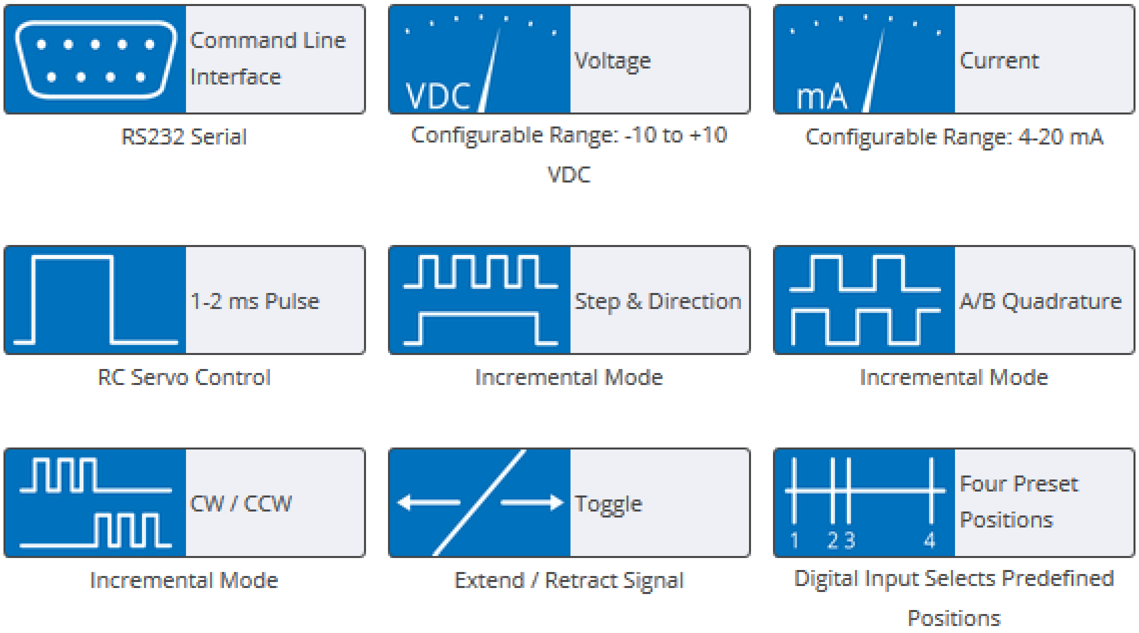
Operating Modes

There are 9 distinct operating modes available for the Servo Cylinder. The icons below represent each available command mode/command input.

IMPORTANT: The RS-232 port and any non-motion related serial commands from the command language can be used in ALL operating modes. Motion related serial commands from the serial command language are only available when in the command line interface operating mode.



There is no need to home the actuator in any of the operating modes

Command Line Interface (RS-232 Serial)

The Servo Cylinder RS-232 serial command line interface (CLI) offers the user complete control over all performance parameters, motion commands, and diagnostic information.

The Servo Cylinder can be controlled through a terminal program such as PuTTY, a PLC, or any program that can operate a serial communication port such as LabVIEW, MATLAB, 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. The Servo Cylinder can also be set to operate in “Machine Mode” where asynchronous messages are turned off, and checksums are sent to ensure communication integrity.

Proportional Mode

Proportional mode offers an extremely simple way to integrate an actuator into an application. The user simply supplies a signal proportional to the desired position, and the Servo Cylinder immediately responds.

Command Types:

Voltage (-10 to 10VDC Range)

Current (4-20mA Range)

PWM (1-2ms Pulse Range)

There is no homing required so the user does not have to worry about intermittent power interruptions causing downtime or failure of their machine due to loss of position. Software ddefinable end-of-stroke limits eliminate the need for limit switches, and the GPIO can be configured to indicate end of stroke, position, velocity, and more, to act as a drop-in replacement to existing systems.

The user simply configures the stroke range, and the corresponding proportional input range, and the Servo Cylinder is ready to use. For example, the user can adjust the configuration file to correlate 0 to 5 VDC to full stroke, or -10VDC to 10VDC to 1” to 3.250”

Incremental Mode

Incremental input mode allows users to realize the benefits of the Servo Cylinder without upgrading their existing control systems or PLCs. The Servo Cylinder will provide high performance BLDC actuation

Command Types:

Step & Direction

CW/CCW

Quadrature Signals

Incremental modes allow the Servo Cylinder to behave as a drop-in replacement to stepper motor systems while providing higher efficiency, increased torque at high speeds, no lost steps or stalling, and smoother operation in an integrated package.

As with all operating modes, there is no homing required. The configurable GPIO can output a bit when the software limit has been met, a PWM signal proportional to the absolute position of the Servo Cylinder, or the absolute position can be read directly over serial.

Two high speed optically isolated digital inputs reject noise and provide robust communication between PLCs and the Servo Cylinder.

Toggle Mode

The Servo Cylinder can be configured to mimic the simplicity of a brushed DC control system with the added performance benefits of a high efficiency, long life BLDC motor.

The actuator immediately responds to a user supplied extend/retract signal sent to the optically isolated digital inputs.

The absolute position capability of the Servo Cylinder eliminates the need for external limit switches and also allows for user configurable acceleration and max velocity for smooth, controlled motion.

Speed or Torque can be controlled by using one of the Servo Cylinder’s analog inputs.

Four Preset Position Mode

Four Preset position mode provides the user with an easy way to perform a variety of positioning tasks. The user selects one of four pre-configured position by toggling the state of the two optically isolated digital inputs (00,01,10,11), causing the actuator to move to the selected position using the Servo Cylinder’s built-in trajectory generator.

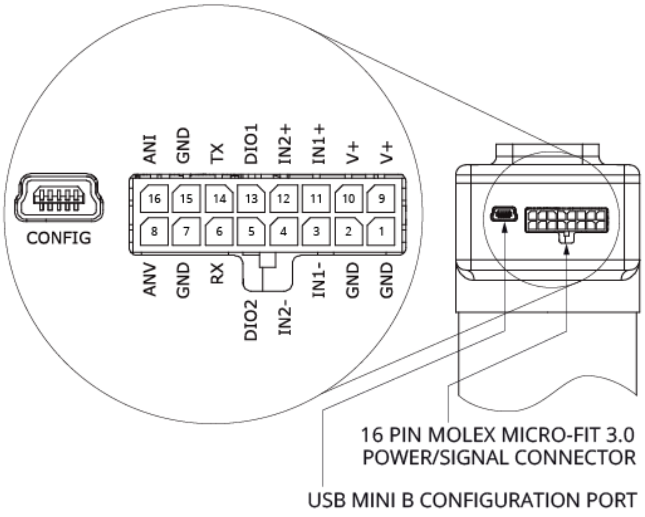
Homing is not required, which increases the ease of integration into machines and reduces complexity.

A user defined input filter is available to reject noise and debounce mechanical switches.

Electrical Specifications

Electrical Interface

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



Power Requirements

Power Shunt: Power shunts are power dissipation devices that engage at a pre-defined voltage level to prevent surplus energy generated by the actuator from further increasing the bus voltage and damaging the Servo Cylinder or other sensitive equipment. Power shunts are always recommended, but especially important in the following applications:

- Applications that require hard/fast deceleration.
- Applications where the load is assisting the actuator's motion (spring, gravity in a vertical application, etc.)

Note: Power shunts must be wired in parallel with the output of the DC power supply. Power shunts must maintain connectivity to the actuator even in the event of a blown power supply fuse or engaged emergency switch. See the **power wiring diagram**

Power Supply:: A 250 Watt, unregulated power supply is recommended. Smaller supplies are suitable for less demanding applications.

