EVA Robotics Evodrive ST-17

Stepper Servo Controller

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EvoDrive ST-23

INTEGRATION MANUAL

EVA Robotics | FW-UM009 Rev C | December 2013

Disclaimer

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Having said that, EVA Robotics takes great pride in the quality of its products and we believe that great documentation is fundamental. If you have any feedback regarding this manual we would love to hear about it.

Manufactured by

EVA Robotics Pty Ltd
ACN 139 161 112

Web: www.evarobotics.com

1. Important Information

1.1 Intended Use

The EvoDrive series of stepper motor controllers are intended to control and drive sub-horsepower stepper motors. They are intended to be used as components in larger systems or products.

The EvoDrive products have been designed to all applicable safety standards but they are not intended to implement safety functions. The risk of unexpected or un-braked movements can not be sufficiently mitigated without additional safety provisions.

For this reason, personnel must never be in any danger zone actuated by an EvoDrive product unless additional safety equipment prevents personal danger. This applies to operation as well as service and maintenance of the product or system.

In all cases the applicable safety regulations and the specified operating conditions, such as environmental conditions and specified technical data, must be observed.

The EvoDrive may be one component of more complex systems, all machinery, EMC, and safety regulations that apply to the system as a whole must be observed before installation and operation.

To prevent personal injury and damage to property, damaged EvoDrive products must not be installed or operated.

Changes and modifications to the EvoDrive are prohibited and will void any warranty and liability.

The EvoDrive is not intended for use in explosive environments.

1.2 Qualification of personnel

The safe and successful integration of the EvoDrive requires a certain level of competency in designing and working with motor drive technologies.

Only engineers/technicians who are familiar with and understand the contents of the EvoDrive documentation are authorised to integrate the EvoDrive ST-23.

The system designers must be able to identify, assess, and control the potential risks inherent in the operation of mechatronic systems.

The designers must be familiar with the relevant standards and regulations that apply to the end product or system.

1.3 Safety Labels

This manual may contain warnings and cautions which, when properly followed, can prevent personal injury and damage to the EvoDrive.

Caution. This label will be used to bring attention to a general caution or warning which provides important information to protect against injury to an operator or damage to equipment.

Electrical Hazard. This label will be used to warn the reader of an electrical hazard.

Mechanical Hazard. This safety label will be used to warn the reader of a mechanical hazard.

1.4 General Safety Instructions

Hazardous Voltages

While the EvoDrive does not operate at hazardous voltages, the use of open frame power supplies, or non-conforming wiring practices, such as routing EvoDrive cables together with high voltage cables, may expose the EvoDrive to hazardous voltages under fault conditions.

This will result in damage to the EvoDrive and may result in injury or death to the operator.

Loss of Control

The system designer must assess the hazards and risks inherent in safety critical functions, and implement controls to mitigate the risk.

Some examples of failure modes that should be considered include:

- Unexpected delays in commands or responses
- Loss of power and restart
- Failure of sensors and signals
- Over-Temperature cut-outs and fire hazards

Failure to observe the relevant safety and risk management standards may result in death or injury to the operator.

High Temperatures

The EvoDrive will typically run much cooler than other stepper motor controllers when in closed loop mode.

When operating in an open-loop mode it is still possible to generate high temperatures when driving or holding the motor with higher current levels than are necessary.

In this situation the stepper motor and EvoDrive casing temperatures can both exceed 60°C.

Contents

2. Introduction

This integration manual will provide the detail required to safely and effectively integrate the EvoDrive ST-23 into your design. This manual should be read and understood together with the EvoDrive Programmers Manual.

The EvoDrive ST-23 embodies a thorough change in how stepper motors are controlled, and therefore how they are used.

As an open-loop controller the EvoDrive ST-23 provides the equivalent of 512 micro-step accuracy with exceptionally smooth current control. This results in incredibly quiet and smooth motion control.

As a closed-loop controller the EvoDrive moves away from traditional drive technology and transforms the humble stepper motor into a true servo motor with a high dynamic bandwidth and exceptional efficiency.

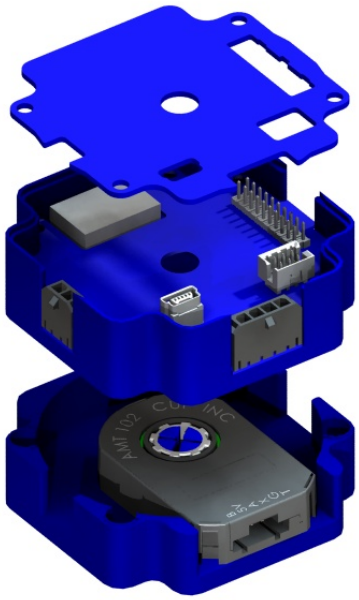
This is achieved through a series of cascaded control systems, some traditional, and some proprietary which together form what we call the Phase Vector Drive system.

