Purple
5	IN2+	Grey
6	IN1+	Blue
7	V+	Red (Spade Terminal)
8	V+	Red (Spade Terminal)
9	ANV	Green
10	GND	Red (DB9- Connector)
11	RX	Yellow (DB-9 Connector)
12	DIO2	Orange
13	IN2-	Grey w/white stripe
14	IN1-	Blue w/white stripe
15	GND	Black
16	GND	Black

Table 1: Pin Numbers and associating pins and wire colors for A1 series actuators

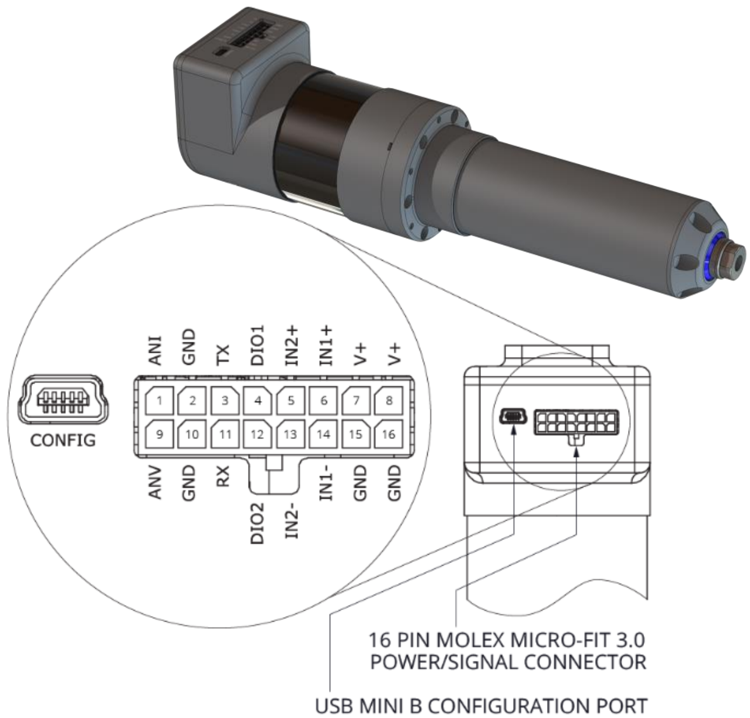
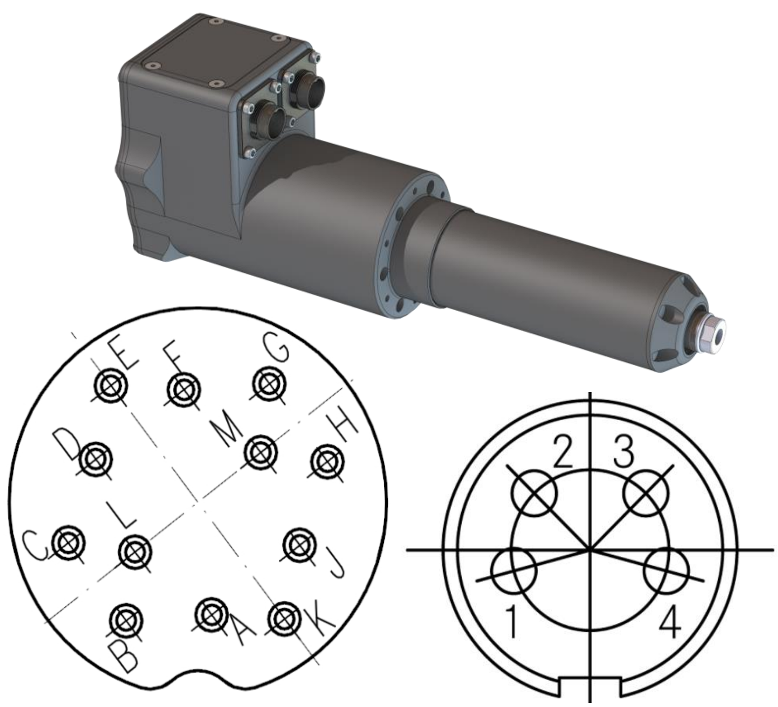


Figure 3: Pinout for A1 series Actuators

A2 Series Actuator Pinout

Connector	Pin No.	Pin	Wire Color
Command & Signal	**A**	IN1+	BLUE
	B	IN1-	TAN
	C	IN2+	GRAY
	D	IN2-	PINK
	E	DIO1	VIOLET
	F	DIO2	ORANGE
	G	ANV	RED
	H	GND	BLACK
	I	*(REMOVED)*	*(REMOVED)*
	J	ANI	WHITE
	K	TX	GREEN
	L	GND	BROWN
	M	RX	YELLOW
Power Input	**1**	V+	RED
	2	V+	GREEN
	3	GND	BLACK
	4	GND	WHITE

Table 2: Pin Numbers and associating pins and wire colors for A2 series actuators



Figures 4 & 5: Pinouts for Command & Signal (left) and Power Input (right) on A2 series actuators.

Input and Output Specifications

Power Supply Input (V+)

Input Voltage: 8 to 36 VDC Recommended (43 VDC Absolute Max)

Ground: 2x GND (High current, two (2) grounding pins required)

Max Current: See product datasheets for continuous and peak current ratings for your model.

Refer to Power Supply Requirements and Wiring Details below for recommendations.

⚠ WARNING: Controller electronics will be damaged if your bus voltage ever exceeds 50 VDC. This includes voltage spikes due to self-induced Back-EMF.

⚠ WARNING: Read section about Back-EMF to completely understand voltage spikes before operating.

⚠ WARNING: Do not reverse polarity on the power input. If poles are reversed, internal protection circuitry will result in the two poles being shorted, potentially causing damage to the PSU.

⚠ WARNING: Never "Hot Plug" or connect/disconnect power to the servo cylinder until all wiring and connectors are in place.

Back-EMF (Voltage Spikes) and Back-Driving

During normal operation it is common to see fluctuations or spikes in your power bus voltage which are the result of voltage draws and regenerations from the motor. The most likely drivers of severe voltage spikes are:

1. Rapid acceleration and deceleration
2. Back-driving the actuator. Back-driving occurs when the actuator has sufficient load applied to it to move the shaft and spin the motor. A scenario in which this might occur is if a non-self-locking actuator is lifting a mass in vertical direction while electrical power is lost, causing the lifted weight to force down on the actuator shaft, resulting in back-driving.

The Servo Cylinder has an automatic dynamic braking feature that will attempt to clip voltage spikes at 44VDC. When this happens, the energy is dissipated in the motor windings as heat. When this feature engages, you will notice the actuator stutter as the feature flutters on and off. If normal operation results in this feature engaging, we strongly recommend you remedy the issue by adding a Power Shunt to your system or using an Ultra Motion PS-1X series Power Supply Unit.

Power Shunt

A Power Shunt, such as the Ultra Motion Power Shunt, is a type of Over-Voltage Protection (OVP) device. They protect a power bus by engaging at a predefined voltage level and dissipating energy across a high-power shunt resistor until voltage is restored to nominal levels. This protects the Servo Cylinder and other equipment on the same power bus from damage due to excessive voltage spikes and back-EMF. The use of a power shunt is always recommended for safety, but especially important in the following situations:

- Applications which require hard/fast acceleration and deceleration.
- Applications where the load is assisting the actuator's motion (spring, gravity in a vertical application, etc.).
- Applications which require the use of a regulated power system.
- Applications where the actuator must share a power bus with other sensitive equipment.

Power shunts must be wired in parallel with the output of the DC power supply. In order to be effective, power shunts must maintain connectivity to the actuator in the event of a loss of power, blown fuse, or engaged Emergency Power-Off (EPO) switch. See Figure 6: Power Wiring Diagram.

NOTE: A power shunt is not necessary when using an Ultra Motion PS-1X series PSU, which has integrated OVP.

Power Supply Requirements and Wiring Details

Voltage Rating: 8-36 VDC Recommended (43VDC Absolute Max)

Power rating: 180-200W, smaller supplies are suitable for less demanding applications

We strongly recommend using an Ultra Motion PS-1X series Power Supply Unit to power Servo Cylinder. The PS-1X Series PSUs have been specifically designed for use with Servo Cylinder and other intensive motion control applications. Benefits of the PS-1X Series PSUs over other PSUs include:

- Unregulated power conversion (greatly preferred over regulated for motion control applications, see below).
- Integrated Over-Voltage Protection (OVP) device eliminates the need for a power shunt.
- High Voltage (36 VDC), gets highest speed performance out of Servo Cylinder.
- High-efficiency regenerating supply, >80% efficient at draws 10-100% of capacity, quiescent power <5 W.
- AC- and DC-side fuses: DC-side fuse isolates the capacitor when blown, removing need for external fuse.
- Robust design, dust resistant (IP50), EPO Ready, all in integrated package.

A third-party PSU or existing power system may also be used if it meets the power supply requirements. When considering power systems, take into consideration the tradeoffs of regulated vs unregulated power supplies:

- Unregulated Power Supplies (Preferred): An unregulated power supply is preferred for servo applications because of its ability to supply bursts of energy during acceleration, and its ability to absorb energy during deceleration/back-driving events. The large smoothing capacitor of a properly sized unregulated supply maintains safe actuator voltage levels when absorbing/supplying large amounts of electrical energy. The use of an unregulated power supply reduces but does not eliminate the need for a power shunt.
- Regulated Power Supplies: Many popular benchtop power supplies are regulated, which is acceptable for applications that don't require high accelerations and cannot be back-driven. Regulated power supplies cannot absorb the energy created during deceleration or back-driving events as effectively as unregulated supplies, which can cause the supply voltage to quickly rise to unsafe levels. The power supply can also fall below required voltage levels due to high current demands during acceleration or high force events. A power shunt can reduce the risk of over-voltage in a regulated power supply system.

The power system should also have following safety features, shown in the circuit below:

- Emergency Power-Off (EPO) switch: Generally this is a "push-lock" type NC switch or relay which serves the purpose of immediately removing power from the system. An AC power cut-off is generally inadequate for rapidly removing power to the actuator due to stored energy in power supply capacitors.
- External Fuse: A slow burning fuse should be used on the positive leg of the DC power supply to isolate the Servo Cylinder from the DC power stored in capacitors in an overloading condition.
- Power Shunt: A power shunt, described above, must not be isolated by a blown fuse or EPO switch.

The Ultra Motion Power Supply Unit is has an integrated power shunt, fuse, and is EPO switch ready. Please ensure you have properly designed your power system and addressed all safety concerns.

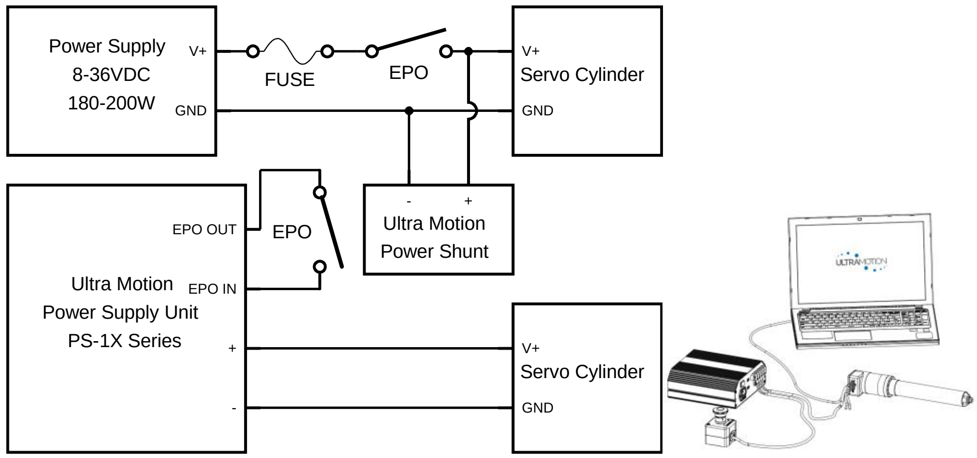


Figure 6: Power Wiring Diagrams. The top circuit is a diagram of an adequate power supply setup, featuring a fuse, and Emergency Power-Off (EPO) switch, and power shunt. The bottom circuit is an Ultra Motion Power Supply Unit configuration.

Analog Current Input (ANI)

Input Current Range: 4-20mA (adjustable to range within 4-20mA in configuration file)

Ground: Any GND

Used for Proportional Mode with Current Control and for proportional speed control in toggle mode.

Care should be taken to ensure analog signals are properly shielded against EMI, and are routed separately from power wires and other sources of interference. When possible, a 100% foil shield should be used and the shield electrically connected to chassis ground.

Analog Voltage Input (ANV)

Input Voltage Range: -10 to +10 VDC (adjustable to range within -10 to +10 VDC in configuration file).

Ground: Any GND

Used for Proportional Mode with Voltage Control and for proportional speed control in toggle mode. Ground to any GND

Care should be taken to ensure analog signals are properly shielded against EMI, and are routed separately from power wires and other sources of interference. When possible, a 100% foil shield should be used and the shield electrically connected to ground.

Optically Isolated Digital Inputs (IN1+, IN1-, IN2+, and IN2-)

Input Voltage: 5 VDC, or up to 24 VDC with appropriate current limiting resistor (R). *(See Table 3)*.

Ground: Use isolated grounds for optimal noise mitigation. Actuator ground can be used for IN1- or IN2-, but does not provide complete isolation.

Used for Proportional Mode (with 1 to 2 ms Pulse Control), Preset Position Mode, All Incremental Modes.

⚠ WARNING: Damage will occur if voltage exceeds 5 VDC without a current limiting resistor (R) *(see Table 3)*.