8-36VDC Recommended (7-48VDC Absolute Max)

<u>Unregulated Power Supplies (Preferred):</u> 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 does not eliminate the need for a power shunt.

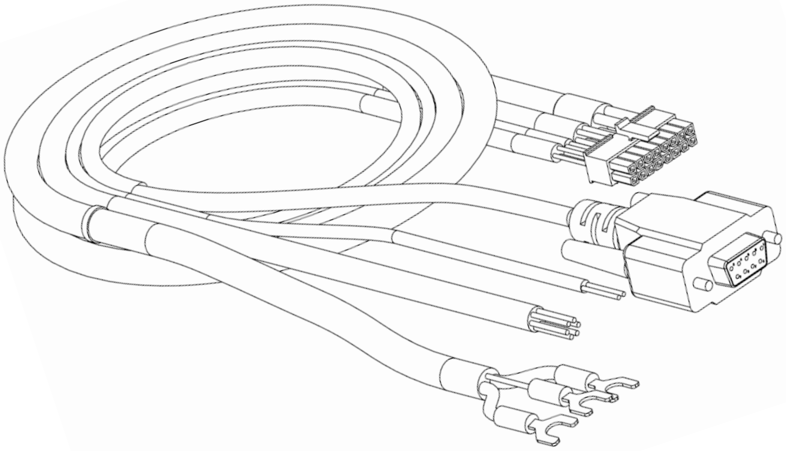
<u>Regulated Power Supplies:</u> Many popular benchtop power supplies are regulated, which are acceptable for applications that don't require high accelerations and cannot be back-driven. Regulated power supplies cannot absorb the energy created during deceleration or back-driving events as effectively 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. To protect the Servo Cylinder from high voltages, a power shunt should be wired in parallel with the power supply. If the power supply has built-in overvoltage protection, this should be set to a maximum of 48VDC to protect the Servo Cylinder.

Fuseable Link: An external, slow burning fuse should be used on the positive leg of the DC power supply to isolate the Servo Cylinder from the power supply in an overloading condition.

Emergency Stop Switch: The use of an emergency stop switch should always be considered by the system designer. The switch should be wired in series and provide a means to easily and rapidly cut power to the actuator during emergency situations. The system designer must fully understand the power-off behavior of the Servo Cylinder in their application before deciding to use an emergency off switch. For instance, cutting power in applications that are lifting a load vertically will result in backdriving of the Servo Cylinder.

Cable Requirements

You will need a Power/Signal Cable and a USB mini B cable to interface with the actuator. These cables can be purchased from Ultra Motion or you can provide your own.



Purchasing Cables from Ultra Motion:

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

POWER/SIGNAL CABLE: Use the information below to specify a cable part number based on what functions your 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 will all wires populated.

All cables start with the base part number **CBL.** See base power cable section below for details.

<u>Choose the additional functions as required:</u>

-S (adds serial capability). See serial cable section below for details.

-AC <u>or</u> **-AV** (adds analog voltage or analog current capability) . See analog cable section below for details.

-D (adds all digital capability including GPIO). See digital cable section below for details.

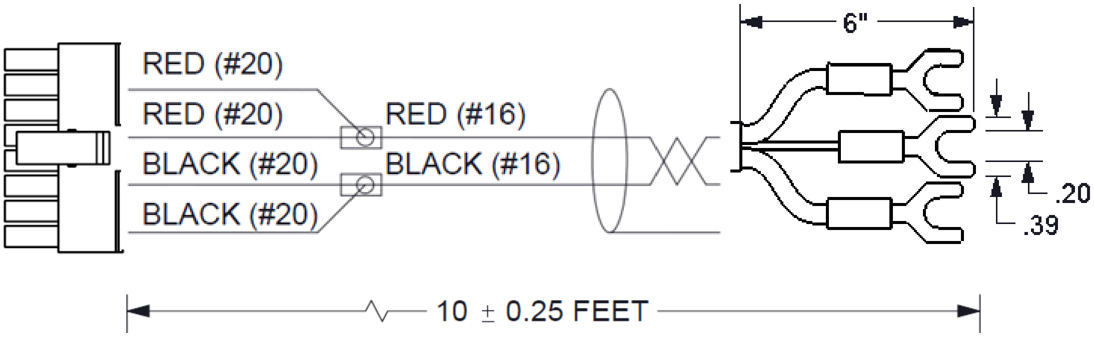
CABLE PART NUMBER EXAMPLE: A user planning to control the actuator with an analog voltage signal (-AV) who also wants access to the Servo Cylinder's GPIO (-D) would specify the following cable assembly part number: CBL–AV–D.

Please note that there is no need to double specify a cable if it is used in two functions. For example, if the user is interested in 1 to 2 ms pulse proportional mode (-D) and also GPIO functionality (-D), the full cable assembly part number is: CBL-D.

- **Base Power Cable (CBL)**

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

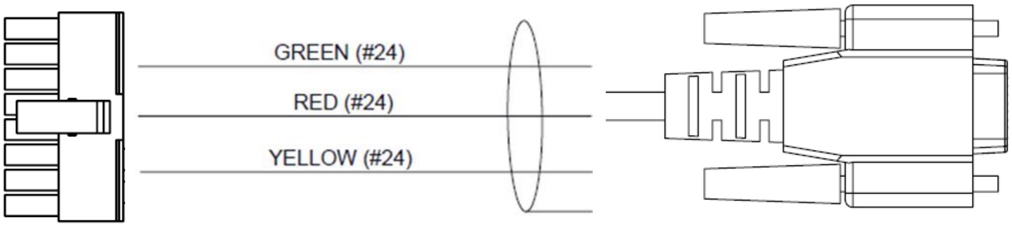
Uses: 1. Supply Power to the Servo Cylinder (Mandatory)



- **RS-232 Serial Cable (-S)**

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

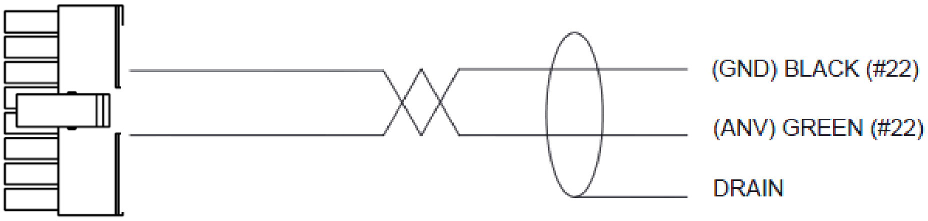
Uses:
1. Command Line Interface Mode
2. RS-232 Diagnostic Information and Data Streaming
3. Updating Firmware



- **Analog Voltage Cable (-AV)**

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

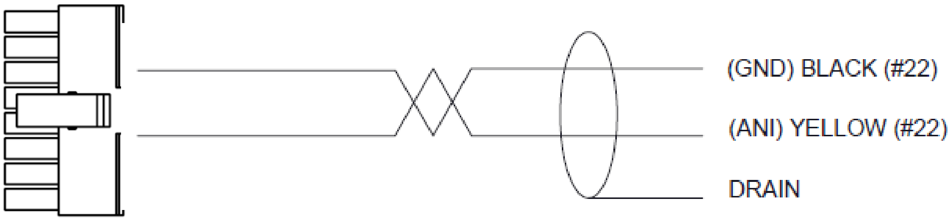
Uses:
1. -10V to 10V Proportional Input Mode
2. Toggle Mode with -10V to 10V control of speed or force