The EvoDrive ST-23 form factor allows mounting directly to NEMA Frame 23 stepper motors, however the product designer is not restricted in their selection of the stepper motor or mounting arrangement.

The top PCB is a customisable applications PCB which can be designed to host custom logic, connectors, or communications protocols. This allows the product designer to host their own applications on the EvoDrive platform.

In this way the EvoDrive can be transformed into an entirely new device. Take advantage of the onboard motor drive and general I/O and add product specific functionality. This allows an accelerated time to market in a compact, powerful, and branded package. Furthermore this approach protects the supply of spare parts to your customers.

2.1 System Components



The EvoDrive ST-23 main casing provides for mounting and is an efficient heat-sink.

Two internal PCB's provide the EvoDrive's control and drive functions, as well as all connectors for power, motor, communications, and I/O.

The 3rd PCB is removable to allow for expansion using a custom, application specific PCB. By customising this applications PCB custom designs can be assembled directly into the EvoDrive casing to implement:

- Custom communication protocols or networks
- Legacy control code or connectors
- Application specific functionality
- Distributed processing across functional modules.
- Design aids are available for download from www.evarobotics.com.

The EvoDrive ST-23 can operate in a closed-loop mode using any incremental encoder with a resolution of 2048 PPR or better (8192 counts after quadrature).

The default encoder is an optical 16,384 count encoder. This mounts directly to the motor and can sit directly between the motor and the EvoDrive, providing a neat and compact stack.

3. Installation and Mounting

The EvoDrive ST-23 allows the product designer to select a mounting configuration that suits the available space and architecture.

This section shows some possible configurations for mounting the EvoDrive ST-23 directly to a stepper motor.

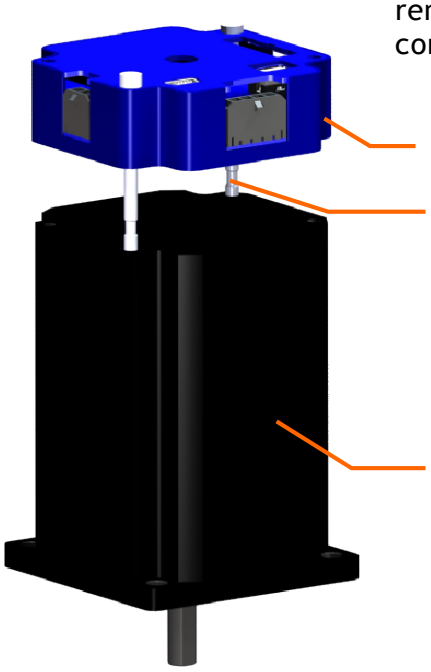
Note that the EvoDrive ST-23 control module does not need to be mounted directly to the stepper motor.

The encoder (if fitted) should be mounted directly to the motor shaft, or via a rigid coupling. Flexible couplings will degrade the performance of the EvoDrive.

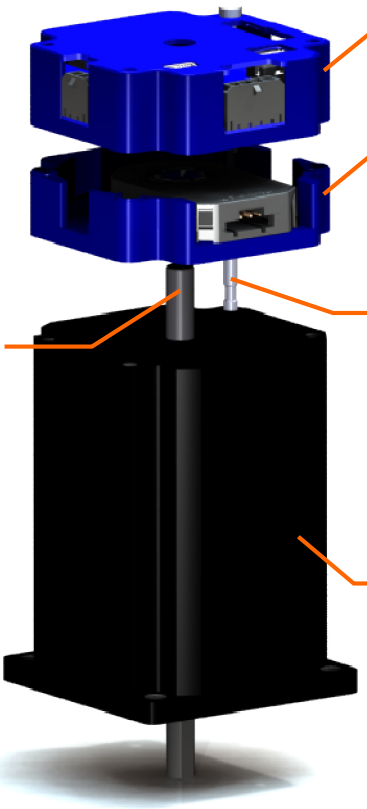
3.1 Example Configurations

EvoDrive Only, Single Shaft Motor

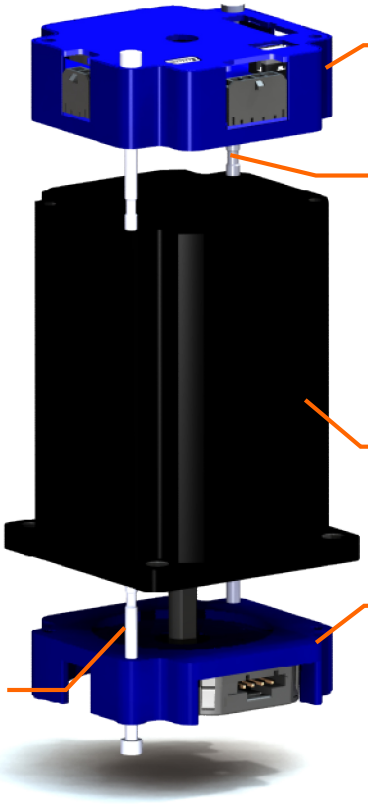
If mounting to an unmodified stepper motor, then the EvoDrive ST-23 should mount directly to the rear of the stepper motor. If it is necessary to remove screws from the motor to expose mounting points, never remove more than two screws, and only at opposite corners.