The Servo Cylinder has two dedicated, optically isolated digital inputs, IN1 and IN2. An opto-isolator transmits an electrical signal between two electrically isolated circuits via a light emitting diode and photodiode pair. The use of optically isolated inputs allow for high data transfer rates, protection from high voltages, and superior noise rejection.

The Servo Cylinder's digital inputs can be driven by a +5 VDC signal, or up to +24 VDC when used with an appropriately sized external current limiting resistor (R) in series with the inputs. Suggested values for the external resistor (R) are in Table 3 below. The +5V and/or ground of the optically isolated input can be supplied externally or by one of the Servo Cylinder's on-board digital General Purpose Input / Output (GPIO) pins.

For maximum noise rejection, the input signal should be grounded separately from the Servo Cylinder, but this is not a requirement.

Suggested wiring for the optically isolated inputs is shown in Figure 7 below.

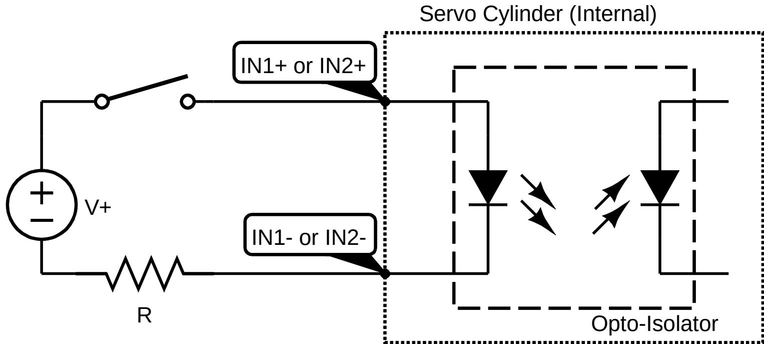


Figure 7: Schematic for Digital Inputs

Signal Voltage (V+)	Suggested Resistor (R) Size
+5 VDC	None (0 Ohm)
+12 VDC	430 Ohm
+24 VDC	1.1 kOhm

Table 3: Current limiting resistor (R) sizes for digital inputs (IN1 and IN2)

RS232 Serial Input (TX and RX)

Baud Rate: 2400 to 256,000

The serial connection to the actuator uses the RS232 protocol. If the device you are connecting the Servo Cylinder to does not have a standard serial port, you can use any standard USB-to-Serial converter (such as an FTDI converter).

General Purpose Input/Outputs (GPIOs) (DIO1 and DIO2)

Input Voltage Range: 0 to 5 VDC

The Servo Cylinder has two (2) GPIO pins which can be used for a wide variety of tasks

⚠ WARNING: Damage will occur if input voltage exceeds 5 VDC or if 5 VDC output is shorted to GND

The GPIO pins can be configured to be used as a high impedance digital input, or to output any of the following:

- +5 VDC supply (up to 250 mA)
- Ground (sink up to 250 mA)
- 1kHz PWM waveform proportional to a variable set by **ioPWM1**
  - Output variables include position, velocity, force, or bus voltage
- Limit switch signals (Triggers at specified travel distances)
- Output the result of the masked status register (1 kHz refresh rate)
  - The GPIO pin will output a digital signal depending on the result of the Servo Cylinder's status word masked with a user defined bit mask. See "Status Word Description" for more information.

It is important to note that DIO1 and DIO2 are NOT optically isolated, meaning that they may be more prone to inject inadvertent noise into the system. They are capable of sinking or sourcing current to drive an external lamp, switch, etc.

See Configuring General Purpose Input / Outputs on Page 30 for details on setting up these inputs.

Cabling

To use the Servo Cylinder, you will need a USB mini B cable (For configuration). In addition, you need Power & Communication Cables to interface with the actuator. The A1 and A2 series have differing Power & Communication Cable types.

- **A1 Series:** The A1 series actuators use a single Power & Communication Cable that terminates with a Molex Micro-Fit 3.0™ type connector. This cable carries both the power and communications signals in a single harness. Read the below sections to learn how to purchase a cable appropriate for your application.
- **A2 Series:** The A2 series (IP-65) rated actuators have separate cable assemblies for power and communications. Each cable comes with an environmentally sealed connector, and with all conductors populated, and with flying (pigtail) leads on the opposite end. Note that the connector receptacle on the actuator must have the mating plug or cap tightened to 1.5 Nm in order to be IP65.

Purchasing Cables from Ultra Motion

Select a USB cable, as well as a Power & Communications Cable appropriate to your actuator series

USB Cable

Use part number **CBL-USB** to purchase USB Mini B 6ft cable.

A1 Series Power & Communications Cable

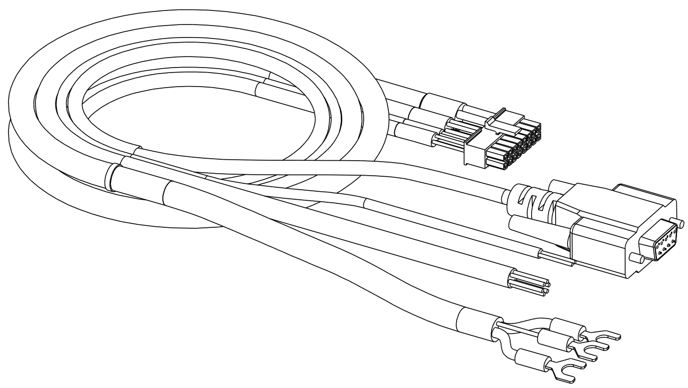


Figure 8: A1 series Power & Communications Cable (CLB-S-AV-D)

Use the information below to specify a cable part number based on what functions you would like. A complete part number **CBL-S-AV-D** (with analog voltage) <u>or</u> **CBL-S-AC-D** (with analog current) will come with all wires populated.

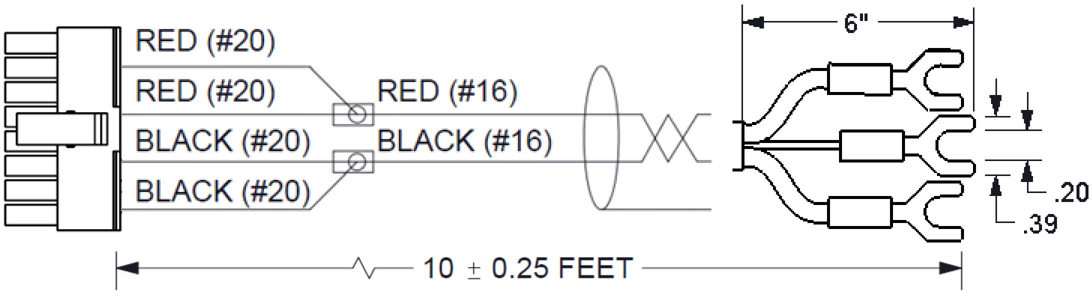
1. Start with Base Power Cable
   - **CBL** (Base Power cable, has power connectors only) Base Power Cable (CBL) below.
2. Choose additional functions as required, and add their dash code to the end of the CBL
   - **-S** (adds serial capability). See serial cable section below for details.
   - **-AC** <u>or</u> **-AV** (adds analog current or analog voltage capability respectively). See analog cable section for details. Only one analog function may be selected.
   - **-D** (adds all digital capability including GPIO). See digital cable section below for details.

CABLE PART NUMBER EXAMPLE: A user planning to control the actuator with an analog voltage signal (-AV) who also wants access to the Servo Cylinder's GPIO (-D) would specify the following cable assembly part number: CBL–AV–D.

Base Power Cable (CBL)

<u>Cable Specification</u>: Four (4) 20 AWG conductors are spliced to two (2) 16 AWG conductors in a twisted, shielded cable terminated with 5 mm stud, crimp spade terminals.

Use: Supply power to the Servo Cylinder

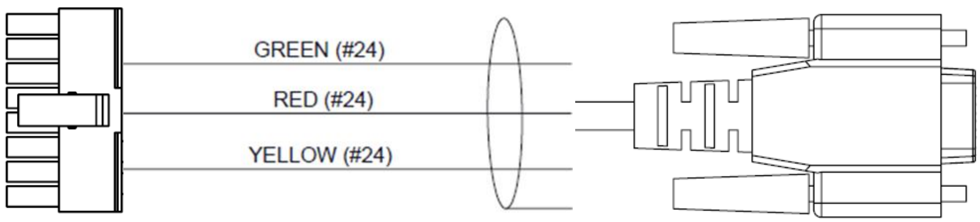


RS232 Serial Cable (-S)

Cable Specification: Shielded cable with three (3) 24 AWG conductors terminated in an overmolded DB9 connector

Uses:

1. Command Line Interface Mode
2. RS232 diagnostic information and data streaming
3. Updating firmware

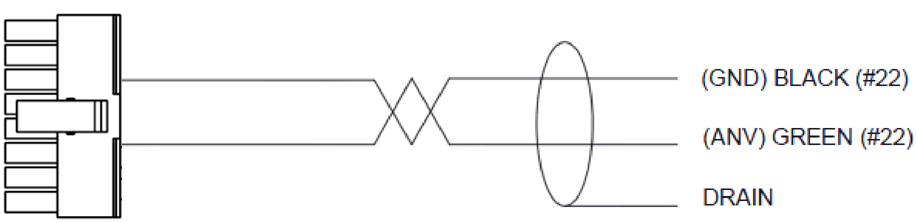


Analog Voltage Cable (-AV)

Cable Specification: Two (2) 22 AWG conductors in a shielded twisted pair terminated with 6” flying leads.

Uses:

1. -10V to +10V Proportional Input Mode
2. Toggle Mode with -10V to +10V control of speed or force

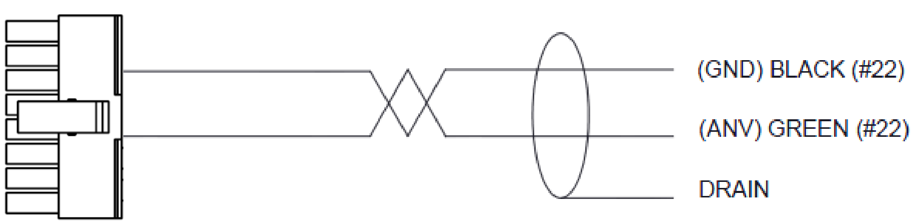


Analog Current Cable (-AC)

Cable Specification: Two (2) 22 AWG conductors in a shielded twisted pair terminated with 6” flying leads.

Uses:

1. 4-20mA Proportional Input Mode
2. Toggle Mode with 4-20mA control of speed or force

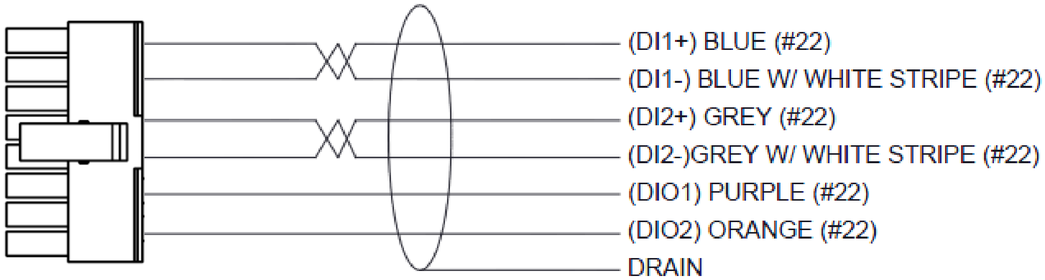


Digital Cable (-D)

Cable Specification: Six (6) 22 AWG conductors in a shielded cable, terminated with 6” flying leads.

Uses:

1. 1 to 2 ms Pulse Proportional Input Mode
2. Incremental Modes
3. Four Preset Position Mode
4. Toggle Mode
5. General Purpose Input/Output (GPIO) functionality



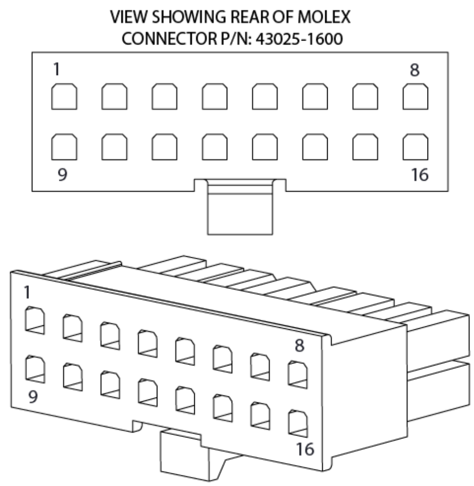
Building Your Own Cable and Connector

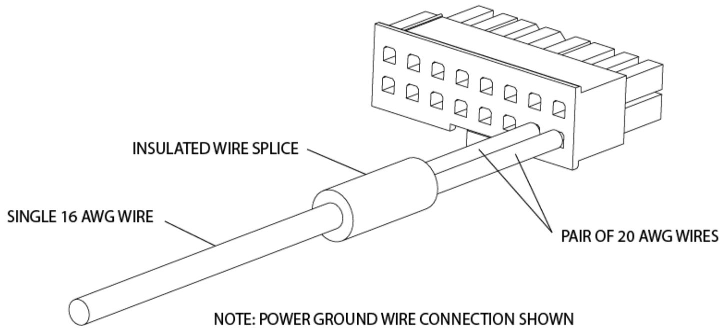
You may choose to assemble your own cable assembly. Use the information in this section to assemble your own cable and connector. The part numbers for the required Molex parts are listed below:

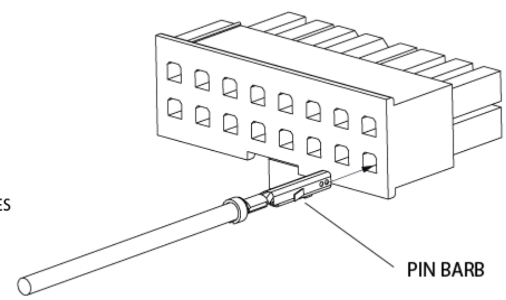
1. MOLEX Connector P/N: 43025-1600
2. MOLEX Crimping Tool P/N: 63819-000
3. MOLEX Crimp Pins (20-24 AWG): 43030-0008
4. MOLEX Pin Extraction Tool: 11-03-0043

The illustrations below provide the mating connector pinout and show proper orientation when inserting pins into a connector.