- **Analog Current Cable (-AC)**

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

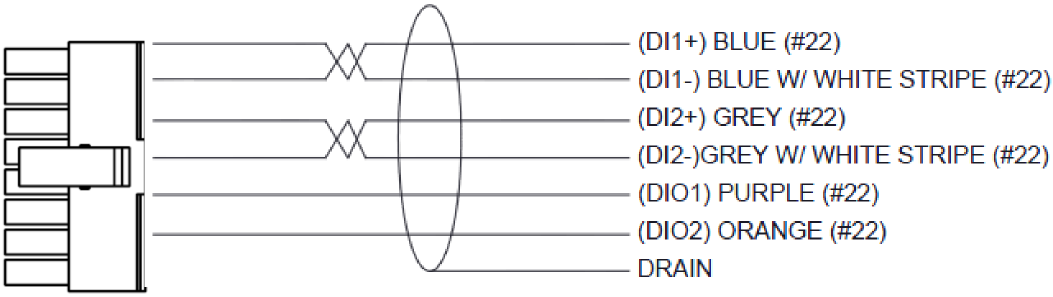
Uses:
1. 4 to 20 mA Proportional Input Mode
2. Toggle Mode with 4 to 20 mA control of speed or force



- **Digital Cable (-D)**

Cable Specification: (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 Functionality



Building Your Own Cable

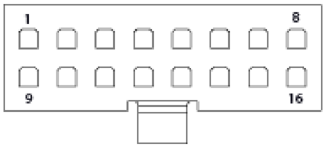
If you choose to create your own cable assembly, the following information will detail everything required to build your own.

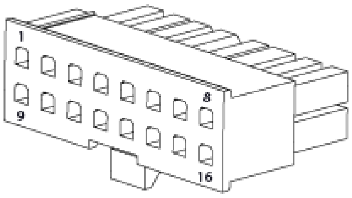
The part numbers for the required Molex parts are listed below:

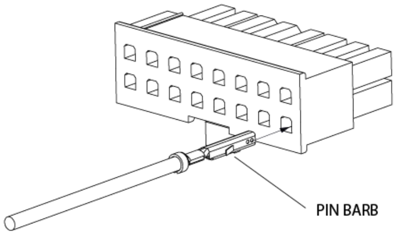
1. MOLEX Connector P/N: 43025-1600
2. MOLEX Crimping Tool P/N: 63819-000
3. MOLEX Crimp Pins (20-24 AWG): 43030-0008
4. MOLEX Pin Extraction Tool: 11-03-0043

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

PIN NUMBER	FUNCTION
1	ANI
2	GND
3	TX
4	DIO1
5	IN2+
6	IN1+
7	V+
8	V+
9	ANV
10	GND
11	RX
12	DIO2
13	IN2-
14	IN1-
15	GND
16	GND



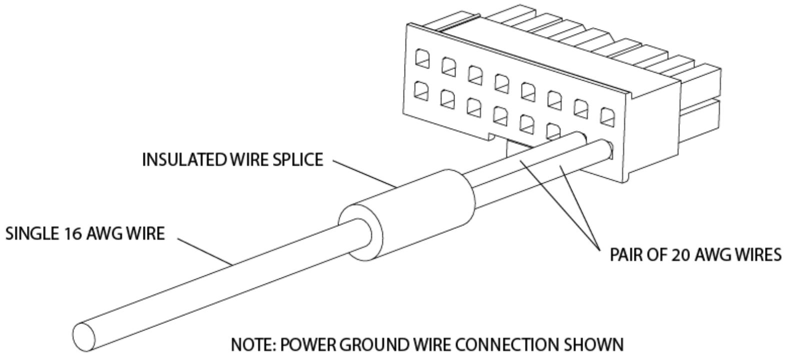




Note: The pin barbs should always be on the side of pins as they are inserted into the socket

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. The pair of 20AWG wires from V+ are to be inserted into pins 7 and 8 of the connector. Likewise, the pair of 20AWG wires from PWRGND are to be inserted into pins 15 and 16 of the connector. Multiple Servo Cylinders **should not** be daisy chained together by their power pins.

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



NOTE: POWER GROUND WIRE CONNECTION SHOWN

3.0 Operation

Getting Started

IMPORTANT: 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.

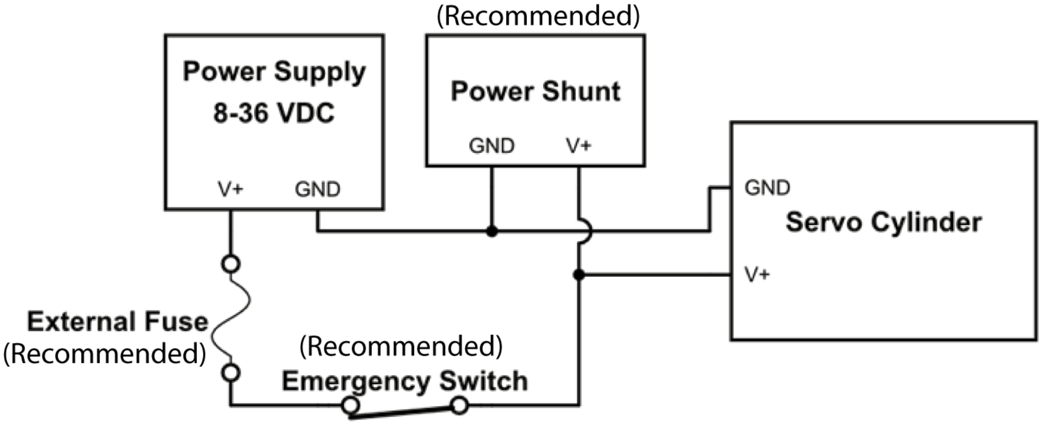
Make sure you have read the Cabling Requirements section before getting started.

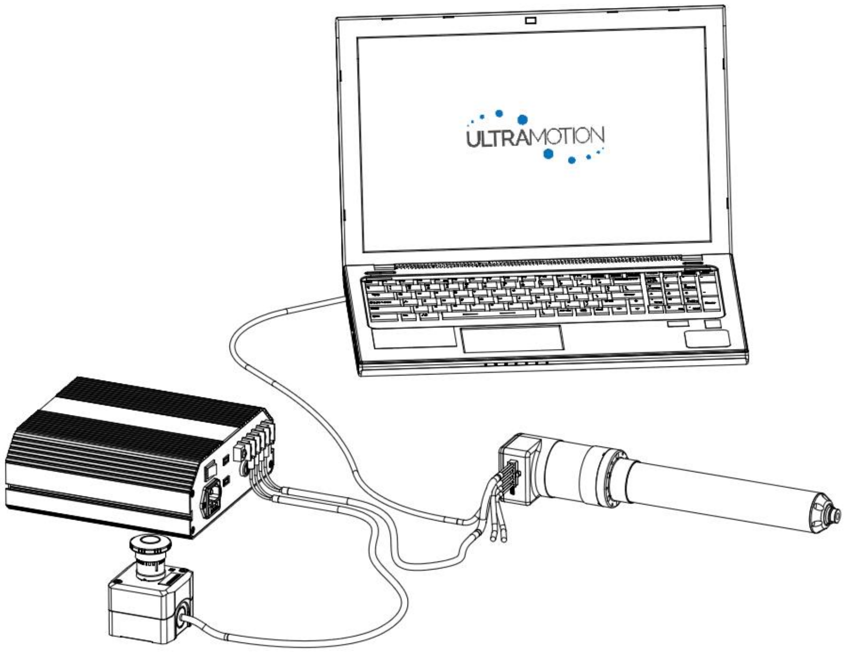
Connecting the Servo Cylinder

Wiring to a DC power source

⚠ DO NOT TURN POWER ON THE SERVO CYLINDER UNTIL ALL WIRING IS COMPLETE.

Once you have your cabling, wire the power leads to a power supply as shown below. We recommend using a power shunt, external fuse, and emergency off switch. Please ensure you have properly designed your power system and addressed all safety concerns.