EvoDrive with Encoder, Dual Shaft Motor

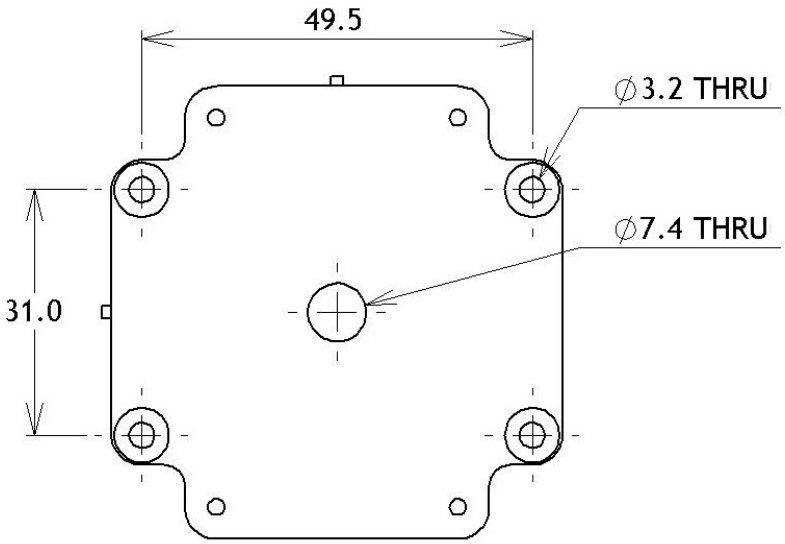


EvoDrive with Encoder, Single Shaft Motor



3.2 Mounting Pattern

When mounting to a panel, bracket, or other component, the same mounting holes can be used. The hole pattern on the EvoDrive ST-23 Controller is shown below.



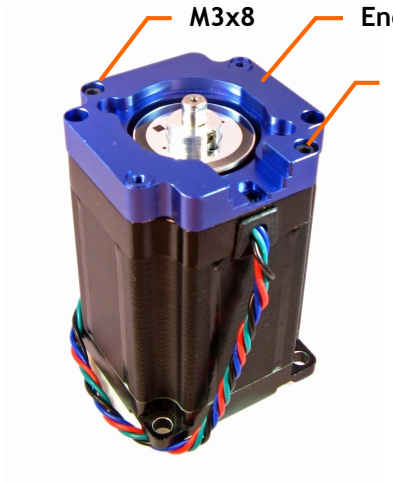
All connectors are accessible from the top of the EvoDrive.

There is no need to maintain any electrical or thermal conductivity between the EvoDrive and the mating surface.

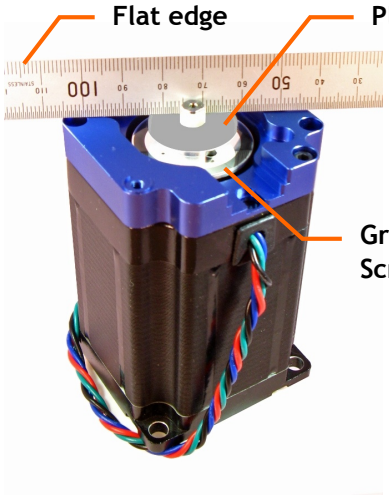
3.3 Fitting FW-A209 Optical Encoder Kit (16384 count)

These instructions show how to fit the standard optical encoder (FW-A209) to the rear of a dual shaft motor. The process remains the same for any stack configuration.

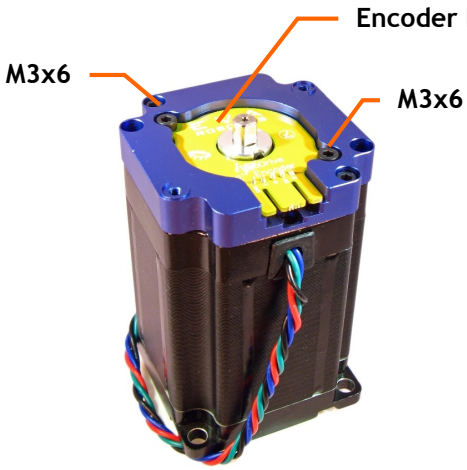
1. Fit code wheel loosely over the motor shaft.
2. **Do not tighten the grub screw.** The code lines should be facing away from the motor and the grub screw should be aligned with the flat on the motor shaft.



3. Position the encoder casing around the code wheel. Ensure the opening in the side of the casing sits over the motor wires.
4. Fasten it to the motor using two M3x8 cap screws.