PIN NUMBER	LABEL	FUNCTION
1	ANI	Analog Current Input
2	GND	Ground
3	TX	RS-232 Transmit
4	DIO1	General Purpose Input/Output 1
5	IN2+	Optically Isolated Input 2 (+)
6	IN1+	Optically Isolated Input 1 (+)
7	V+	Power
8	V+	Power
9	ANV	Analog Voltage Input
10	GND	Ground
11	RX	RS-232 Receive
12	DIO2	General Purpose Input/Output 2
13	IN2-	Optically Isolated Input 2 (-)
14	IN1-	Optically Isolated Input 1 (-)
15	GND	Power Ground
16	GND	Power Ground







Note: The pin barbs should always be on the side of pins as they are inserted into the socket

Note: The power wires to the Servo Cylinder require the use of 4 pins on the Molex connector. You will need to splice a pair of 20AWG wires into a single 16AWG wire for both the V+ and GND connections. Servo Cylinders **should not** be daisy chained together by their power pins.

Be sure to properly insulate your wire splices. The illustration above shows an example of a proper wire splice going into the two power GND pins

A2 Series Power & Communications Cable

For A2 series actuators, you must purchase a Signal & Communication cable and a Power Cable. Speak to sales at Ultra Motion to find out which cable is right for you.

Configuration

Getting Started

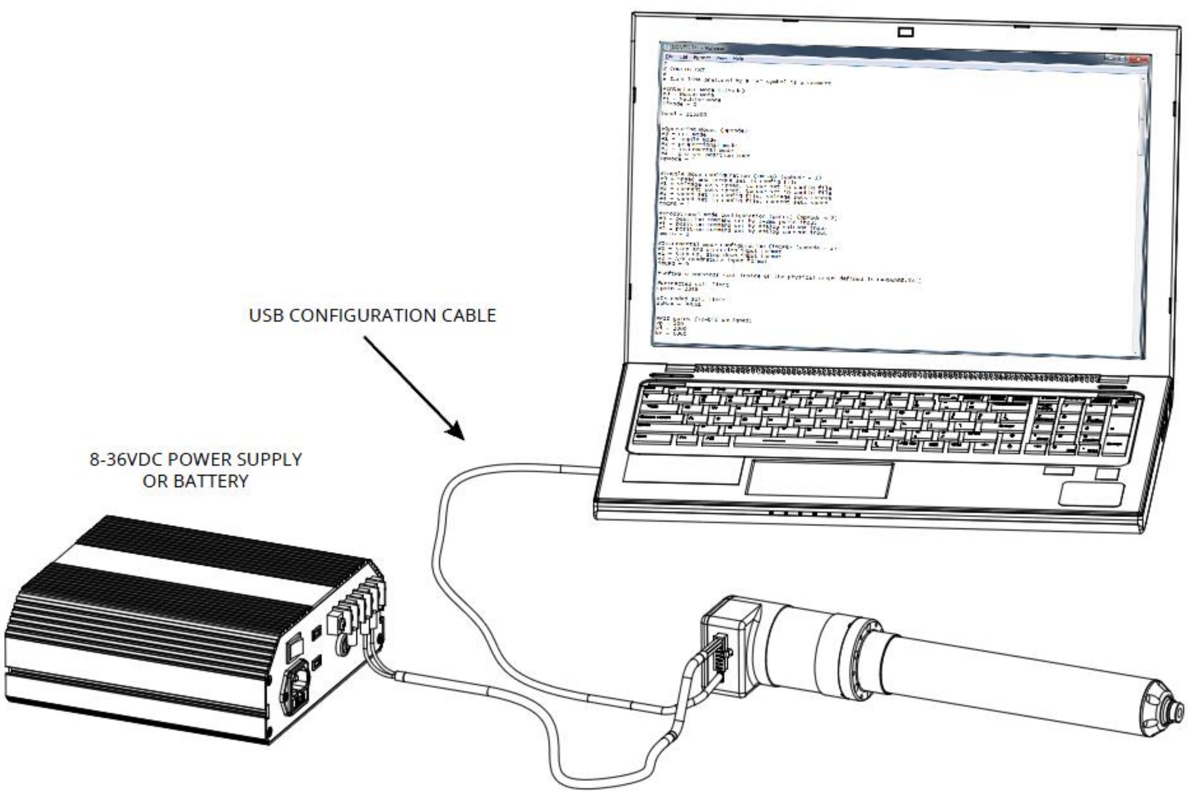
You must determine what control mode you wish to operate in before getting started. At a minimum, you must provide the Servo Cylinder with power and a command signal. If you need assistance in determining which control mode is right for your application, please contact one of our application engineers or review the control modes section.

IMPORTANT: Configuration of the A2 series actuators can be performed over serial commands, or by removing the rear access cover on the end of the actuator to configure over USB. We recommend configuration over serial to avoid the risk of compromising the cover seal O-ring during removal.

Make sure you have read the Cabling Requirements section before getting started.

Wiring to a DC power source

WARNING: Never "Hot Plug" or power the servo cylinder until all wiring and connectors are in place.



How the Configuration Process Works

The Servo Cylinder has a small **10KB** section of non-volatile flash memory that is used to store configuration data. Upon startup, the Servo Cylinder's microprocessor looks for two files called CONFIG.TXT (user defined parameters) and HARDWARE.TXT (factory defined values). These files contain parameters that determine how the actuator will behave.

WARNING: The Servo Cylinder's microcontroller needs both HARDWARE.TXT and CONFIG.TXT to operate. Deleting, removing, or renaming this file will result in a fault mode. We recommend creating a backup of these files to your local drive before starting to edit them. Do not back up on Servo Cylinder.

WARNING: Do not use the 10KB of flash memory to store backup copies of CONFIG.TXT and HARDWARE.TXT. Storing any files other than CONFIG.TXT and HARDWARE.TXT will use up the available storage space.

Hardware Specific Parameters (within HARDWARE.TXT) – Not Intended for Editing

This file contains hardware specific information (such as FOC gains, sensor calibration information, etc.). This file is not intended to be edited by the user unless suggested by Ultra Motion application engineers after a consultation. This file is specific to each actuator and cannot be copied between multiple Servo Cylinders. If for some reason this file is lost, it can be automatically regenerated with a calibration routine command in the Command Line Interface (RS232 Serial).

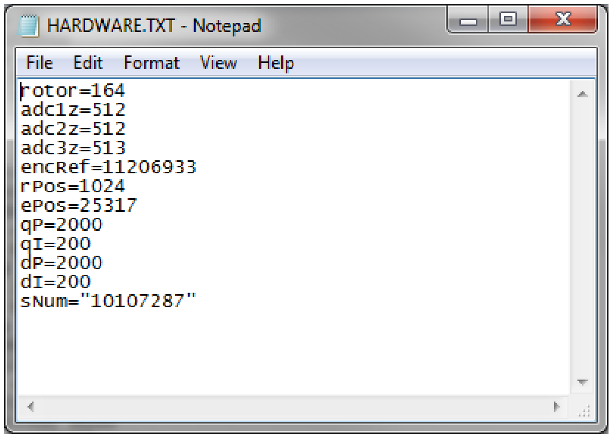
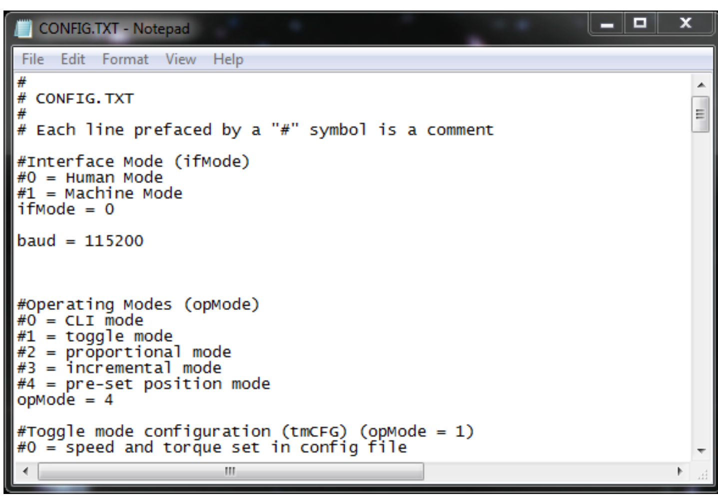


Figure 9: Example of a HARDWARE.TXT file. Several of these values are specific to each individual actuator.

Editing User Configuration Parameters (Within CONFIG.TXT)

This file contains user configurable parameters that change how the actuator behaves (operating mode, position limits, input ranges, etc.). CONFIG.TXT can be edited manually through any text file editor, or generated using Ultra Motion's A1 Series configuration file generator. The configuration file generator offers a graphical interface and makes defining the configuration parameters easier if you are not comfortable with manual configuration.



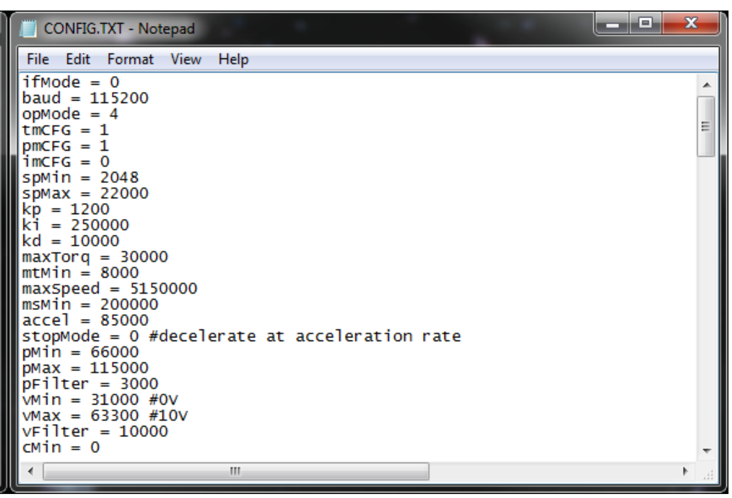


Figure 10 and 11: CONFIG.TXT file, as default (left) and after running ZW which removes all comments and notes

Once your CONFIG.TXT file is properly configured for your application, this file can be copied across multiple Servo Cylinders. If you need to replace a Servo Cylinder, simply copy the existing CONFIG.TXT file to the new Servo Cylinder and it is ready to go.

NOTE: The Servo Cylinder is pre-configured to operate in Command Line Interface (CLI) RS232 Serial Mode by default. We recommend you configure the actuator for your application, but you can skip this step if you want to just run the actuator in Command Line Interface (CLI) RS232 Serial Mode with default settings and travel limits.

How to configure CONFIG.TXT (Windows)

1. Connect Power Cables between Servo Cylinder and Power Supply Unit (PSU).
2. Connect USB cable to Servo Cylinder and any standard USB port on a Windows based computer.
3. Turn on power. Note that Servo Cylinder must be powered by the PSU for the entire configuration process.
4. The computer will automatically recognize the Servo Cylinder as a mass storage device (like a flash drive). Note: If the computer fails to automatically recognize the actuator, please contact Ultra Motion for support.
5. Browse to "My Computer" and open the new storage drive labeled "Ultra Motion".
6. Locate the text file "CONFIG.TXT" and open it in a text editor.
7. Edit configuration parameters to set the the actuator to behave as desired. Refer to Table 4 below for information on critical settings for each operating mode.
8. Save the file locally to your windows machine, and then copy it to the Ultra Motion drive to OVERWRITE the CONFIG.TXT file currently on the Servo Cylinder. If there is no existing CONFIG.TXT file, simply copy this new file onto the drive. Alternatively, you can download and save the website generated CONFIG.TXT directly to the "Ultra Motion" drive.

Default "Factory Set" Behavior

The Servo Cylinder comes with a "factory set" CONFIG.TXT file. The file is populated with values that limit the performance to about 50% of max capability. These values can be safely changed once you are comfortable using the product and understand the repercussions of changing these values. Below is a list of default settings that control performance. We strongly recommend using Error Mode, read more about this feature in errMode – Error Mode (Actuator Hardware Protection Feature) on page 24.

Parameter	Default "Factory Set" Parameter Values	Notes
opMode - Operating mode	0	Servo Cylinder ships in CLI Mode by default.
kp, ki, kd – PID Gains	P=1200, I=250000, and D=10000	Set to stable, generic values.
spMin - Software position minimum	2048	One (1) full revolution (1024 counts) ahead of physical limit.
spMax - Software position maximum	Varies by model	One (1) full revolution (1024 counts) before physical limit.
maxTorq - Max Torque	10000	Approximately the continuous torque output of the actuator
maxSpeed - Maximum Speed	1000000	~20% of maximum speed .
Accel - Acceleration and Deceleration Rate	1000	A moderate acceleration rate.
errMode – Error Mode (Actuator Hardware Protection Feature)	6	Actuator's errMode trips if motor torque is greater than ovTorq (below) and there is no motion for 1 second
ovTorq	10000	Max torque value before triggering errMode

Table 4: Default parameters within CONFIG.TXT

Configuration Parameter Definitions (within CONFIG.TXT)

This section completely outlines and defines all of the settings and parameters within CONFIG.txt. Once you have selected your basic operating mode, look at Table 5 below to find the specific parameters which must be edited for proper use of that mode. If using Command Line Interface (CLI) RS232 Serial Mode, you may be able to get started with default values (detailed in Table 4 above).