Note that the Ultra Motion power supply shown above has an internal DC side fuse, power shunt, and two external terminals for an emergency switch wired to properly maintain connections to the power shunt and protect the Servo Cylinder from back-emf in the event of a blown fuse, or tripped E-switch.

Wiring the Analog Inputs (Used for Proportional Mode with Voltage or Current Control Only)

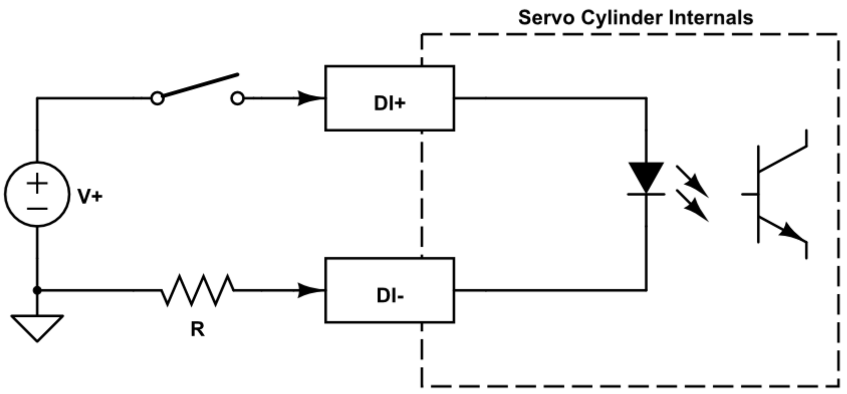
Care should be taken to ensure analog signals are properly shielded against EMI, and are routed separately from power wires and other sources of interference. When possible, a 100% foil shield should be used and the shield electrically connected to ground.

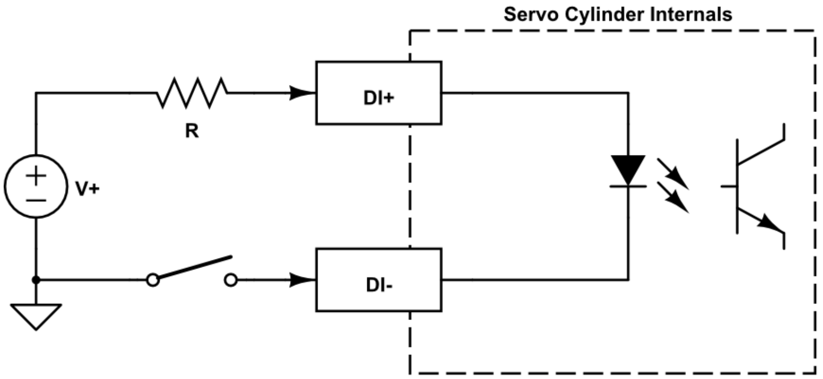
Wiring the Digital Inputs (Used for Proportional Mode with 1-2ms Pulse Control, All Incremental Modes and access to the general purpose I/O)

The Servo Cylinder has two dedicated, optically isolated digital inputs. An opto-isolator transmits an electrical signal between two electrically isolated circuits via light. The use of optically isolated inputs allow for high data transfer rates, protection from high voltages, and very effective noise rejection.

For the highest level of noise rejection, the input signal and ground to the opto-isolator should be completely separate from the Servo Cylinder, but this is not a requirement. The +5 V or ground of the optically isolated input can be supplied by one of the Servo Cylinder’s on-board digital input/output pins.

Suggested wiring for the optically isolated inputs is shown below for both high side and low side switching arrangements.

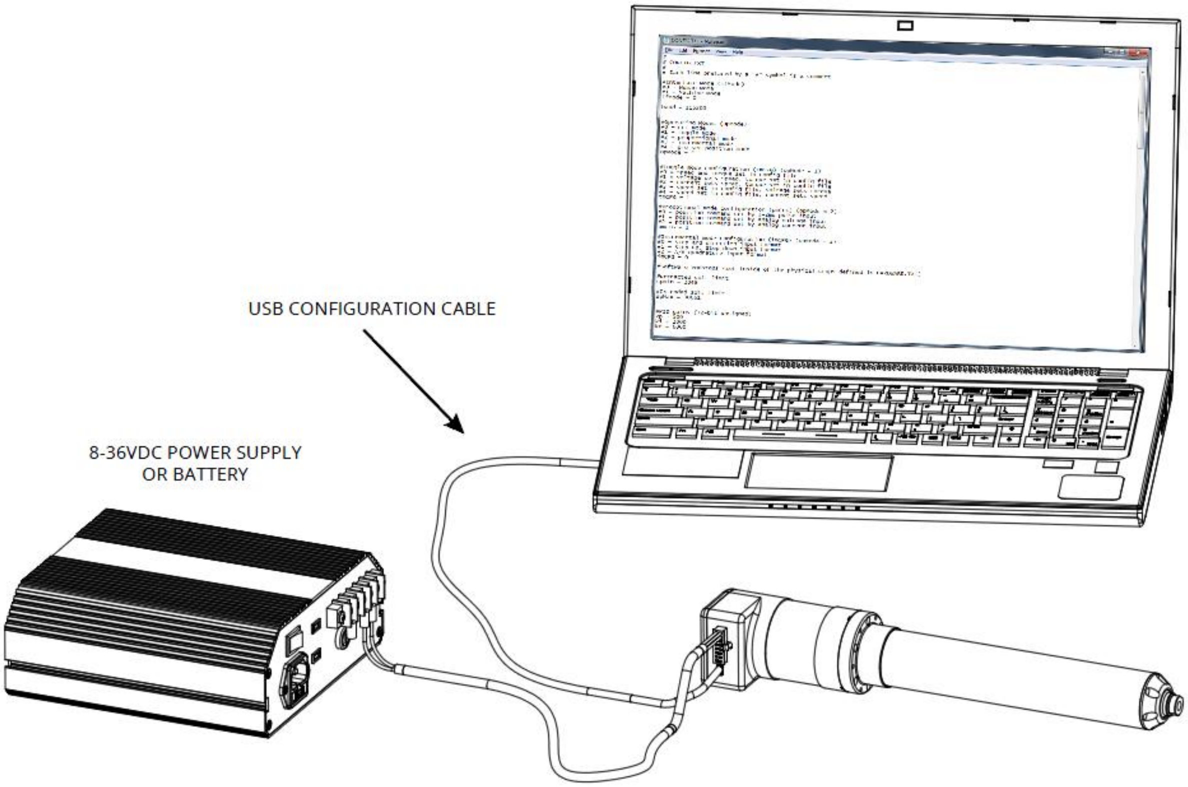




The Servo Cylinder’s digital inputs can be driven by a +5VDC to +24VDC signal. Depending on the voltage, the suggested values for the external resistor (R) are as follows.

Signal Voltage (V+)	Suggested Resistor (R)
+5 VDC	No external resistor required
+12 VDC	430 Ohm Resistor
+24 VDC	1.1 kOhm Resistor

Configuring the Servo Cylinder



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 variables that determine how the actuator will behave.