5. Place the plastic spacer (colored grey in this picture) over the motor shaft so it sits on top of the code wheel hub.
6. Place a ruler, or any other flat edge, on top of the encoder casing as shown.
7. Insert the supplied hex key into the grub screw and use it to move the code wheel up until the plastic spacer sits against the ruler.
8. Tighten the grub screw, ensuring the grub screw sits perpendicular to the flat on the motor shaft. If the grub screw is tightened on the round of the shaft, or at an angle to the flat, it may come loose during operation and cause the EvoDrive to fail.
9. Remove the plastic spacer.

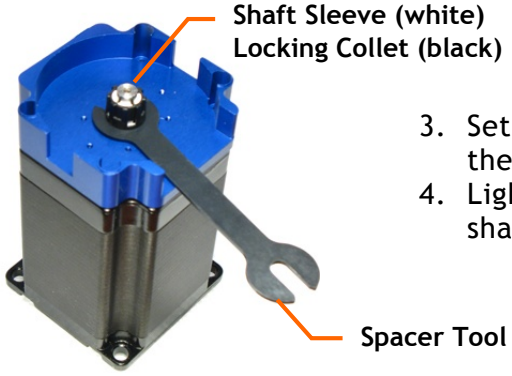


10. Sit the encoder PCB over the code wheel as shown. It will fit over the code wheel hub and sit on a small shelf in the encoder casing.
11. Loosely fit two M3x6 cap screws through the encoder PCB tabs.
12. Gently position the encoder PCB so the central cut-out in the PCB and the code wheel hub are concentric. That is, ensure there is an even gap all the way around the code wheel hub.
13. Tighten the two M3x6 cap screws to hold the PCB securely.

3.4 Fitting FW-A202 non-optical (8,192 step) encoder

These instructions show how to fit the non-optical 8,192 count encoder (FW-A202) to the rear of a dual shaft motor. The process remains the same for any stack configuration.

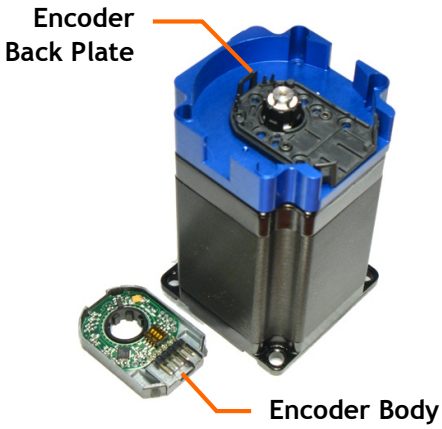
1. Fit the EvoDrive encoder case to the motor using M3 screws.
2. Select a shaft sleeve to match the motor shaft diameter. The shaft sleeve should hold contact with the shaft on all sides, but be able to slide easily.



3. Set the correct height of the shaft sleeve using the spacer tool as shown.
4. Lightly push the black locking collet over the shaft sleeve.

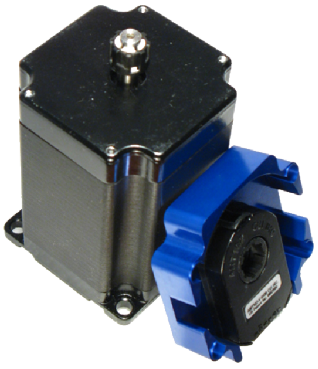
5. Press the locking collet onto the shaft sleeve using the press tool as shown. The spacer is still held in position to maintain the correct collet height. The black locking collet should completely enclose the shaft sleeve.

6. Remove the spacer and the press tool.



7. Unclip the encoder back plate from the encoder body and position over the locking collet as shown.
8. Line up the four M2 holes in the encoder casing with the M2 holes in the encoder back plate.
9. Screw the encoder back plate to the encoder case using four M2 x 4 screws.