Mode	Command Signals	Shared Configuration Parameters	Mode-Specific Configuration Parameters
Command Line Interface (CLI)	Command Line Interface (CLI)	All General Configuration Parameters & Baud, maxSpeed, Accel	ifMode
Proportional Mode	Analog Voltage, Analog Current, 1-2ms Pulse (PWM)	All General Configuration Parameters & Baud (only if using serial)	*All Command Types:* pmCFG *Voltage:* vMin, vMax, vFilter *Current:* cMin, cMax, cFilter *PWM:* pMin, pMax, pFilter
Incremental Mode	Step & Direction, A/B Quadrature, CW/CCW	All General Configuration Parameters & Baud (only if using serial)	*All Command Types:* imCFG, stepSize
Preset Position Mode	Preset Position Mode	All General Configuration Parameters & Baud (only if using serial), maxSpeed, Accel, stopMode	posTime, Pos1, Pos2, Pos3, Pos4
Toggle Mode	Toggle Mode	All General Configuration Parameters & Baud (only if using serial), maxSpeed, Accel, stopMode	tmCFG, mtMin, msMin

Table 5: All parameters which need configuration (in CONFIG.TXT) for each respective operating mode and command signal

General Configuration Parameters

Configuration parameters in this section are relevant to all operating modes and must be set for proper operation of the Servo Cylinder.

opMode - Operating mode

Setting Used in: All Modes
Parameter Type: Integer
Valid Range: 0 to 4

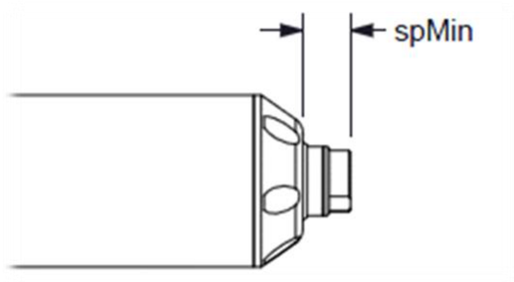
This setting sets the Servo Cylinder's operating mode. Here you choose whether you wish to operate in Command Line Interface, Toggle, Proportional, or Preset Position mode.

Parameter	Mode	Description
0	Command Line Interface (CLI)	• Full control through Ultra Motion Serial Command Language • Operates via RS232 connection. • Ultra Motion Serial Command Language includes a full command set for position moves, trajectory moves, acceleration, speed, torque, etc.
1	Toggle Mode	• Extend/Retract control with adjustable acceleration, speed, and force. • See "tmCFG – Toggle Mode Configuration" for additional configuration options.
2	Proportional Mode	• Actuator moves proportional to the command signal. • See "pmCFG - Proportional Mode Configuration" for additional configuration options.
3	Incremental Mode	• Actuator moves as it receives each incremental command signal.
4	Preset Position Mode	• Actuator has up to four preset positions. • See "Pos1, Pos2, Pos3, Pos4 – Preset Positions 1, 2, 3, and 4" to define the positions.

spMin - Software position minimum

Setting Used in: All Modes
Parameter Type: Integer
Valid Range: rPos to ePos (Note: rPos and ePos are the physical travel limits, found in HARDWARE.TXT)
Rules: rPos ≤ spMin < spMin

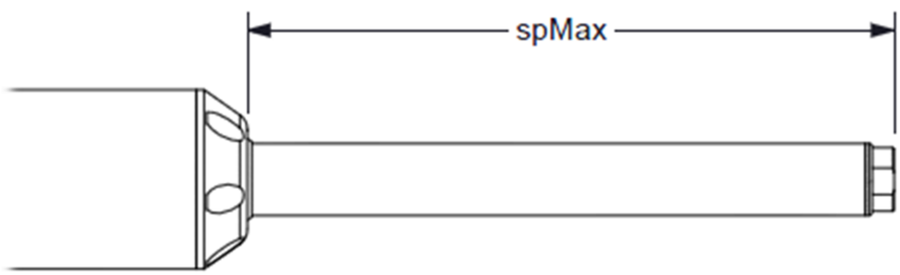
This setting sets the minimum allowable position of the Servo Cylinder. spMin can be treated as a retracted software limit switch. The value is expressed in Phase Index sensor counts and there are 1024 counts per revolution.



spMax - Software position maximum

Setting Used in: All Modes
Parameter Type: Integer
Valid Range: rPos to ePos (Note: rPos and ePos are the physical travel limits, found in HARDWARE.TXT)
Rules: spMin < spMax ≤ ePos

This setting sets the maximum allowable position of the Servo Cylinder. spMin can be treated as an extended software limit switch. The value is expressed in Phase Index sensor counts and there are 1024 counts per revolution.



maxTorq - Max Torque

Setting Used in: All Modes
Parameter Type: Integer
Valid Range: 0 to 32767

This setting sets the limit for the current controlled by the Field-Oriented Control loop, thereby limiting the maximum force produced by the Servo Cylinder. The value represents a percentage of force output whereas 32767 equals 100%. The relationship is linear with a slight offset do to unloaded running friction of the system. Contact Ultra Motion engineering for more detailed information.

kp, ki, kd – PID Gains

Setting Used in: All Modes
Parameter Type: Integer
Valid Range: See PID Tuning section

These three values represent the gains for the proportional, integral, and derivative terms of the position PID control loop. They are to tune the response. See the section in the manual on PID tuning for more information about what these values represent.

errMode – Error Mode (Actuator Hardware Protection Feature)

Setting Used in: All Modes
Parameter Type: Integer
Valid Range: 0 to 8 (see table below)
Rules: Configured ovErrP (for errMode 1 to 4) or ovTorq (for errMode 5to 8) (see below)

Error Mode is a setting that defines the behavior of the Servo Cylinder during error conditions such as over torque or a large position error. Its purpose is to protect the Servo Cylinder from burning out the motor or control electronics. Error Mode can be set to any of the following:

errMode Setting	Setting Definition	Setting Notes
0	Error Mode Disabled	Does not protect the motor from burning out
1	Absolute Position Error > ovErrP for 1/2 second	User must define the ovErrP value
2	Absolute Position Error > ovErrP for 1 second	User must define the ovErrP value
3	Absolute Position Error > ovErrP for 2 seconds	User must define the ovErrP value
4	Absolute Position Error > ovErrP - no delay	User must define the ovErrP value
5	Absolute motor current > ovTorq and speed = 0 for 1/2 second	User must define the ovTorq value
6	Absolute motor current > ovTorq and speed = 0 for 1 second	User must define the ovTorq value
7	Absolute motor current > ovTorq and speed = 0 for 2 second	User must define the ovTorq value
8	Absolute motor current > ovTorq and speed = 0 - no delay	User must define the ovTorq value

Table 6: All available protection behaviors when using the errMode feature.

Shared Configuration Parameters

Configuration variables in this section are relevant to several operating modes and must be set for proper operation of the Servo Cylinder in these modes.

Baud – Serial Baud Rate

Setting Used in: All modes (only if using for non-motion serial commands or data streaming) or Command Line Interface (CLI) (All command types)
Parameter Type: Integer
Valid Range: 2400 to 256000

This setting sets the Baud rate for serial communication. Setting this is only necessary if you plan to use a serial connection to the actuator. Serial is accessible in all control modes and is used for streaming output information and diagnostics.

Note: Default Baud rate is 115200. Lower baud rates are more tolerant to noise and crosstalk.

maxSpeed - Maximum Speed

Setting Used in: Command Line Interface (CLI), Preset Position Mode, Toggle Mode
Parameter Type: Integer
Valid Range: 0 to 50000000 (50×10^6)
Rules: opMode = 0 or opMode = 4

This parameter limits the maximum speed the Servo Cylinder will reach when executing trajectory moves.

$$Maximum\ Speed\ \left(\frac{in}{s}\right) = \frac{N \times 1250 \times L}{2^{16} \times 1024}, \qquad L = screw\ lead, \qquad N = maxSpeed\ parameter$$

Note that this variable does not control the speed in proportional modes. Speed is controlled in proportional modes by controlling the rate of change of the signal from your PLC or signal source.

Accel - Acceleration and Deceleration Rate

Setting Used in: Command Line Interface (CLI), Preset Position Mode, and Toggle Mode

Parameter Type: Integer

Valid Range: 0 to 131000

Rules: opMode = 0 or opMode = 4

This parameter defines the acceleration and deceleration the Servo Cylinder will use in trajectory moves. Note: the acceleration and deceleration must be equal to one another.

$$Acceleration\left(\frac{in}{s^2}\right) = \frac{N \times 1{,}250^2 \times L}{2^{16} \times 1024}, \qquad L = screw\ lead, \qquad N = Accel\ parameter$$

Note that this variable does not control the acceleration of the actuator when in proportional modes. Acceleration and deceleration are controlled in proportional modes by controlling the rate of change of the slew rate of the analog signal.

stopMode – End-of-Trajectory Stopping mode

Setting Used in: Preset Position mode, and Toggle Mode

Parameter Type: Integer

Valid Range: 0 to 2 (see table below)

Rules: opMode = 4

This parameter defines the behavior of the actuator when stopping at a preset position.

Parameter	Behavior
0	Snap to position
1	Decelerate at rate set by “accel” variable
2	Dynamically brake for 100 ms, then snap to position

Command Line Interface (CLI) Mode Configuration

The user will have complete control over the Servo Cylinder as well as access to detailed diagnostic information. See Appendix A: Serial Command Line Interface (CLI) List of Commands for the full set of available serial commands.

ifMode – Interface mode

Parameter Type: Integer

Valid Range: 0 to 2 (see table below)

Serial Command: IM

This setting changes the behavior of the Serial Command Line Interface to be either human mode or machine mode. Serial Command Mode allows for use of the Servo Cylinder’s built-in trajectory generator when moving from one position to the other. To define the characteristics of the trajectory generator, the maximum speed and acceleration values must be set.

Parameter	Mode	Description
0	Human Mode	• All commands are followed by an ACK or NACK • Asynchronous error messages are sent to the serial prompt • Detailed information regarding actuator commands is written to the serial prompt
1	Machine Mode 1 (MACHINE1)	• Asynchronous error messages are disabled • No detailed information is sent to the serial prompt • ”im0 26” sets interface back to Human Mode (Case Sensitive)
2	Machine Mode 2 (MACHINE2)	• Every command must be followed by a checksum

The difference between Machine Mode 1 and Machine Mode 2 is that Machine Mode 2 requires a checksum is sent with *all* commands (see Checksums below). Both MACHINE1 and MACHINE2 modes return a checksum with the response, and a checksum is also added to any streaming data.

Checksums

A checksum is a single byte represented by two hexadecimal digits. It is added to the end of each line, including both commands and streaming data. It must be preceded by a delimiter (' ', '\t', or ',') except when a command takes no argument. The checksum is the least significant byte of the sum of all bytes received in the line before the checksum.

Proportional Mode Configuration Parameters

pmCFG - Proportional Mode Configuration

Parameter Type: Integer
Valid Range: 0 to 2 (See below for details)

This setting selects the type of proportional mode behavior

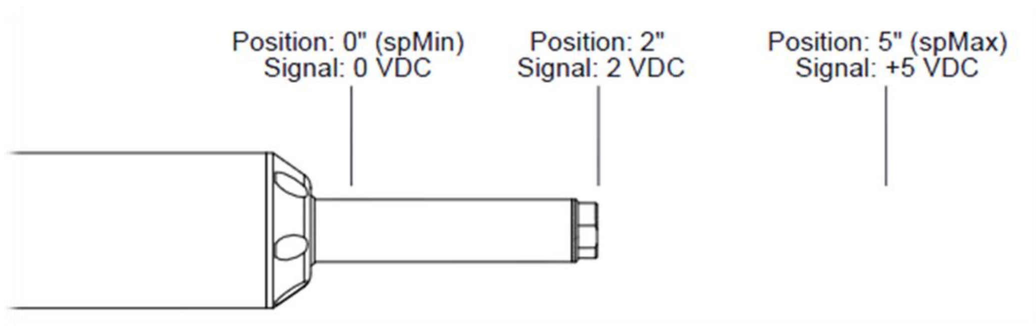
Parameter	Mode	Description
0	1 to 2 ms Pulse (PWM)	Position command set by 1 to 2 ms pulse input
1	Analog Voltage	Position command set by analog voltage input
2	Analog Current	Position command set by analog current input

vMin, vMax – Analog Voltage Min and Analog Voltage Max

Parameter Type: Integer
Valid Range: 0 to 65535* (Note: this integer corresponds to sensor count, not volts)
Rules: opMode=2, pmCFG = 1
vMin < vMax

This setting defines the usable range of the -10 to +10V analog voltage input that will relate to the Servo Cylinder travel range (spMin to spMin). An example configuration is shown below.

*For optimal results the user should calibrate the minimum and maximum voltage range to each actuator.



vFilter – Analog Voltage filter

Parameter Type: Integer
Valid Range: 0 to 65535
Rules: opMode=2, pmCFG = 1

The analog voltage input can be filtered in software to reduce the effect of noise from the transceiver. The larger the value the less filtering will occur, allowing for more dynamic movements. A smaller value will increase the level of filtering, leading to smoothed motion and less dithering.

cMin, cMax – Analog Current min and Analog Current max

Parameter Type: Integer
Valid Range: 0 to 65535 (Note: this integer corresponds to sensor count, not amps)
Rules: opMode = 2, pmCFG = 1, cMin < cMax

These parameters define the usable range of the 4-20mA input that will relate to the Servo Cylinder travel range (spMin to spMin).