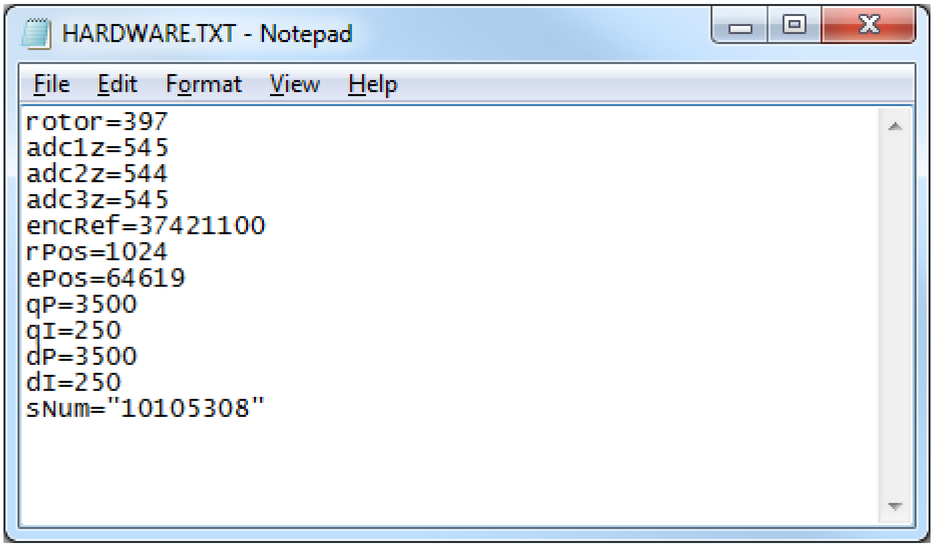
WARNING: The Servo Cylinder's microcontroller needs both HARDWARE.txt and CONFIG.txt to operate. Deleting, removing, or renaming this file will result in a fault mode. We recommend creating a backup of these files to your local drive before starting to edit them.

WARNING: Do not use the 10KB of flash memory to store backup copies of CONFIG.txt and HARDWARE.txt. Storing any files other than 1 CONFIG.txt and 1 HARDWARE.txt will use up the available storage space.

HARDWARE.txt

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 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 SCL language.

Example of a hardware.txt file:



```
rotor=397
adc1z=545
adc2z=544
adc3z=545
encRef=37421100
rPos=1024
ePos=64619
qP=3500
qI=250
dP=3500
dI=250
sNum="10105308"
```

CONFIG.txt

This file contains user settable variables that change how the actuator behaves (operating mode, retracted position limit, extended position limit, 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 variables easier if you are not comfortable with manual configuration.

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

NOTE: The Servo Cylinder comes pre-configured to operate in SCL Mode. We recommend you configure the actuator for your application, but you can skip this step if you want to just run the actuator in SCL mode with default settings and travel limits.

Steps to complete for Manual Configuration of CONFIG.txt:

1. Use the provided USB cable to connect the Servo cylinder to a USB port on any Windows based computer
2. Switch on your power supply. Note that you must power the Servo Cylinder before starting the configuration process. The USB cable is used only for data transmission and will not power the Servo Cylinder
3. Once powered, the computer will automatically recognize the Servo Cylinder as a mass storage device

Note: If the computer fails to automatically recognize the actuator, please contact Ultra Motion for support

4. Browse to “my computer” and open the new storage drive labeled “Ultra Motion”
5. Locate the text file “CONFIG.txt” and open it in a text editor
6. Edit the variables to configure the actuator to behave as desired. Reference the following sections “Manditory Configuration Variables for All Operating Modes”.
7. Based on your chosen operating mode, reference the relevant section for configuration variables specific to your control mode.
8. Save the file locally and then copy it to the Ultra Motion drive to REPLACE the config.txt file currently on the Servo Cylinder. If there is no CONFIG.txt file, just copy this new file onto the drive. Alternatively, you can download and save the generated CONFIG.txt directly to the “Ultra Motion” drive.

Mandatory Configuration Variables for All Operating Modes

Several configuration variables are relevant to all operating modes and must be set for proper operation of the Servo Cylinder. The configuration variables that apply in all modes are the following:

opMode (Operating mode)

What it does: Sets the Servo Cylinder’s operating mode

Argument Type: Integer

Valid Range: 0 to 4 (See below for details)

0 = CLI mode

- Full control through Ultra Motion Serial Command Language
- Operates via a RS-232 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/deceleration speed, and force.
- See tmCFG variable for additional configuration options.

2 = proportional mode

- Actuator moves proportional to the command signal.
- See pmCFG variable for additional configuration options.

3 = incremental mode

- Actuator moves as it receives each incremental command signal.
- See imCFG variable for additional configuration options.

4 = pre-set position mode

- Actuator has up to four preset positions.
- See Pos1, Pos2, Pos3, Pos4 variables for defining the positions.

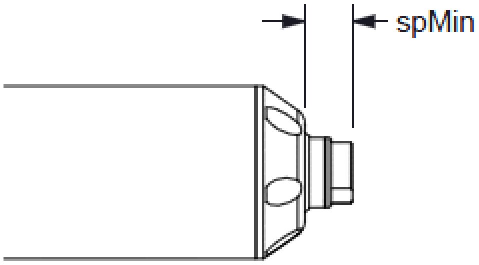
spMin (Software position minimum)

What it does: 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.

Argument Type: Integer

Valid Range: 0 to ePos (ePos is the physical extended travel limit which can be found in hardware.txt)

Rules: 0 ≤ spMin < spMax



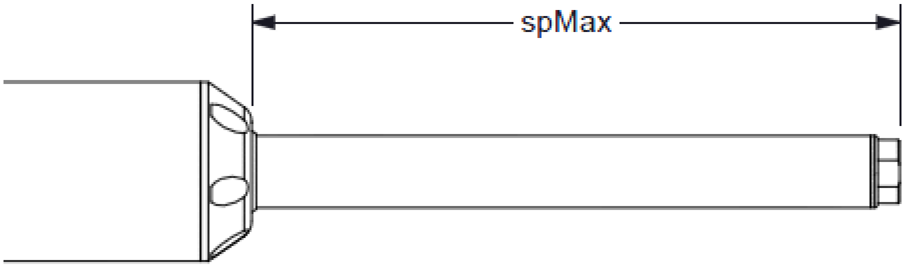
spMax (Software position maximum)

What it does: Sets the maximum allowable position of the Servo Cylinder. spMax 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.

Argument Type: Integer

Valid Range: 0 to ePos (ePos is the physical extended travel limit which can be found in hardware.txt)

Rules: spMin < spMax ≤ ePos



maxTorq (Max Torque)

What it does: 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.

Argument Type: Integer

Valid Range: 0 to 32767.

kp, ki, kd

What it does: 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.

Argument Type: Integer

Valid Range: 1 to 32767

Baud (Serial baud rate)

What it does: 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.

Argument Type: Integer

Valid Range: 2400 to 256,000

Notes: Default Baud rate is 9600, maximum Baud rate is 115200. Lower baud rates are more tolerant to noise and cross talk.

Proportional Mode- Voltage Control Configuration:

The actuator position will be directly proportional to the value of the analog voltage supplied to the Servo Cylinder. You can set your input voltage range to be anywhere between -10 VDC to +10 VDC. Typical signal sources include PLC's, potentiometers, signal generators, etc.

pmCFG (Proportional Mode Configuration)

What it does: Sets behavior in proportional mode

Argument Type: Integer

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

0 = position command set by 1-2ms pulse input

1 = position command set by analog voltage input

2 = position command set by analog current input

vMin/vMax

**Only applies when setting pmCFG=1

What it does: Define the usable range of the -10 to +10 V input that will relate to the Servo Cylinder travel range (sMin to sMax).