10. Clip the encoder body onto the backing plate, ensuring the black locking collet meshes with the encoder hub.

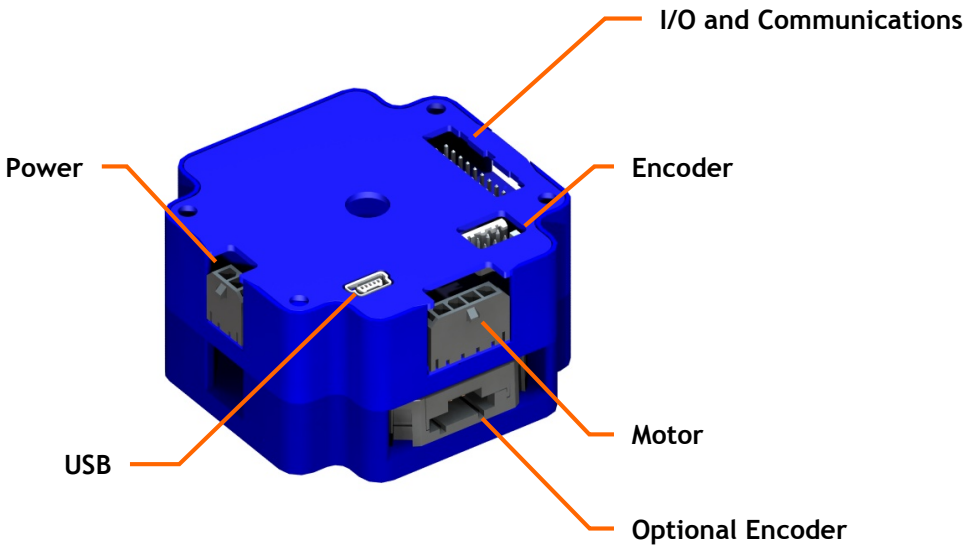


11. The entire encoder assembly can now be removed and replaced without disassembly of the locking collet.

4. Connectors

This section will detail the connectors used for the motor drive, power supply, communications and I/O available on the EvoDrive ST-23.

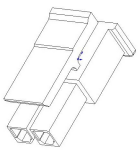
All connectors are rated for Extra Low Voltage (SELV) applications. If greater voltages than those specified in section 10 are applied, the safety of the final product may be compromised.

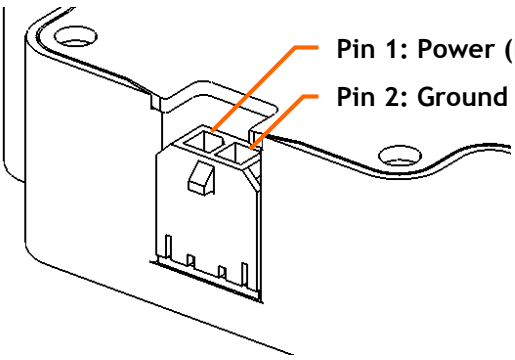


Power

This is the DC power input. It provides power to the vector drive, and via internal regulators to the control logic, I/O, and encoder.

Mating Connector
Molex Micro-Fit
Housing 43645-0200
Contact 43030-0008

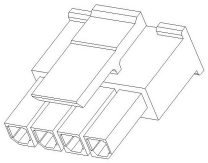


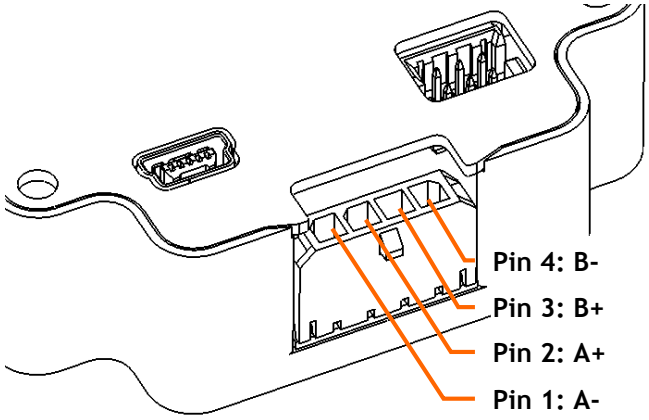


Motor

This connector is the output of the vector drive and connects to any bipolar stepper motor.

Mating Connector
Molex Micro-Fit
Housing 43645-0400
Contact 43030-0008

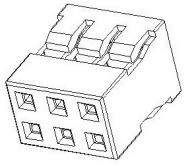


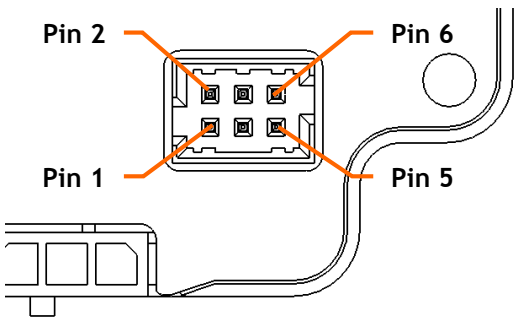


Encoder

The encoder power and quadrature signals are connected via this header.

Mating Connector
Molex Milli-Grid
Housing 51110-0660
Contact 50394-8051





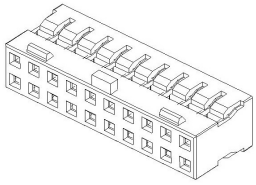
Pin	Signal
1	5V
2	Ch B
3	3.3V
4	Idx
5	Gnd
6	Ch A

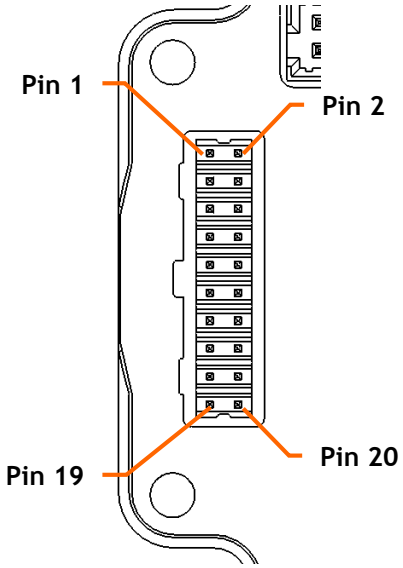
I/O Header

This header provides all I/O and communications signals.