For optimal results the user should calibrate the minimum and maximum current range to each actuator.

cFilter - Current filter

Parameter Type: Integer
Valid Range: 0 to 65535
Rules: opMode = 2, pmCFG = 1

The analog current input can be filtered in software to reduce the effect of noise from the transceiver. The larger the value the less filtering will occur, allowing for more dynamic movements. A smaller value will increase the level of filtering, leading to more stable motion and less dithering.

pMin, pMax – Pulse Width Minimum and Maximum

Parameter Type: Integer
Valid Range: 48000 to 70000 (for pMin) and 108000 to 132000 (for pMax)
Rules: opMode = 2, pmCFG = 0

This parameter defines the usable range of the 1 to 2 ms pulse inputs that will relate to the Servo Cylinder travel range (spMin to spMin).

The parameters for pMin/pMax use units of 1/60,000th of a millisecond.

Note: The Servo Cylinder can accept a 1 to 2 ms pulse input at both standard update frequencies of 50 Hz and 333 Hz

Example:

To have a command signal that consists of a Pulse Width between 1.5 and 1.75 ms correspond to a position between spMin and spMin (respectively), the values to be usedfor pMin and pMax are calculated below:

$$pMin = Pulse\ Width \times 60000\frac{counts}{ms} = 1.5ms \times 60000\frac{counts}{ms} = 90000$$

$$pMax = Pulse\ Width \times 60000 \frac{counts}{ms} = 1.75ms \times 60000 \frac{counts}{ms} = 105000$$

Pulse width [ms]	Parameter for pMin/pMax	Note
1.0000	60000	Exactly 1ms
1.1000	66000	A common lower limit for some PWM controllers
1.9166	115000	A common upper limit for some PWM controllers
2.000	120000	Exactly 2ms

Table 7: Commonly used pulse widths and associating pMin/pMax parameters

pFilter – Pulse Width filter

Parameter Type: Integer
Valid Range: 0 to 65535
Rules: opMode = 2, pmCFG = 0

The 1 to 2 ms pulse input can be filtered in software to reduce the effect of noise from the transceiver. The larger the value the less filtering will occur, allowing for more dynamic movements. A smaller value will increase the level of filtering, leading to more stable motion and less dithering.

Incremental Mode Configuration (Step & Direction, A/B Quadrature, CW/CCW)

imCFG - Incremental mode configuration

Parameter Type: Integer
Valid Range: 0 to 2 (See below for details)
Rules: opMode = 3

This parameter sets the behavior in incremental mode

Parameter	Mode
0	Step & Direction
1	Step up, Step down input format
2	A/B Quadrature

stepSize – Incremental Step Size

Parameter Type: Integer
Valid Range: 1 to 65535
Rules: opMode = 3

The value of the stepSize parameter defines the amount of actuator motion (Phase Index steps taken) per incremental command.

Toggle Mode Configuration

tmCFG – Toggle Mode Configuration

Parameter Type: Integer
Valid Range: 0 to 4
Rules: opMode = 1

This parameter sets behavior in toggle mode

Parameter	Description	Notes
0	Speed and Torque set in CONFIG.TXT	Torque and speed are static settings
1	Voltage sets speed, torque set in CONFIG.TXT	Dynamically controllable torque
2	Current sets speed, torque set in CONFIG.TXT	Dynamically controllable torque
3	Speed set in CONFIG.TXT, voltage sets torque	Dynamically controllable speed
4	Speed set in CONFIG.TXT, current sets torque	Dynamically controllable speed

mtMin - Max Torque Minimum

Parameter Type: Integer
Valid Range: 0 to 32766
Rules: tmCFG = 1 or 2

Since you are using an adjustable range to set the torque limit, this variable defines the lower limit for the maxTorq variable.

For Example: You want to use a 0 to 10V input to control torque in a range from mtMin to maxTorq

msMin – Max Speed Minimum

Parameter Type: Integer
Valid Range: 0 to 32766
Rules: tmCFG = 1 or 2

Since you are using a range to define the speed, this defines the lower limit for the range. The upper limit is defined by maxSpeed.

For Example: You want to use a 0 to 10V input to control speed in a range from msMin to maxSpeed

Preset Position Mode Configuration

Preset position mode is a simple way to move between up to four absolute positions with simple digital commands. The state of the Servo Cylinder’s two optically isolated digital inputs (IN1 and IN2) corresponds to the absolute position command. Four preset position mode uses the maximum speed and acceleration values (maxSpeed, accel) to create trajectories when moving from one preset position to another. A user configurable time delay (posTime) is used to reject noise or invalid states sent to the actuator.

posTime – Preset Position Response Time

Parameter Type: Integer
Valid Range: 0 to 65535
Rules: opMode = 4

This parameter defines the amount of time in milliseconds it takes for a state change on the optically isolated digital inputs (IN1 and IN2) to register as a valid command.

Pos1, Pos2, Pos3, Pos4 – Preset Positions 1, 2, 3, and 4

Parameter Type: Integer
Valid Range: spMin to spMin
Rules: opMode = 4

These parameters define the absolute position that corresponds to each state of the digital inputs.

Position	Input 1 (IN1) Status	Input 2 (IN2) Status
Position 1 (Pos1)	0 (Off)	0 (Off)
Position 2 (Pos2)	1 (On)	0 (Off)
Position 3 (Pos3)	0 (Off)	1 (On)
Position 4 (Pos4)	1 (On)	1 (On)

Table 8: All four (4) possible positions and the corresponding states of the optically isolated inputs (IN1 and IN2)

Configuring Outputs and Diagnostics

Configuring General Purpose Input / Outputs (GPIO's)

The Servo Cylinder has two GPIO pins that can be configured as a high impedance input, or to output signal ground, +5 VDC, the result of a status word bit mask, or a PWM data source. The following configuration variables control the functionality of the Servo Cylinder's GPIO. Note: Damage will occur if the +5 VDC output is shorted to GND.

ioPin1, ioPin2 – GPIO Behavior for pins 1 and 2 (Respectively)

Parameter Type: Integer

The parameters ioPin1, ioPin2 set the operating mode for General Purpose Input / Outputs (GPIO) pin 1 and pin 2 respectively.

Parameter	Description	Notes
0	High speed digital input	Useful for Custom Applications
1	Ground	Sink up to 250 mA
2	+5 V Output	Source up to 250 mA
3	Output the result of the masked status register	1 kHz refresh rate
4	1 kHz, +5 V PWM Output	Proportional to a variable set by *ioPWM1* or *ioPWM2*

ioPWM1, ioPWM2 – Output PWM Signal Type for GPIO pin 1 and 2 (Respectively)

Parameter Type: Integer
Valid Range: 0 to 7 (See below for details)
Rules: ioPin1 = 4

The parameters ioPWM1 and ioPWM2 set the variable to be output via a 1 kHz PWM waveform on General Purpose Input / Outputs (GPIO) pin 1 and 2 respectively.

Parameter	Description
0	Actuator Position (spMin to spMin)
1	Actuator Velocity (-512 to 511)
2	Actuator Torque (-32768 to 32767)
3	Bus Voltage (0 to 1023)
4	Commanded position (spMin to spMin)
5	1 to 2 ms pulse input channel 2 (pMin to pMax)
6	Analog voltage input (vMin to vMax)
7	Analog current input (cMin to cMax)

Data Streaming

Over a serial connection, the Servo Cylinder can report the values of up to three variables over serial at a defined rate. This is useful for debugging, graphing output data, and confirming Servo Cylinder performance. The following configuration variables control the serial data streaming functionality:

sFlag

Parameter Type: Integer

Valid Range: 0 or 1 (See below for details)

This parameter defines the start-up behavior of the data streaming functionality.

Parameter	Description
0	Data streaming off at startup
1	Data streaming on at power-up

sTime

Parameter Type: Integer

Valid Range: 0 to 65535 (See below for details)

This parameter defines the rate at which data is streamed from the actuator. This will be limited by the pre-selected baud rate. 65535 is the minimum data transfer rate (~3.576 Hz), the maximum data transfer rate is a function of the baud rate.

Baud Rate	Maximum Streaming Frequency
9600	24.0 Hz
19200	48.0 Hz
38400	96.0 Hz
57600	144.0 Hz
115200	287.9 Hz

Strx1, Strx2, Strx3 – Streamed Variables

Parameter Type: Integer

Valid Range: 0 to 19 (See below for details)

This parameter defines the variable that will be streamed in columns 1, 2, and 3 respectively.

Parameter	Description
0	Column Off
1	Actuator Position
2	Position Command Setpoint
3	Motor Current
4	Motor Current Setpoint
5	Motor Phase 1 Current
6	Motor Phase 2 Current
7	Motor Phase 3 Current
8	Actuator Velocity at 312.5 kHz
9	Actuator Velocity at 78.125 Hz
10	Encoder Interval Timer
11	Supply Voltage
12	Status Bit Register
13	1 to 2 ms pulse (PWM) Input
14	Filtered 1 to 2 ms pulse (PWM) Input
15	Analog Voltage Input
16	Filtered Analog Voltage Input
17	Analog Current Input
18	Filtered Analog Current Input
19	Temperature Sensor Input
20	Psition Error
21	Quadrature Input Errors
22	1 to 2 ms pulse (PWM) input errors
23	32-bit Timer with 100 μs Increments

Table 9: All available streamed variables

Installation and Use

We highly recommend running the servo cylinder unloaded on a benchtop to gain familiarity with the system before using it to drive a load. Please use Error Mode until the system is fully understood to protect the hardware and prevent motor burn outs.

Integrating Servo Cylinder into Your System

WARNING: Do not apply torque to actuator rod when torqueing hardware into the rod tip. Use the rod-end wrench flats to apply torque here.

Understanding Hard-Stop Behavior

The Servo Cylinder has internal physical “hard-stop” travel limits, but it comes factory-calibrated to prevent the user from being able to command the actuator into these hard-stops. If the Servo Cylinder was able run into these travel limits with maxTorq set above the maximum continuous “safe” limit, the motor electronics will burn out and cease to function.

When installing the Servo Cylinder into a system with hard-stops, you should configure spMin and spMax accordingly to prevent running into the external hard-stops of your mechanism.

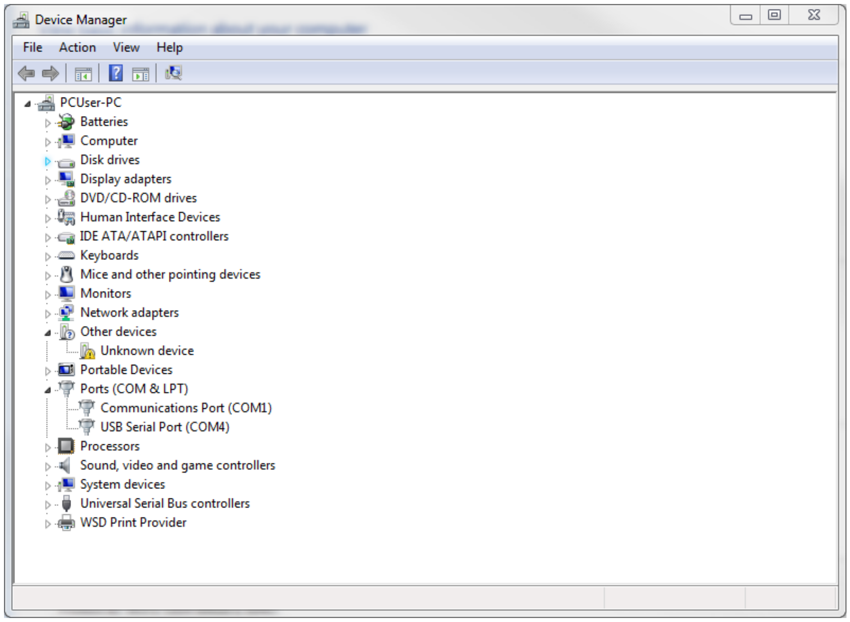
Using the Command Line Interface (CLI)

To use the command line interface connect via the RS232 serial port and open a serial terminal. Any compatible RS232 serial terminal will work.

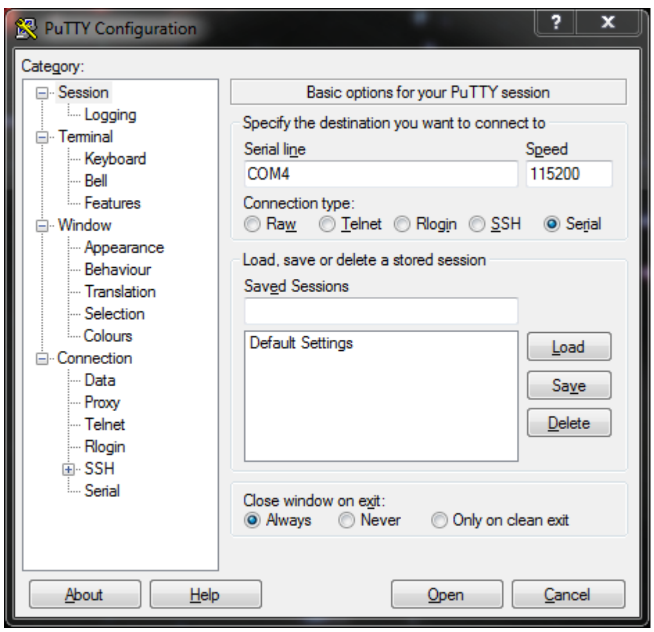
Setting up the Command Line Interface (CLI)

In this example, the CLI will be set up using a PuTTY terminal on a Windows 7 machine with a RS232 Serial-to-USB converter with an FTDI Chip. The Serial CLI can be used on any platform capable of communicating via RS232.