Argument Type: Integer

Valid Range vMin: 0 to 65520

Valid Range vMax: 0 to 65520

Rules: vMin < vMax

Example: To have a signal of 0 to +5V correspond to a position of sMin to sMax, the following values should be used for vMin and vMax.

$$vMin =$$

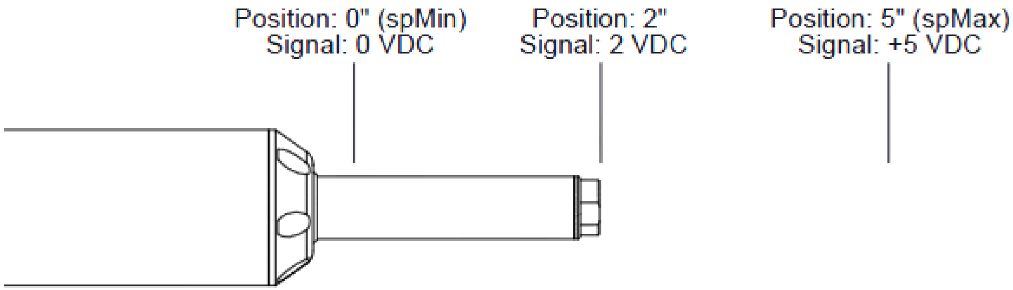
$$vMax =$$

vFilter (Voltage filter)

**Only applies when setting pmCFG=1

What it does: 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 more stable motion and less dithering.

Valid Range: 0 to 65535



Proportional Mode- Current Control Configuration:

The actuator position will be directly proportional to the value of the analog current supplied to the Servo Cylinder. You can set your input voltage range to be anywhere between 4-20 mA. Typical signal sources include PLC's, signal generators, etc.

pmCFG (Proportional Mode Configuration)

What it does: Sets behavior in proportional mode

Argument Type: Integer

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

0 = position command set by 1-2ms pulse input

1 = position command set by analog voltage input

2 = position command set by analog current input

cMin/cMax (Current min/current max)

**Only applies when setting pmCFG=2

What it does: Define the usable range of the 4 to 20 mA input that will relate to the Servo Cylinder travel range (sMin to sMax).

Pre-Requisite: opMode = analog current mode

Valid Range cMin: 0 to 65520

Valid Range cMax: 0 to 65520

Rules: cMin < cMax

Example: To have a signal of 6 mA to 15 mA to correspond to a position of sMin to sMax, the following values should be used for cMin and cMax.

$$cMin =$$

$cMax =$

cFilter (Current filter)

**Only applies when setting pmCFG=1

What it does: 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.

Valid Range: 0 to 65535

Proportional Mode- 1-2ms Pulse Control Configuration:

The actuator position will be directly proportional to the value of the 1-2 ms pulse supplied to the Servo Cylinder. Typical signal sources include PLC's, RC Transceivers, etc.

pmCFG (Proportional Mode Configuration)

What it does: Sets behavior in proportional mode

Argument Type: Integer

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

0 = position command set by 1-2ms pulse input

1 = position command set by analog voltage input

2 = position command set by analog current input

pMin/pMax (Pulse minimum and pulse maximum)

**Only applies when setting pmCFG=0

What it does: Defines the usable range of 1-2 ms pulse inputs that will relate to the Servo Cylinder travel range (sMin to sMax).

0 = 0.954 ms

65535 = 2.046 ms

Argument Type: Integer

Valid Range pMin: 48000 to 70000

Valid Range pMax: 108000 to 132000

Example: To have a signal of 1.5 to 1.75 ms correspond to a position of sMin to sMax, the following values should be used for pMin and pMax.

$$pMin = \frac{(1.5\ ms - 0.954\ ms)}{(2.046\ ms - 0.954\ ms)} * 65535\ counts = 32{,}767$$

$$pMax = \frac{(1.75\ ms - 0.954\ ms)}{(2.046\ ms - 0.954\ ms)} * 65535\ counts = 47{,}770$$

<u>pFilter (Pulse filter setting)</u>

**Only applies when setting pmCFG=0

What it does: The 1-2 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.

Range: 1 to 65534

Incremental Modes Configuration (Step and Directio, A/B Quadrature, Step up Step Down)

<u>imCFG (Incremental mode configuration)</u>

What it does: Sets the behavior in incremental mode

Argument Type: Integer

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

0 = Step and direction input format

1 = Step up, Step down input format

2 = A/B quadrature input format

<u>stepSize</u>

What it does: The value of stepSize details the amount of Phase Index steps taken per incremental command.

Argument Type: Integer

Valid Range: 1 to 65535

Command Line Interface Mode Configuration

The user will have complete control over the Servo Cylinder as well as detailed diagnostic information. Reference Appendix A for the full set of available serial commands.

Baud (Serial baud rate)

What it does: Sets the Baud rate for serial communication.

Argument Type: Integer

Valid Range: 2400 to 256,000

Notes: Default Baud rate is 9600, maximum Baud rate is 115200. Lower baud rates are more tolerant to noise and cross talk.

ifMode (Interface mode)

What it does: Set the behavior of the Serial Command Line Interface to be either human mode or machine mode.

Argument Type: Integer

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

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

- Checksum follows every command
- Asynchronous error messages are disabled
- No detailed information is sent to the serial prompt
- (\”SI0 CC\” sets interface back to Human 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/deceleration values must be set.

maxSpeed (Maximum speed)

What it does: Limits the maximum speed the Servo Cylinder will reach when executing trajectory moves.

Argument Type: Integer

Valid Range: 0 to 50,000,000

Accel (Acceleration and deceleration)

What it does: Defines the acceleration and deceleration the Servo Cylinder will use when calculating motion profiles for trajectory moves.

Argument Type: Integer

Range: 0 to 131071

Preset Position Mode Configuration

Four 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 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

What it does: Defines the amount of time in milliseconds it takes for a state change on the optically isolated digital inputs to register as a valid command.

Argument Type: Integer

Valid Range: 0 to 65535

Pos1

What it does: Defines the absolute position that corresponds to the first state of the digital inputs. This position is active when digital Input 1 = 0 and digital Input 2 = 0

Argument Type: Integer

Valid Range: 0 to 65535

Pos2

What it does: Defines the absolute position that corresponds to the second state of the digital inputs. This position is active when digital Input 1 = 1 and digital Input 2 = 0

Argument Type: Integer

Valid Range: 0 to 65535

Pos3

What it does: Defines the absolute position that corresponds to the third state of the digital inputs. This position is active when digital Input 1 = 0 and digital Input 2 = 1

Argument Type: Integer

Valid Range: 0 to 65535

Pos4

What it does: Defines the absolute position that corresponds to the fourth state of the digital inputs. This position is active when digital Input 1 = 1 and digital Input 2 = 1

Argument Type: Integer

Valid Range: 0 to 65535

maxSpeed (Maximum speed)

What it does: Limits the maximum speed the Servo Cylinder will reach when executing trajectory moves.

Argument Type: Unsigned long

Valid Range: 0 to 50,000,000

Accel (Acceleration and deceleration)

What it does: Defines the acceleration and deceleration the Servo Cylinder will use when calculating motion profiles for trajectory moves.

Argument Type: Integer

Range: 0 to 131071

stopMode

What it does: Defines the stopping behavior when stopping

Argument Type: Integer

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

0 = snap to position

1 = decelerate at rate set by “accel” variable

2 = brake for 100 ms, then snap to position

Toggle Mode Configuration

tmCFG (Toggle mode configuration)

What it does: Sets behavior in toggle mode

Argument Type: Integer

Valid Range: 0 to 4 (See below for details)

0 = speed and torque set in config file (both torque and speed are static settings)
1 = voltage sets speed, torque set in config file (dynamically controllable torque)
2 = current sets speed, torque set in config file (dynamically controllable torque)
3 = speed set in config file, voltage sets torque (dynamically controllable speed)
4 = speed set in config file, current sets torque (dynamically controllable speed)

mtMin (Max torque minimum)

**Only applies when tmCFG = 1 or tmCFG = 2

What it does: Since you are using an adjustable range to set the torque limit, this variable defines the lower limit for the maxTorque variable when using

Argument Type: Integer

Valid Range: 0 to 32766

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

msMin

**Only applies when tmCFG = 1 or tmCFG = 2

What it does: 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.