It is designed to be stackable with the applications PCB, so where a custom application PCB is fitted, this connector is not necessarily exposed.

Mating Connector
Molex Milli-Grid
Housing 51110-2051
Contact 50394-8051



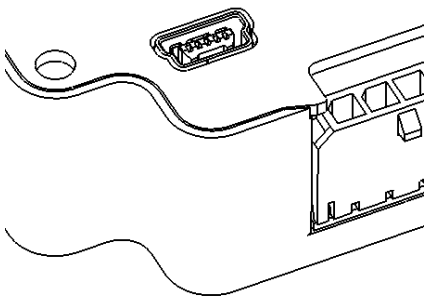


Pin	Signal	Pin	Signal
1	3.3V	2	Gnd
3	RS232 Tx	4	Reset
5	RS232 Rx	6	RS485 B
7	Gnd	8	RS485 A
9	NC	10	NC
11	Gnd	12	5V
13	Output 1	14	Input 1
15	Output 2	16	Input 2
17	Output 3	18	Input 3
19	Output 4	20	Input 4

USB Connector

The USB connection provides a virtual RS232 port for control via a PC or laptop. It is also used for firmware upgrades.

Mating Connector
USB Mini-B

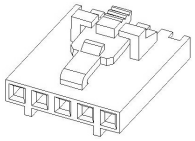


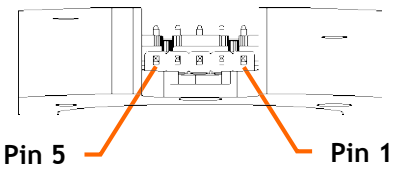
Standard Encoder - FW-A009 (16,384) count

The 16,384 count encoder can be stacked with the EvoDrive ST-17 or mounted separately.

For stacked mounting, interface cables are available from EVA Robotics (FW-C002)

Mating Connector
Molex C-Grid
Housing 5057-9405
Contact 1602-0086





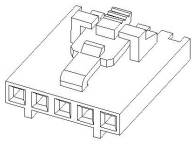
Pin	Signal
1	Ch B
2	5V
3	Ch A
4	Index
5	Gnd

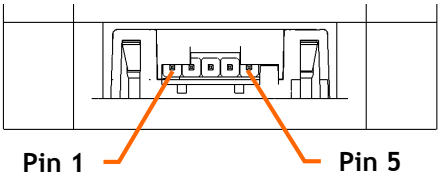
Optional Encoder - FW-A202 (8,192) count

The 8,192 count encoder can be stacked with the EvoDrive ST-23 or mounted separately.

For stacked mounting, interface cables are available from EVA Robotics (FW-C002)

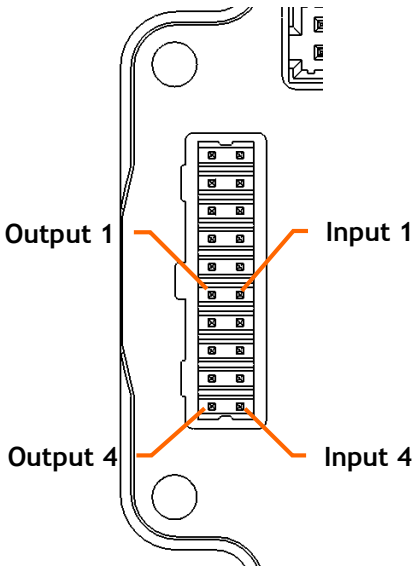
Mating Connector
Molex C-Grid
Housing 5057-9405
Contact 1602-0086





Pin	Signal
1	Ch B
2	5V
3	Ch A
4	Index
5	Gnd

4.1 Digital I/O



The EvoDrive ST-23 has 4 digital inputs and outputs available for general use.

They are provided on the I/O header as shown. For a full pin-out of the I/O header, including voltage and ground rails, refer to the previous section.