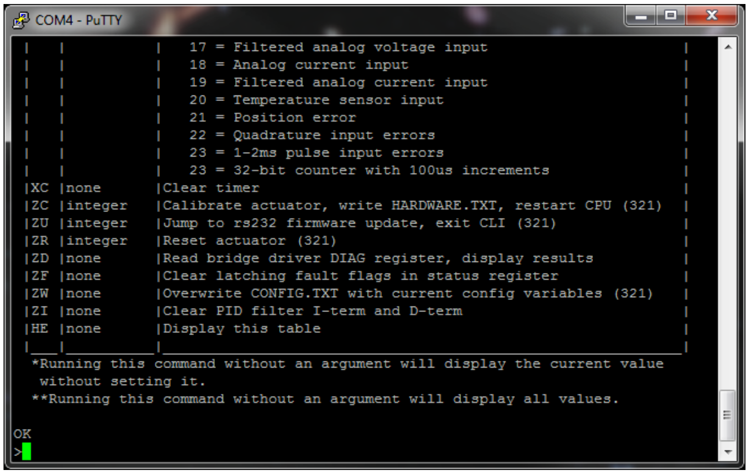
1. (If not done already) Install VCP (Virtual COM Port) drivers, which can be found on the FTDI website.
2. (If not done already) Install PuTTY
3. Plug both Power/Signal cable(s) into the Servo Cylinder
4. Connect the power cable to a PSU
5. Connect the serial port to the RS232 Serial-to-USB Converter, and connect to a free USB port.
6. Power the Servo Cylinder
7. In Windows, determine which COM port number was assigned to the Servo Cylinder. This can be done by opening Device Manager (Right click My Computer and click Device manager). In Device manager, expand the “Ports” menu, and make a note of the number of the COM port for the USB Serial Port (COM4 in the window below)



8. Open PuTTY.
9. Set up PuTTY to run a serial command line interface. Click the "Serial" Radio Button. Under Serial Line, enter the correct COM port for the Servo Cylinder (COM4 in this example). Under Speed, enter the correct Baud Rate set up in CONFIG.TXT (115200 by default).



10. Click Open to open the Command Line Interface. A blank terminal window should open.
11. As a test, issue the Help command (HE) by typing HE and pressing enter. If correctly set up, the Servo Cylinder should return a table of available serial commands (below).



Information about the Command Line Interface

The Servo Cylinder will respond to single line commands. All commands consist of two letter characters (not case sensitive) and may or may not be followed by a parameter (also known as an argument) and/or a checksum.

Each line is a string of text followed by a carriage-return (CR) character. Newline characters are ignored. Commands are executed when a carriage-return character is received at the end of a line.

Using the Status Register Feature

The Servo Cylinder updates a 32-bit status register to provide the user with an indication of actuator health. The entire status register can be read over the serial connection or can be masked and output over the general purpose I/O pins (DIO1 and/or DIO2) at a refresh rate of 1 kHz.

Bit Number	Status Register
0	State of optically isolated input 1
1	State of optically isolated input 2
2	Temperature sensor > ovTemp
3	Excessive position error detected, MOTOR OFF
4	Over-voltage on Vbus, dynamic brake enabled
5	Motor Control Enabled
6	Trajectory Active
7	Direction (extend)
8	Position < spMin
9	Position > spMin
10	Command input below min value, capped at min
11	Command input above max value, capped at max
12	Position Error < atTarg
13	Position error > ovErrP
14	Speed > ovSpeed
15	Torque > ovTorq
16	Position > posGrtr
17	Position < posLess
18	RS232 Connected
19	USB Connected
20	Retracted physical stop has been hit
21	Extended physical stop has been hit
22	Supply voltage has been too low
23	Supply voltage has been too high
24	Bridge drove fault condition was reported

25	Over-current detected on motor phase
26	1 to 2 ms pulse input error
27	A/B Quadrature input error
28	File system has been modified
29	HARDWARE.TXT file contains errors
30	CONFIG.TXT file contains some errors
31	Critical error(s) in configuration file, MOTOR OFF

Table 10: Status Bit Definitions

User Settable Status Bit Thresholds

Several of the bits require a user defined threshold that defines when they are active and when they are inactive.

atTarg – At Target Position Threshold

Parameter Type: Integer

Valid Range: 0 to 4095

Defines the position error threshold that cause bit 12 (Position Error < atTarg) to go active. The "at target position" bit will flip when the actuator position falls between setpoint ± atTarg.

ovErrP – Position Error Threshold

Parameter Type: Integer

Valid Range: 0 to 65535

Defines the position error threshold that causes status bit 13 (Position error > ovErrP) to trigger.

ovSpeed – Over Speed Threshold

Parameter Type: Integer

Valid Range: 0 to 127

Defines the speed error threshold that causes status bit 14 (Speed > ovSpeed) to go active.

ovTorq – Over Torque Threshold

Parameter Type: Integer

Valid Range: 0 to 32767

Defines the torque threshold that causes status bit 15 (Torque > ovTorq) to go active.

posGrtr – Position Greater Than Threshold

Parameter Type: Integer

Valid Range: 0 to 65535

Defines the threshold that causes status bit 16 (Position > posGrtr) to go active. For example, setting posGrtr = 35000 will cause an active bit if the actuator position is 35001 and an inactive bit if the actuator position is 34999.

posLess – Position Less Than Threshold

Parameter Type: Integer

Valid Range: 0 to 65535

Defines the threshold that causes status bit 17 (Position < posLess) to go active. For example, setting posLess = 5000 will cause an active bit if the actuator position is 4999 and an inactive bit if the actuator position is 5001.

Reading the Status Register over Serial

The complete status register (or individual status bits) can be read over a serial connection using the "SR" command.

Sending the SR command without an argument will return the value of the status register in hex format. Calling the SR command followed by a value from 0 to 31 will return the value of the corresponding status register bit.

For example:

Input: SR 4
Output: bit4: "Emergency over-volt" = false

Input: SR
Output: Status Register: 0x000610A7

Reading the Status Register over the General Purpose I/O Pins (DIO1 and DIO2)

Unlike the serial connection, the DIO pins can only output a single bit at a 1 kHz update rate. In order to provide more useful information over this single bit, the status register must be masked. For this to be possible, you must first configure the GPIO pins (1 and/or 2) to output the masked status register. See the GPIO section for information on configuring the GPIO pins.

Once the GPIO pins are properly set to output the masked status register value, you must define one (or both) mask values. These values are ioBit1 and ioBit2.

ioBit1, ioBit2 – Status Bit Output to GPIO

The value of ioBit1 and ioBit2 will be compared to the value of the status register, and a high or low bit will be signaled by the DIO1 or DIO2 pin respectively depending on whether or not the two are equal.

Parameter Type: Unsigned Long
Valid Range: 0 to 4294967295 (2^{32})
Rules: ioPin1 = 3 and/or ioPin2 = 3

Masking Example

Your complete status register may read:

Bit 0	Bit 1	Bit 2	Bit 3	**Bit 4**	**Bit 5**	**Bit 6**	Bit 7	Bit 8	Bit 9	Bit 10	Bit 11	Bit 12	Bit 13	Bit 14	**Bit 15**	Bit 16	Bit 17	Bit 18	Bit 19	Bit 20	Bit 21	Bit 22	Bit 23	Bit 24	**Bit 25**	Bit 26	Bit 27	Bit 28	Bit 29	Bit 30	Bit 31
0	0	0	0	**1**	**1**	**1**	0	0	0	0	0	0	0	0	**1**	0	0	0	0	0	0	0	0	0	**1**	0	0	0	0	0	0

This indicates that Bits 4, 5, 6, 15, and 25 are active.

If you only care about looking at status of bit 6 (Trajectory Active) and bit 15 (Torque > ovTorq) on GPIO pin 1, you need to set the configuration variable ioBit1 to the value that represents these two bits: 32832

The value of 32832 is obtained by adding the integer representation of the bits you want to mask together. In this case: 64 (for Bit 6) + 32768 (for Bit 15) = 32832

When both bit 6 AND (not or) bit 15 are active, DIO1 pin will output a 1

When both bit 6 AND/OR bit 15 are not active, DIO1 pin will output a 0

Tuning Performance

PID Basics

The PID circuit is often utilized as a control loop feedback controller and is very commonly used for many forms of servo circuits. The letters making up the acronym PID correspond to Proportional (P), Integral (I), and Derivative (D), which represents the three control settings of a PID circuit. The purpose of any servo circuit is to hold the system at a predetermined value (set point) for long periods of time. The PID circuit actively controls the system so as to hold it at the set point by generating an error signal that is essentially the difference between the set point and the current value. The three controls relate to the time-dependent error signal; at its simplest, this can be thought of as follows: Proportional is dependent upon the present error, Integral is dependent upon the accumulation of past error, and Derivative is the prediction of future error. The results of each of the controls are then fed into a weighted sum, which then adjusts the output of the circuit, u(t). This output is fed into a control device, its value is fed back into the circuit, and the process is allowed to actively stabilize the circuit's output to reach and hold at the set point value. The block diagram below illustrates very simply the action of a PID circuit. One or more of the controls can be utilized in any servo circuit depending on system demand and requirement (i.e., P, I, PI, PD, or PID).

Proportional Response

The proportional component depends only on the difference between the set point and the process variable. This difference is referred to as the Error term. The *proportional gain (K_c)* determines the ratio of output response to the error signal. For instance, if the error term has a magnitude of 10, a proportional gain of 5 would produce a proportional response of 50. In general, increasing the proportional gain will increase the speed of the control system response. However, if the proportional gain is too large, the process variable will begin to oscillate. If K_c is increased further, the oscillations will become larger and the system will become unstable and may even oscillate out of control.

Integral Response

The integral component sums the error term over time. The result is that even a small error term will cause the integral component to increase slowly. The integral response will continually increase over time unless the error is zero, so the effect is to drive the Steady-State error to zero. Steady-State error is the final difference between the process variable and set point. A phenomenon called integral windup results when integral action saturates a controller without the controller driving the error signal toward zero.

Derivative Response

The derivative component causes the output to decrease if the process variable is increasing rapidly. The derivative response is proportional to the rate of change of the process variable. Increasing the derivative time (T_d) parameter will cause the control system to react more strongly to changes in the error term and will increase the speed of the overall control system response. Most practical control systems use very small derivative time (T_d), because the Derivative Response is highly sensitive to noise in the process variable signal. If the sensor feedback signal is noisy or if the control loop rate is too slow, the derivative response can make the control system unstable

Parameter Increased	Rise Time	Overshoot	Settling Time	Steady-State Error	Stability
K_p	Decrease	Increase	Small Change	Decrease	Degrade
K_i	Decrease	Increase	Increase	Decrease Significantly	Degrade
K_d	Minor Decrease	Minor Decrease	Minor Decrease	No Effect	Improve (for small K_d)

Tuning

In general the gains of P, I, and D will need to be adjusted by the user in order to optimally control the system. While there is not a static set of rules for what the values should be for any specific system, following the general procedures should help in tuning a circuit to match one's system and environment. In general a PID circuit will typically overshoot the SP value slightly and then quickly damp out to reach the SP value.

Manual tuning of the gain settings is the simplest method for setting the PID controls. However, this procedure is done actively (the PID controller turned on and properly attached to the system) and requires some amount of experience to fully integrate. To tune your PID controller manually, first the integral and derivative gains are set to zero. Increase the proportional gain until you observe oscillation in the output. Your proportional gain should then be set to roughly half this value. After the proportional gain is set, increase the integral gain until any offset is corrected for on a time scale appropriate for your system. If you increase this gain too much, you will observe significant overshoot of the SP value and instability in the circuit. Once the integral gain is set, the derivative gain can then be increased. Derivative gain will reduce overshoot and damp the system quickly to the SP value. If you increase the derivative gain too much, you will see large overshoot (due to the circuit being too slow to respond). By playing with the gain settings, you can maximize the performance of your PID circuit, resulting in a circuit that quickly responds to changes in the system and effectively damps out oscillation about the SP value.

Control Type	K_p	K_i	K_d
P	$0.5K_u$	-	-
PI	$0.45K_u$	$\frac{1.2K_p}{P_u}$	-
PID	$0.6K_u$	$\frac{2K_p}{P_u}$	$\frac{K_p P_u}{8}$

While manual tuning can be very effective at setting a PID circuit for your specific system, it does require some amount of experience and understanding of PID circuits and response. The Ziegler-Nichols method for PID tuning offers a bit more structured guide to setting PID values. Again, you'll want to set the integral and derivative gain to zero. Increase the proportional gain until the circuit starts to oscillate. We will call this gain level Ku. The oscillation will have a period of Pu. Gains are for various control circuits are then given below in the chart.

Updating the Firmware

Introduction:

The firmware on the Servo Cylinder is field upgradeable through a serial connection. The update process uses a windows based utility called PC_Loader.exe to load the new version of the firmware onto your Servo Cylinder. Contact Ultra Motion to obtain a copy of the firmware and the windows update utility before getting started.

Pre-requisites:

- A cable assembly with a minimum of a power and serial connection.
- A USB mini-B cable
- The PC_Loader.exe utility.
- The firmware .HEX file.