Argument Type: Integer

Valid Range: 0 to 32766

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

maxSpeed (Maximum speed)

What it does: Limits the maximum speed the Servo Cylinder will reach when executing trajectory moves.

Argument Type: Integer

Valid Range: 0 to 50,000,000

Accel (Acceleration and deceleration)

What it does: Defines the acceleration and deceleration the Servo Cylinder will use when calculating motion profiles for trajectory moves.

Argument Type: Integer

Range: 0 to 131071

stopMode

What it does: Defines the stopping behavior when stopping

Argument Type: Integer

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

0 = snap to position
1 = decelerate at rate set by “accel” variable
2 = brake for 100 ms, then snap to position

Configuring Outputs and Diagnostics (Available in all Control Modes)

General Purpose Input/Outputs

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.

ioPin1

What it does: Sets the operating mode for digital input/output pin 1

Argument Type: Integer

Valid Range: 0 to 4 (See below for details)

0 = High speed digital input
1 = Output ground (sink up to 2 Amps)
2 = Output +5V (source up to 250 mA)
3 = Output the result of the masked status register (1 kHz update rate)
4 = Output 1 kHz PWM proportional to a variable set by **ioPWM1**

ioPin2

What it does: Sets the operating mode for digital input/output pin 2

Argument Type: Integer

Valid Range: 0 to -4 (See below for details)

0 = High speed digital input
1 = Output ground (sink up to 2 Amps)
2 = Output +5V (source up to 250 mA)
3 = Output the result of the masked status register (1 kHz update rate)
4 = Output 1 kHz PWM proportional to a variable set by **ioPWM2**

ioPWM1

Pre-requisite: ioPin1 is configured to output a 1 kHz PWM waveform (ioPin1 = 4)

What it does: Sets the variable to be output via a 1 kHz PWM waveform on digital input/output pin 1.

Argument Type: Integer

Valid Range: 0 to 7 (See below for details)

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

ioPWM2

Pre-requisite: ioPin2 is configured to output a 1 kHz PWM waveform (ioPin2 = 4)

What it does: Sets the variable to be output via a 1 kHz PWM waveform on digital input/output pin 2.

Argument Type: Integer

Valid Range: 0 to 7 (See below for details)

0 = Actuator Position (Smin to Smax)

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

ioBit1

Pre-Requisite: ioPin1 is configured to output the result of the masked status word (ioPin1 = 3)

What it does: The value of ioBit1 will be compared to the value of the status word, and a high or low bit will be signaled by the digital input output pin depending on whether or not the two are equal. See **Status Word** for more detailed diagnostic information.

Argument Type: Unsigned long

Valid Range: 0 to 4294967295

ioBit2

Pre-Requisite: ioPin2 is configured to output the result of the masked status word (ioPin2 = 3)

What it does: The value of ioBit2 will be compared to the value of the status word, and a high or low bit will be signaled by the digital input output pin depending on whether or not the two are equal. See **Status Word** for more detailed diagnostic information.

Argument Type: Unsigned long

Valid Range: 0 to 4294967295

Data Streaming

Pre-Requisite: Serial connection is made to the actuator

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

What it does: Defines the start-up behavior of the data streaming functionality.

Argument Type: Integer

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

0 = data streaming off at startup
1 = data streaming on at power-up

sTime

What it does: 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.

Argument Type: Integer

Valid Range: 0 to 65535

Baud Rate	Approximate Maximum Streaming Frequency
9600	
19200	
38400	
57600	
115200	

Strx1

What it does: Defines the variable that will be streamed in column 1

Argument Type: Integer

Valid Range: 0 to 19 (See “Streaming variables” below for details)

Strx2

What it does: Defines the variable that will be streamed in column 2

Argument Type: Integer

Valid Range: 0 to 19 (See “Streaming variables” below for details)

Strx3

What it does: Defines the variable that will be streamed in column 3

Argument Type: Integer

Valid Range: 0 to 19 (See “Streaming variables” below for details)

Streaming Variables

0 = Column Off
1 = System Bus Voltage
2 = Motor Phase 1 Current
3 = Motor Phase 2 Current
4 = Motor Phase 3 Current
5 = Force Feedback
6 = Actuator Position
7 = Actuator Velocity
8 = Status Bits
9 = Digital Inputs
10 = 1-2 ms Pulse Input 1
11 = 1-2 ms Pulse Input 2
12 = Analog Voltage Input
13 = Analog Current Input
14 = Position Command Setpoint
15 = Position Error (Feedback – Command)
16 = Bus Voltage Rate of Change
17 = Encoder Reference Error
18 = Force Command Setpoint
19 = 32 bit timer with 100 µs increments

Status Word

Pre-Requisite: Serial connection is made to the actuator

The Servo Cylinder updates a 32-bit status word to provide the user with an indication of health. Several of the bits require a user defined threshold that defines when they are active and when they are inactive. The following configuration variables are used to define thresholds that trigger several of the status bits:

Several of the bits in the status word require a user defined threshold that defines when they trigger.

atTarg

What it does: Defines the position error threshold for status bit 6 “at target position”. The “at target position” bit will flip when the actuator position falls between setpoint ± atTarg.

Argument Type: Integer

Valid Range: 0 to 4095

ovErrP

What it does: Defines the position error threshold (status bit 7) is active when the actuator error exceeds the user defined maximum.

Argument Type: Integer

Valid Range: 0 to 65535

ovSpeed

What it does: Defines the speed over threshold (status bit 8) is active when the actuator speed exceeds the user defined maximum.

Argument Type: Integer

Valid Range: 0 to 127

ovTorq

What it does: Torque Over Threshold (status bit 9) is active when the actuator torque exceeds the user defined maximum.

Argument Type: Integer

Valid Range: 0 to 32767

posGrtr

What it does: Position greater than threshold is a bit that defines what portion of the stroke the actuator is currently within. 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.

Argument Type: Integer

Valid Range: 0 to 65535

posLess

What it does: Position less than threshold is a bit that defines what portion of the stroke the actuator is currently within. 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.

Argument Type: Integer

Valid Range: 0 to 65535

Using the Servo Cylinder

⚠ IT IS A GOOD IDEA TO RUN THE SERVO CYLINDER UNLOADED ON A BENCHTOP TO GAIN FAMILIARITY WITH THE PRODUCT BEFORE USING IT TO DRIVE ANY LOAD.

Once you have configured your Servo Cylinder. You are ready start sending a command signal.

Appendix A: CLI Command Reference Command List

Read Commands

AN – Read Analog Inputs

Argument Type: None, 1 to 3

Description: 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 with the following conversions:

$$\square\square\square\square\square\ (\square) = \frac{10 * \square\square_{\square}}{32768} - 10$$

$$\square\square\square\square\square\square\square\ (\square\square) = \frac{16 * \square\square_{\square}}{65536} + 4$$

$$\square\square\square\square\square\square\square\square\square\square\square\ ({}^{\circ}\square) =$$

AP – Read Actuator Position

Argument Type: None

Description: 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

Argument Type: None

Description: 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

Argument Type: None, 1 to 4

Description: Request the value of the Servo Cylinder's digital inputs.

DI1 = value of OPTO1
DI2 = value of OPTO2
DI3 = value of DIO1
DI4 = value of DIO2

Sending this command with no argument will return the value for all of the digital inputs.