Inputs

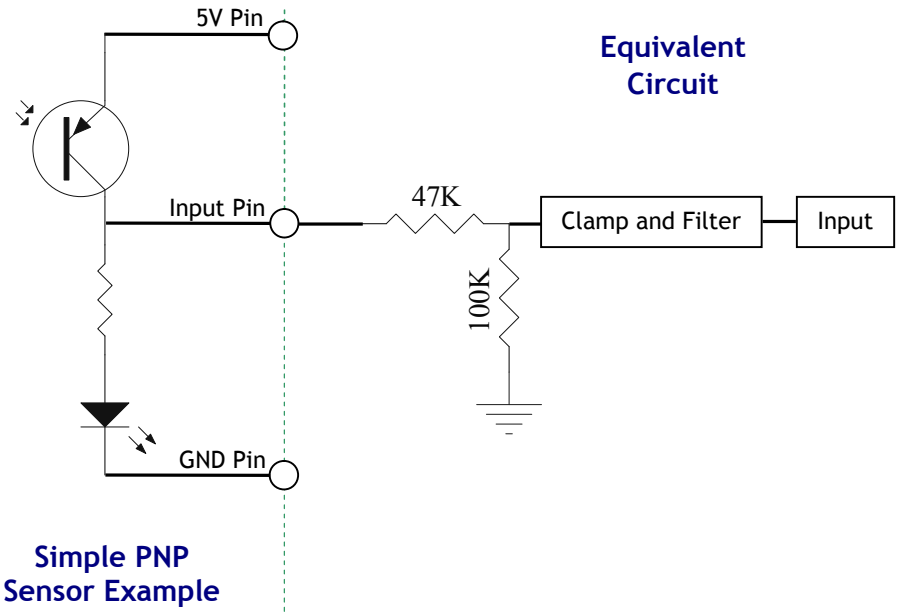
The digital inputs have a weak pull-down and so must be driven high. 5V and 3.3V rails are provided on the I/O header.

All inputs are 24V tolerant.

The input logic levels are

Low Level Input Voltage: 0 – 0.9 VDC

High Level Input Voltage: 1.4 – 24 VDC

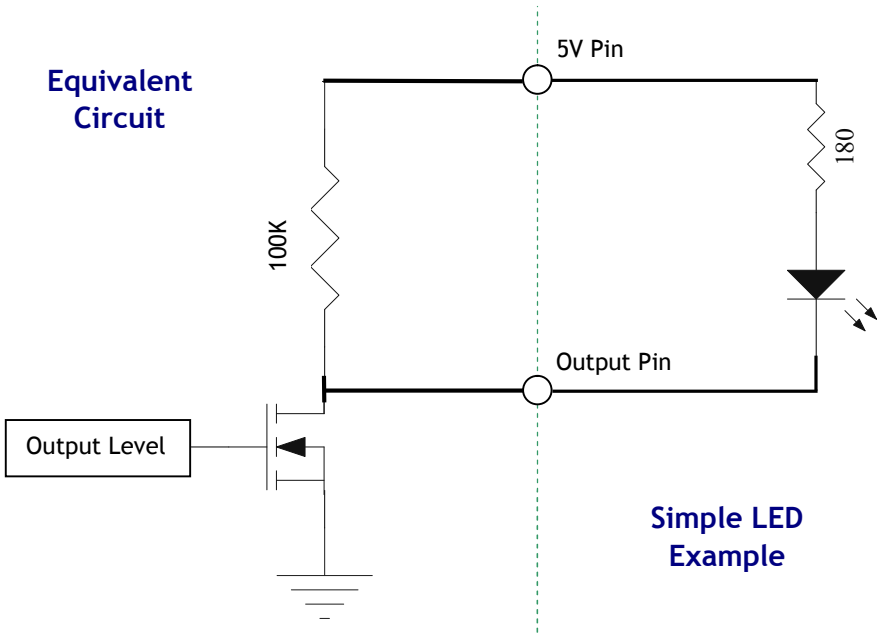


Outputs

The digital outputs are active low outputs.

When switched OFF the output provides an open circuit with a weak pull-up to 5V.

When switched ON they clamp the output to ground and are able to sink up to 200mA continuously.



If the load is inductive, such as a solenoid, a motor, or a relay coil, then it must be fitted with a flyback diode.

Inductive loads generate a back EMF which will cause a voltage spike when the output is switched off.

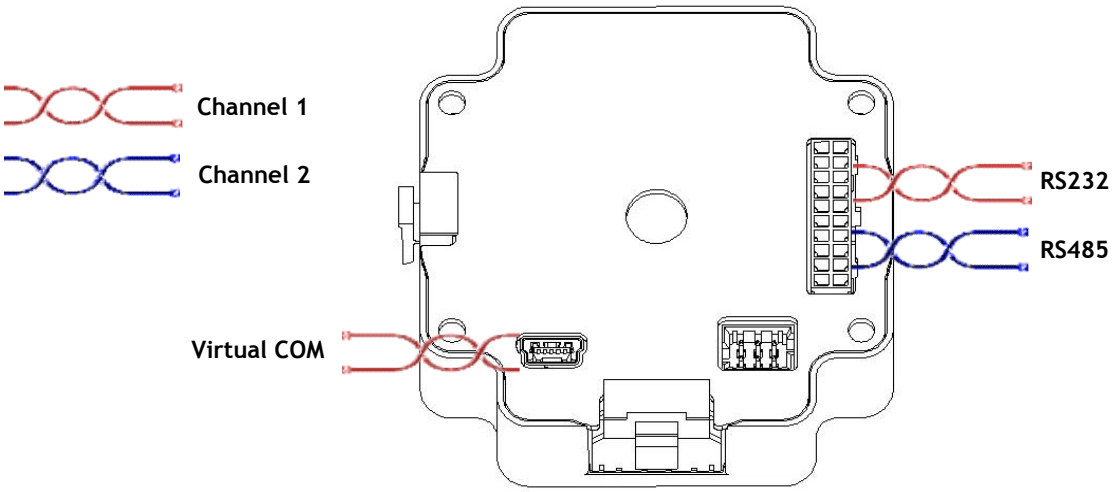
If this voltage spike exceeds the MOSFET breakdown voltage (30VDC), then the output will fail closed (it will conduct continuously until power is removed).