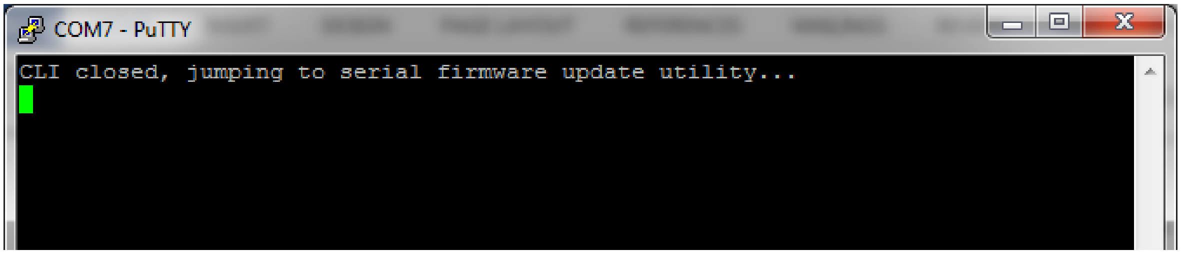
Update Instructions:

WARNING: While updating your firmware the Servo Cylinder will be put into an inoperable state. Make sure there is no load applied to the Servo Cylinder before starting this process. It is a good practice to remove the Servo Cylinder from the machine or installed location before initiating the update.

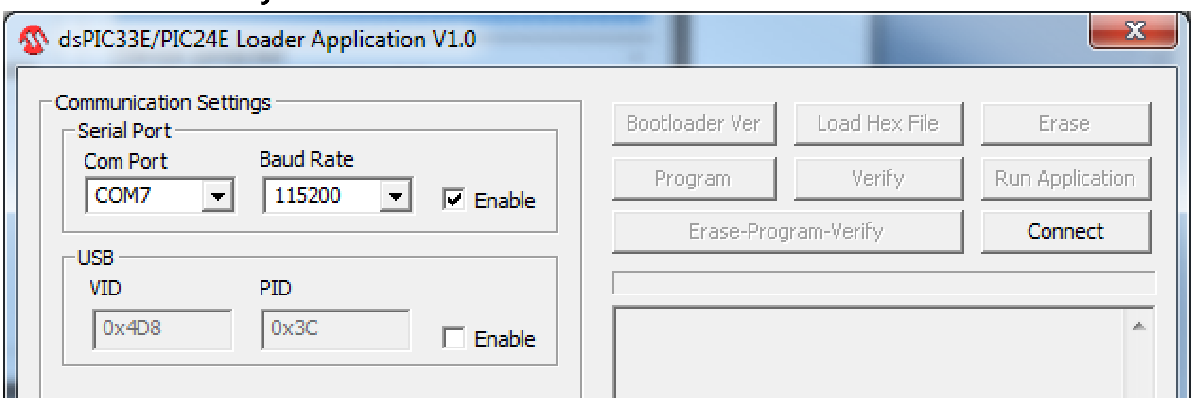
WARNING: Do not unplug or power cycle the Servo Cylinder until the update process has completed.

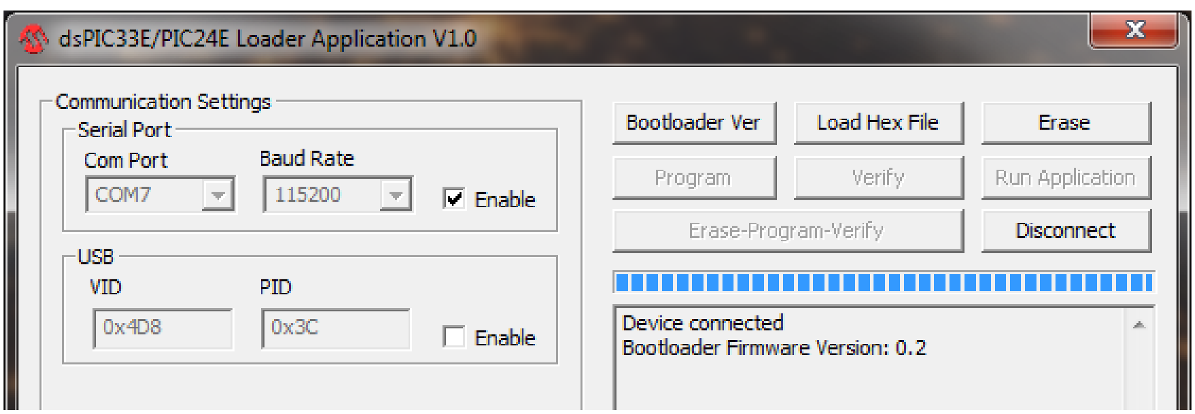
1. Connect the Servo Cylinder to the serial port on a windows computer.
2. Connect the "config" port on the Servo Cylinder to a USB port on your windows computer with the USB mini-B cable.
3. Connect the Servo Cylinder to a power supply and turn on power.
4. On the windows computer, browse to the drive labeled "Ultra Motion".
5. Copy the CONFIG.TXT and HARDWARE.TXT files on the drive and paste them in a location of your choice on the computer to create a backup.
6. Determine which COM port you are connected to:
   a. Open Windows Device Manager.
   b. Expand the port section.
   c. Determine which of the listed ports is connected to your Servo Cylinder.
7. Open a serial terminal program such as Putty. Establish a serial connection (select appropriate COM port and baud rate). The default baud rate is 115200. If you have changed this in your CONFIG.TXT file, please use whatever value is listed there.

8. Press Enter to ensure that the CLI prompt “>” is printed to the terminal.
9. With a serial connection established, type serial command “ZU321” to enter update mode. The STATUS LED on the Servo Cylinder will flash either blue or blue/green. The image below is what you should see in the terminal window after entering the ZU321 command.

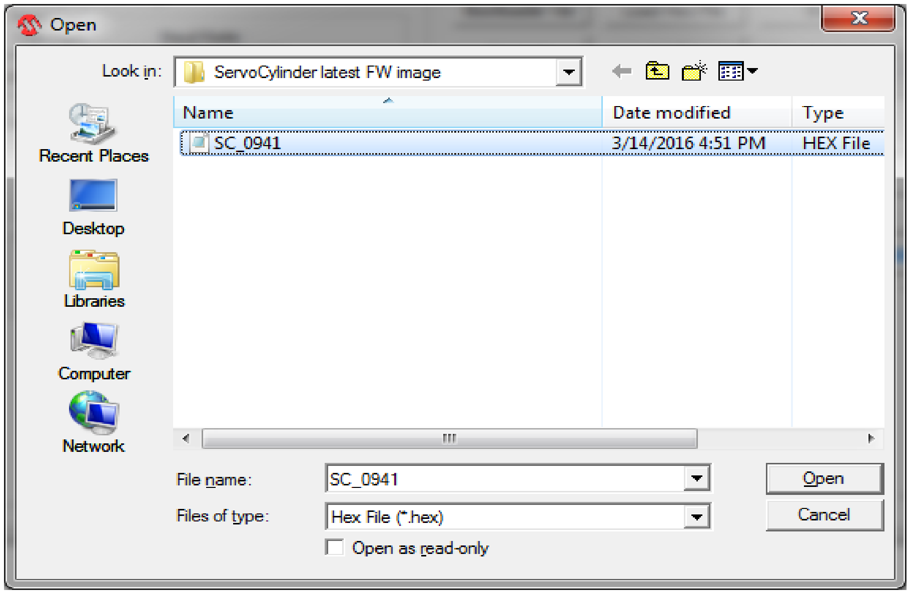


10. Once the updater has been started (indicated by flashing blue or blue/green STATUS LED or the message shown above), close the terminal emulator (Putty or similar) to free the PC’s COM port for the firmware update utility.
11. Launch the PC_Loader.exe program.
12. Select the appropriate COM port. The baud rate for the firmware updater is fixed at 115200.
13. Hit the “connect” button as shown below to establish connection. Once connected you will see confirmation. **It must say Bootloader Firmware Version 0.2** to indicate a successful connection.

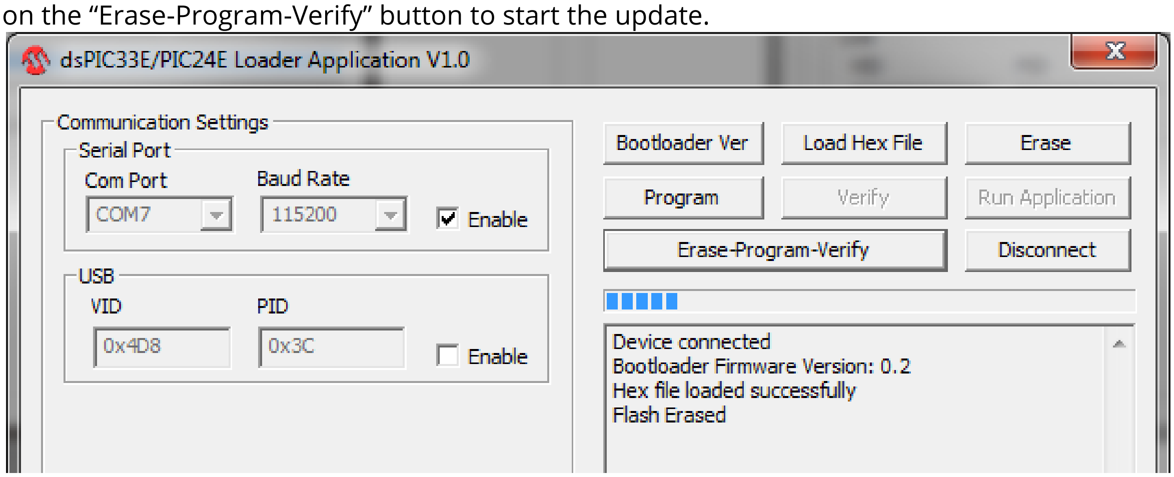




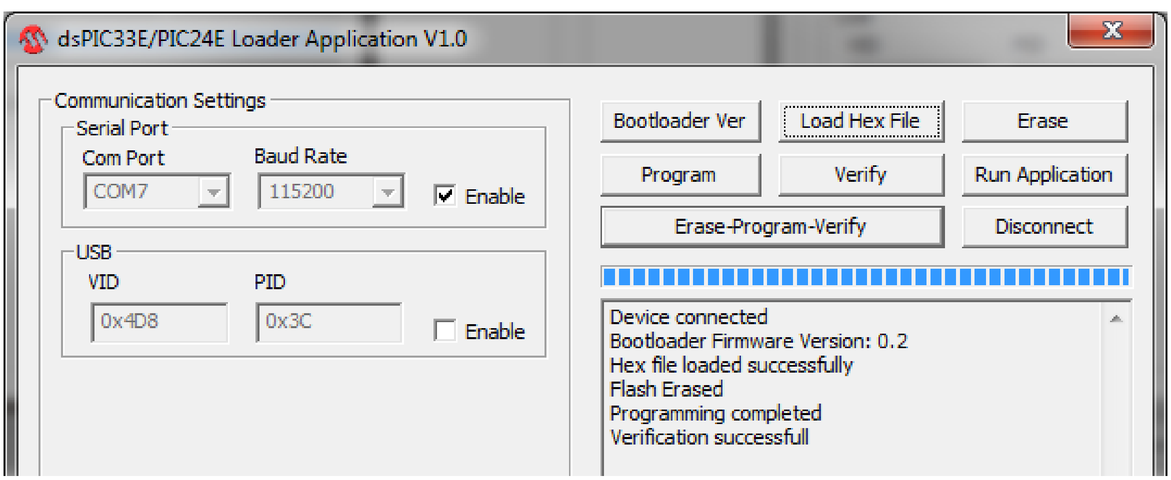
14. Once connected, click “Load Hex File” and navigate to the firmware file you would like to use for the update (Intel .hex file format). Click “Open”



15. Click on the “Erase-Program-Verify” button to start the update.



16. Once complete. You will see “programming complete” and “verification successful”. See screenshot below.



17. Click “Run Application” to run the new firmware image. Since neither the CONFIG.TXT or the HARDWARE.TXT file are present (both have been overwritten by the firmware update), the Servo Cylinder will start in Safe Mode with the motor disabled and the STATUS LED solid red.
18. Close the PC_Loader application.
19. With the USB cable connected, browse to the drive labeled “Ultra Motion” on the windows computer.

20. Paste the previously backed up HARDWARE.TXT and CONFIG.TXT files onto the "Ultra Motion" drive.
    The firmware update will leave an empty CONFIG.TXT on the drive. Overwrite this empty file with the backed up version of CONFIG.TXT.
21. Restart Servo Cylinder. This can be done by cycling the power, or issuing the command "ZR321" to the CLI.
    After restart, the STATUS LED should be solid green.
22. If the STATUS LED is red after restart, establish a serial connection via putty or similar program. Power cycle the actuator and note the error message(s) displayed in the terminal window. Contact Ultra Motion for assistance troubleshooting any error.

Troubleshooting

Status Light Definitions

LED Activity	Indicated Status
Green (solid)	Normal Operation
Red (solid)	Safety Self-Shutdown (Several possible causes): Critical CONFIG.TXT error, critical HARDWARE.TXT error, errMode has triggered a shutdown, dip switches set both ON at startup • Motor disabled (coast)
Green Flash	USB connected (1x flash) or disconnected (2x flash)
Blue Flash	RS232 connected (1x flash) or disconnected (2x flash)
Red Flash	One (1) Flash per fault that has occurred. Faults that cause a red flash: • rStopFault: Actuator has hit retracted physical stop (as defined in HARDWARE.TXT) • eStopFault: Actuator has hit extended physical stop • vBusHFault: Excessive supply voltage(> 44.0V (42.0V hyst)), dynamic braking was triggered • vBusLFault: Supply voltage has been too low (< 6.75V), motor coast was triggered • drvFault: Bridge driver IC has indicated a fault • cpuFault: CPU error trap was hit • adcFault: Current feedback was saturated on one or more of the motor phases (>25 amps) • uartFault: UART error • pulseFault: Pulse was received on outside of the valid PWM range (1-2ms Pulse mode only) • quadFault: A logical error was detected on A/B quadrature input (A/B quadrature mode only)

Appendix A: Serial Command Line Interface (CLI) List of Commands

Read Commands

AN – Read Analog Inputs

Parameter: 1 to 3, or none

Request the value of the Servo Cylinder's voltage input, current input, or built-in temperature sensor. Sending this command with no argument will return the value for all three analog inputs. Returned values will be unsigned integers.