FS – Read Firmware Version and Serial Number

Argument Type: 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

Argument Type: None

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

QP – Read Position Setpoint

Argument Type: None

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

RC – Read 1-2 ms Pulse Input

Argument Type: None

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

SR – Read Status Register

Argument Type: None, 0-31

Description: 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
```

Refer to **Appendix C: Status Register** for detailed information regarding the status word.

TQ – Read Motor Torque

Argument Type: None

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

VL – Read Actuator Velocity

Argument Type: None

Description: 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

Argument Type: Integer (0 to 65535)

Definition: 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.

CG – Coast On

Argument Type: Integer, 321

Description: Disable the Servo Cylinder.

Notes: 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 backdriving is a possibility. **Care must be taken when issuing this command!**

CS – Coast Off

Argument Type: Integer, 321

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

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

D1 – Set Digital I/O Pin 1 Mode

Argument Type: Integer, 0 to 4

Description: Set the function of the Servo Cylinder's digital input/output pin 1

- 0 = Input (high impedance)
- 1 = Output: Ground (sink up to 2A)
- 2 = Output: +5 Volts (source up to 250 mA)
- 3 = Output: Status Bit (See **Outputting Status Bits**)
- 4 = Output: 1 kHz PWM (See **H1 – Set the Source for PWM duty Cycle)**

Sending this command without an argument will return the current value of D1.

D2 – Set Digital I/O Pin 2 Mode

Argument Type: Integer, 0 to 4

Description: Set the function of the Servo Cylinder's digital input/output pin 2

- 0 = Input (high impedance)
- 1 = Output: Ground (sink up to 2A)

- 2 = Output: +5 Volts (source up to 250 mA)
- 3 = Output: Status Bit (See **Outputting Status Bits**)
- 4 = Output: 1 kHz PWM (See **H2 – Set the Source for PWM duty Cycle)**

Sending this command without an argument will return the current value of D2.

H1 – Set the Source for PWM Duty Cycle on I/O pin1

Argument Type: Integer, 0 to 7

Pre-Requisite: Digital Input/Output Pin 1 is set to output a 1kHz PWM waveform (See **D1**)

Description: 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

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

Sending this command without an argument will return the current value of H1.

H2 – Set the Source for PWM Duty Cycle on I/O pin2

Argument Type: Integer, 0 to 7

Pre-Requisite: Digital Input/Output Pin 2 is set to output a 1kHz PWM waveform (See **D2**)

Description: The value assigned to H2 represents the source for the PWM duty cycle. All source ranges are converted to the PWM duty cycle range of 0 to 60,000

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

Sending this command without an argument will return the current value of H2.

IM – Set Serial Interface Mode

Argument Type: integer

Description: The serial interface can be set to operate in “Human Mode” or “Machine Mode”

- 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
  - Checksum follows every command
  - Asynchronous error messages are disabled
  - No detailed information is sent to the serial prompt
  - (\”SI0 CC\” sets interface back to Human Mode)

KD - Set Derivative Gain for Position PID Filter

Argument Type: Integer (0 to 32767)

Description: Coefficient for 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

Argument Type: Integer (0 to 32767)

Description: Coefficient for integral portion of the position PID filter. Sending this command without an argument will return the current value of KI.

KP – Set Proportional Gain for Position PID Filter

Argument Type: Integer (0 to 32767)

Description: Coefficient for proportional portion of the position PID filter. Sending this command without an argument will return the current value of KP.

MT – Set Limit for Maximum Commanded Torque

Argument Type: Integer (0 to 32767)

Description: 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

Argument Type: None, Integer (sMin to sMax)

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

PC – Set Target Position to Current Position

Argument Type: None

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

PO – Set Target Position Offset

Argument Type: Integer

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 sMin or sMax.

SP – Set Maximum Speed for Trajectory Moves

Argument Type: Integer (0 to 50000000)

Definition: 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.

W1 – Set Status Register Bit Mask for I/O pin1

Argument Type: unsigned long

Pre-Requisite: Digital Input/Output Pin 1 is set to output status bit (See **D1**)

Description: The value of DIO1 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 **Appendix C: Status Register** for detailed information regarding the status word. Sending this command without an argument will return the current value of W1.

W2 – Set Status Register Bit Mask for I/O pin2

Argument Type: unsigned long

Pre-Requisite: Digital Input/Output Pin 2 is set to output status bit (See **D2**)

Description: The value of 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 **Appendix C: Status Register** for detailed information regarding the status word. Sending this command without an argument will return the current value of W2.

System Commands

ZC – Run Calibration Routine

Argument Type: Integer, 321

Description: 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

Argument Type: None

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

ZF – Clear Latching Fault Flags in Status Register

Argument Type: None

Description: Clear all latching fault flags in the status register.

ZR – Reset Actuator

Argument Type: Integer, 321

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

ZU – Jump to RS-232 Firmware Updater

Argument Type: Integer, 321

Description: 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

T1 – Trajectory Move to User Defined Pos1

Argument Type: None

Description: Move to Pos1 with user defined speed and acceleration (Pos1 defined in CONFIG.TXT).

T2 – Trajectory Move to User Defined Pos2

Argument Type: None

Description: Move to Pos2 with user defined speed and acceleration (Pos2 defined in CONFIG.TXT).

T3 – Trajectory Move to User Defined Pos3

Argument Type: None

Description: Move to Pos3 with user defined speed and acceleration (Pos3 defined in CONFIG.TXT).

T4 – Trajectory Move to User Defined Pos4

Argument Type: None

Description: Move to Pos4 with user defined speed and acceleration (Pos4 defined in CONFIG.TXT).

TA – Trajectory Move to Absolute Position

Argument Type: Integer (Smin to Smax)

Description: Sending this command with a valid argument between sMin and sMax 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 Extended Position (sMax)

Argument Type: None

Description: Move to sMax with user defined speed and acceleration.

TK – Interrupt the current trajectory

Argument Type: None

Description: Halt the current trajectory before completion.

TM – Trajectory Move to Midpoint (sMin + [sMax – sMin]/2)

Argument Type: None

Description: Move to midpoint with user defined speed and acceleration.

TO – Trajectory Move to Offset (incremental trajectory move)

Argument Type: Integer

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 sMin or sMax.

TR – Trajectory Move to Retracted Position (sMin)

Argument Type: None

Description: Move to sMin with user defined speed and acceleration.

Serial Data Streaming

X1 – Set Data Stream Column 1

X2 – Set Data Stream Column 2

X3 – Set Data Stream Column 3

Argument Type: Integer (0 to 23)

Description: Define what variable each of the three columns are reporting

- 0 = Column Off
- 1 = Position Feedback
- 2 = Position Setpoint
- 3 = Motor Current Feedback
- 4 = Motor Current Setpoint
- 5 = Motor Phase 1 Current
- 6 = Motor Phase 2 Current
- 7 = Motor Phase 3 Current
- 8 = Velocity at 1.25 kHz
- 9 = Velocity at 156.25 Hz
- 10 = Encoder Interval Timer
- 11 = Supply Voltage
- 12 = Supply Voltage Rate of Change
- 13 = Status Register
- 14 = 1-2 ms Pulse Input
- 15 = Filtered 1-2 ms Pulse Input
- 16 = Analog Voltage Input
- 17 = Filtered Analog Voltage Input
- 18 = Analog Current Input
- 19 = Filtered Analog Current Input
- 20 = Temperature Sensor Input
- 21 = Position Error
- 22 = Quadrature Input Errors
- 23 = 32-bit Counter with 100 µs Increments

Reference **Appendix D: Streaming Variables** for more detailed information.

XC – Clear Timer

Argument Type: None

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

XG – Turn Data Streaming On

Argument Type: None

Description: Initiate the data streaming.

XR – Display Data Stream Setup

Argument Type: None

Description: Display the current stream setup including what variables are being streamed, streaming frequency.

XS – Turn Data Streaming Off

Argument Type: None

Description: Stop the data streaming.

XT – Set Data Stream Time Interval

Argument Type: Integer (1 to 65535)

Description: 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.

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