AP – Read Actuator Position

Parameter: None

The AP command will output the absolute position of the Servo Cylinder. One revolution of the Servo Cylinder's screw is equivalent to 1,024 counts of Phase Index.

BV – Read Bus Voltage

Parameter: None

Calling BV will return a value from 0 to 1023 (0 Volts to 50 Volts), which represents the value of the Servo Cylinder supply voltage.

DI – Read Digital Input

Parameter: 1 to 4, or none

Request the value of the Servo Cylinder's digital inputs, both optically isolated inputs (IN1/IN2) and GPIOs (DIO1/DIO2). Sending this command with no argument will return the value for all of the digital inputs.

Important: The digital state of OPTO1 and OPTO2 is inverted from convention. When IN1 or IN2 has voltage applied to it, OPTO1/OPTO2 switches from 1 to 0.

Note: Not to be confused with the command D1, D2 – Set Mode for DIO1 and DIO2 (Respectively)

Parameter	Digital Input
1	OPTO1 (IN1)
2	OPTO2 (IN2)
3	GPIO1 (DIO1)
4	GPIO2 (DIO2)

FS – Read Firmware Version and Serial Number

Parameter: None

Description: Request the firmware version currently running on the Servo Cylinder as well as the unique product serial number.

HE – Display the Help Table

Parameter: None

Sending this command will print out a list of all Serial CLI commands.

QP – Read Position Setpoint

Parameter: None

Request the position setpoint currently being commanded by the chosen operating mode.

RC – Read 1 to 2ms Pulse (PWM) Input

Parameter: None

Request the value of the 1 to 2 ms pulse being read by the Servo Cylinder. This command is only valid in pulse mode.

SR – Read Status Register

Parameter: 0 to 31, or none

Sending the SR command without an argument will return the value of the status register in hex format. Calling the SR command followed by a value from 0 to 31 will return the value of the corresponding status register bit.

For example:

Input: SR 4

Output: bit4: "Emergency over-volt" = false

Another example:

Input: SR

Output: Status Register: 0x000610A7

Refer to “Using the Status Register Feature” on page 35 for detailed information regarding the status word.

TQ – Read Motor Torque

Parameter: None

Request the transformed three phase current feedback, which is a measure of motor torque (-32768 to 32767).

VL – Read Actuator Velocity

Parameter: None

Request the velocity of the actuator as measured by the change in Phase Index over a time interval. Negative values represent motion towards the retracted direction; positive values represent motion towards the extended position.

Set Commands

AC – Set Acceleration for Trajectory Moves

Parameter: 0 to 65535, or none

Set the acceleration/deceleration value to be used in the Servo Cylinder’s built in trajectory generator. Sending this command without an argument will return the current value of AC.

$$Accel\left(\frac{in}{s^2}\right) = \frac{AC * 1{,}250^2 * l}{2^{16} * 1024}$$
$$l = screw\ lead$$

CG – Coast On

Parameter: 321

Disable the Servo Cylinder motion.

WARNING: Enabling Coast electrically decouples the motor from the power stage, removing all power from the motor. Enabling coast is not recommended for applications in which back-driving is possible. **Care must be taken when enabling coast!**

CS – Coast Off

Parameter: 321

Description: Return power to the BLDC motor allowing for normal operation of the Servo Cylinder.

WARNING: Re-energizing the motor will cause the Servo Cylinder to immediately move to the current commanded position. **Care must be taken when disabling Coast!**

D1, D2 – Set Mode for DIO1 and DIO2 (Respectively)

Parameter: 0 to 4, or none

Set the function of the Servo Cylinder's General Purpose Input / Output (GPIO) pins (DIO1 and DIO2). Sending this command without an argument will return the current programmed value.

Note: Not to be confused with the command DI – Read Digital Input

Parameter	DIO Pin Function
0	Input (high impedance)
1	Ground (sink up to 250 mA)
2	Output +5 Volts (source up to 250 mA)
3	Output Status Bit (see Using the Status Register Feature)
4	Output 1 kHz +5 V PWM (See H1, H2 – Set the PWM Output Signal Type on DIO1 and DIO2 (Respectively))

H1, H2 – Set the PWM Output Signal Type on DIO1 and DIO2 (Respectively)

Parameter: 0 to 7, or none

Rules: D1 and/or D2 = 4

The value assigned to H1 represents the source for the PWM duty cycle. All source ranges are converted to the PWM duty cycle range of 0 to 60,000. Sending this command without an argument will return the current value.

Parameter	Output Signal Type	Range
0	Actuator Position	spMin to spMin
1	Actuator Velocity	-512 to 511
2	Actuator Torque	-32768 to 32767
3	Bus Voltage	0 to 1023
4	Commanded Position	spMin to spMin
5	1 to 2ms Pulse (PWM) input channel	pMin to pMax
6	Analog voltage input	vMin to vMax
7	Analog current input	cMin to cMax

IM – Set Serial Interface Mode

Parameter: 0 or 1

The serial interface can be set to operate in "Human Mode" or "Machine Mode"

Parameter	Mode	Description
0	Human Mode	• All commands are followed by an ACK or NACK • Asynchronous error messages are sent to the serial prompt • Detailed information regarding actuator commands is written to the serial prompt
1	Machine Mode 1 (MACHINE1)	• Asynchronous error messages are disabled • No detailed information is sent to the serial prompt • ”im0 26” sets interface back to Human Mode (Case Sensitive)
2	Machine Mode 2 (MACHINE2)	• Every command must be followed by a checksum

KD - Set Derivative Gain for Position PID Filter

Parameter: 0 to 32767, or none

Set coefficient for the derivative portion of the position PID filter. Sending this command without an argument will return the current value of KD.

KI - Set Integral Gain for Position PID Filter

Parameter: 0 to 32767, or none

Set coefficient for the integral portion of the position PID filter. Sending this command without an argument will return the current value of KD.

KP – Set Proportional Gain for Position PID Filter

Parameter: 0 to 32767, or none

Set coefficient for the proportional portion of the position PID filter. Sending this command without an argument will return the current value of KD.

MT – Set Limit for Maximum Commanded Torque

Parameter: 0 to 32767, or none

Vary the maximum allowable force produced by the Servo Cylinder. MT works by limiting the maximum commanded current in the Field-Oriented Control loop. Sending this command without an argument will return the current value of MT.

PA – Set Absolute Target Position

Parameter: spMin to spMin, or none

Sending this command without an argument will return the current value of PA. Sending this command with a valid argument between spMin and spMin will result in an immediate move to the requested position.

The PA command directly writes the position register of the actuator, bypassing all trajectory generation. This leads to a full acceleration, full speed move to the target position. Users will typically use this command for maximum dynamic performance or in conjunction with their own trajectory generator.

PC – Set Target Position to Current Position

Parameter: None

Set the current position as the Servo Cylinder’s setpoint, causing the actuator to hold in place.

PO – Set Target Position Offset

Parameter: See Description

Move a relative distance from the Servo Cylinder’s current position. This command will not execute if the requested offset move will send the actuator beyond spMin or spMax.

The PO command directly writes the position register of the actuator, bypassing all trajectory generation. This leads to a full acceleration, full speed move to the target position. Users will typically use this command for maximum dynamic performance or in conjunction with their own trajectory generator.

SP – Set Maximum Speed for Trajectory Moves

Parameter: 0 to 50000000, or none

Set the max speed value to be used in the Servo Cylinder's built in trajectory generator. Sending this command without an argument will return the current value of SP.

$$l = screw\ lead$$

$$maxSpeed\left(\frac{in}{s}\right) = \frac{SP * 1{,}250 * l}{2^{16} * 1{,}024}$$

W1, W2 – Set Status Register Bit Mask for GPIOs DIO1 and DIO2 (Respectively)

Parameter Type: Unsigned Long

Rules: D1 = 3 and/or D2 = 3

The value of DIO1 or DIO2 will be 0V when the result of a bitwise AND between the status register and the bit mask is equal to zero, and +5V when the result of the operation is a non-zero number. Example uses include limit switch outputs, over-voltage indication, active trajectory indication, etc. See

(page 33) for detailed information regarding the status word. Sending this command without an argument will return the current value.

X1System Commands

ZC – Run Calibration Routine

Parameter: 321

This command should only be sent after consulting with Ultra Motion engineers. The Servo Cylinder must be free to move and be at a position at least one revolution from either hard-stop. The CONFIG.TXT file should be saved to a local location. After calibration, the HARDWARE.TXT file is written and the Servo Cylinder is reset, at this time CONFIG.TXT should be reloaded on to the Servo Cylinder.

ZD– Read Bridge Driver DIAG Register

Parameter: 321

Read the detailed bridge driver diagnostic information from the Servo Cylinder.

ZF – Clear Latching Fault Flags in Status Register

Parameter: None

Clear all latching fault flags in the status register.

ZR – Reset Actuator

Parameter: 321

Power cycle the actuator. This must be done to enact changes to the configuration file.

ZU – Jump to RS232 Firmware Updater

Parameter: 321

Suspend normal operation of the Servo Cylinder and launch the on-board bootloader to update the firmware. The actuator should be removed/disconnected from the machine to prevent potential damages and must be disconnected from USB.

Trajectory Commands

Trajectory commands are used to smoothly move the actuator to a desired position using the user configurable max speed and acceleration.

T1, T2, T3, T4 – Trajectory Move to User Defined Position Pos1, Pos2, Pos3, and Pos4 (Respectively)

Parameter: None

Move to Pos1, Pos2, Pos3, or Pos4 with user defined speed and acceleration (Pos1 through Pos4 defined in CONFIG.TXT).

Command	Position
T1	Pos1
T2	Pos2
T3	Pos3
T4	Pos4

TA – Trajectory Move to Absolute Position

Parameter: spMin to spMin

Sending this command with a valid argument between spMin and spMin will result in a trajectory move to the requested position.

Example: Move to absolute position 25,000 with acceleration value 2,000 and speed 200,000:

AC2000 ↵
SP200000 ↵
TA25000 ↵

TE – Trajectory Move to Fully Extended Position (spMax)

Parameter: None

Move to spMax with user defined speed and acceleration.

TK – Interrupt the current trajectory

Parameter: None

Halt the current trajectory motion before completion.

TM – Trajectory Move to Midpoint

Parameter: None

Move to midpoint with user defined speed and acceleration. The midpoint is defined by

$$\frac{spMin + (spMax - spMin)}{2}$$

TO – Trajectory Move to Offset (incremental trajectory move)

Parameter: See Description

Move a relative distance from the Servo Cylinder's current position using the trajectory generator. This command will not execute if the requested offset move will send the actuator beyond spMin or spMax.

TR – Trajectory Move to Fully Retracted Position (spMin)

Parameter: None

Move to spMin with user defined speed and acceleration.

Serial Data Streaming

X1, X2, X3 – Set Data Stream for Columns 1, 2, and 3 (respectively)

Parameter: 0 to 23

Define what variable each of the three columns are reporting

Parameter	Description
0	Column Off
1	Actuator Position
2	Position Command Setpoint
3	Motor Current
4	Motor Current Setpoint
5	Motor Phase 1 Current
6	Motor Phase 2 Current
7	Motor Phase 3 Current
8	Actuator Velocity at 312.5 kHz
9	Actuator Velocity at 78.125 Hz
10	Encoder Interval Timer
11	Supply Voltage
12	Status Bit Register
13	1 to 2 ms pulse (PWM) Input
14	Filtered 1 to 2 ms pulse (PWM) Input
15	Analog Voltage Input
16	Filtered Analog Voltage Input
17	Analog Current Input
18	Filtered Analog Current Input
19	Temperature Sensor Input
20	Psition Error
21	Quadrature Input Errors
22	1 to 2 ms pulse (PWM) input errors
23	32-bit Timer with 100 μs Increments

XC – Clear Timer

Parameter: None

Reset the 32 bit timer used for synchronizing data to a time interval.

XG – Turn Data Streaming On

Parameter: None

Initiate data streaming.

XR – Display Data Stream Setup

Parameter: None

Display the current stream setup including what variables are being streamed and streaming frequency.

XS – Turn Data Streaming Off

Parameter: None

Stop the data streaming.

XT – Set Data Stream Time Interval

Parameter: 1 to 65535

Define the rate at which data will be sent to the serial prompt. The minimum frequency is 3.576 Hz (XT = 65535); the maximum frequency depends on the Baud rate.

$$Stream\ Rate\ (Hz) = \frac{234375}{XT}$$

$$XT = 2344\ \approx 100\ Hz$$

$$XT = 23438\ \approx 10\ Hz$$

Contact Information

If you have any questions about the Ultra Motion PSU or any of our other products, contact us by one of the following methods:

INQUIRY

Leave a web inquiry (to be replied to within one business day):
ultramotion.com/contact

LIVE CHAT

Live Chat directly with one of our engineers:
ultramotion.com

EMAIL

Email (to be replied to within one business day):
info@ultramotion.com

CALL

PH: 888-321-9178
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