This may permanently damage the output.

5. Serial Control

The EvoDrive ST-23 is typically controlled via commands sent from a Host controller, on one of three serial interfaces, RS232, RS485, or USB (Virtual COM Port).

See the EvoDrive Programmers Manual for more information about the communications interfaces and the serial commands available.



5.1 RS232

The RS232 interface is a standard serial interface with RX, TX, and GND pins accessible via the I/O header.

This interface provides simple connection to embedded devices over a cable, as well as any PC or laptop with a serial port.

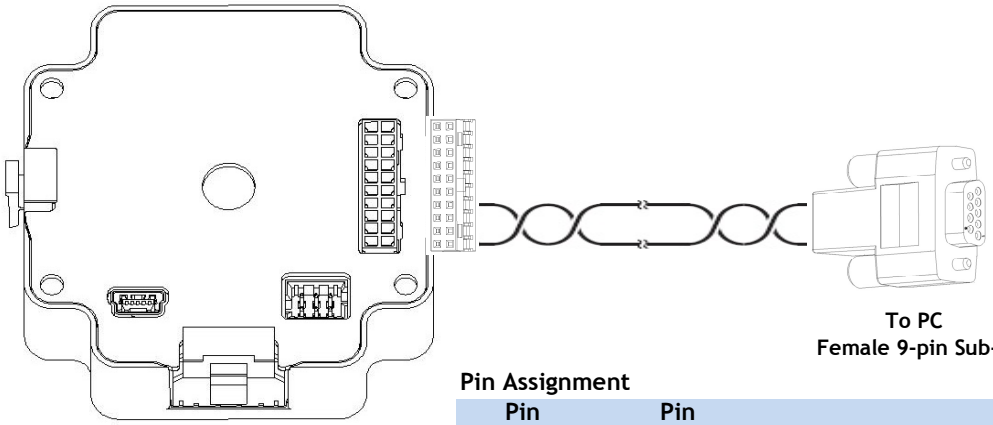
The default serial interface parameters are

- Baud Rate **9600**
- Data Bits **8**
- Stop Bits **1**
- Parity **None**
- Max input buffer **128 characters**

All standard BAUD rates up to 115200 bps are supported and can be configured via EvoLink or the **BAUD** command.

The pin-out for an RS232 connection to a PC is shown below.

The development breakout cable, FW-C001, available from EVA Robotics, also provides this connection.



To PC
Female 9-pin Sub-D

Pin Assignment

Pin EvoDrive	Pin 9-pin Sub-D	Signal
3	2	EvoDrive Tx / PC Rx
5	3	EvoDrive Rx / PC Tx
7	5	Signal Ground

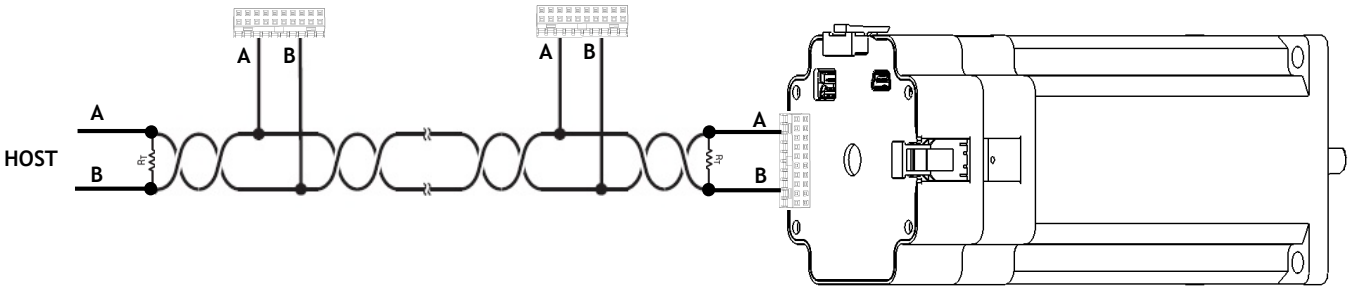
5.2 RS485

The RS485 interface is a half-duplex RS485 bus with A, B, and GND pins accessible via the I/O header.

The RS485 interface allows up to 34 EvoDrive units to be daisy chained together. The maximum communications rate over the RS485 bus is 250kbps.

The RS485 bus should be implemented as a twisted pair cable with terminating resistors at each end (100Ω – 120Ω). With proper cable termination, cable lengths up to 350 metres are possible without loss of data integrity.

An example bus layout is shown below



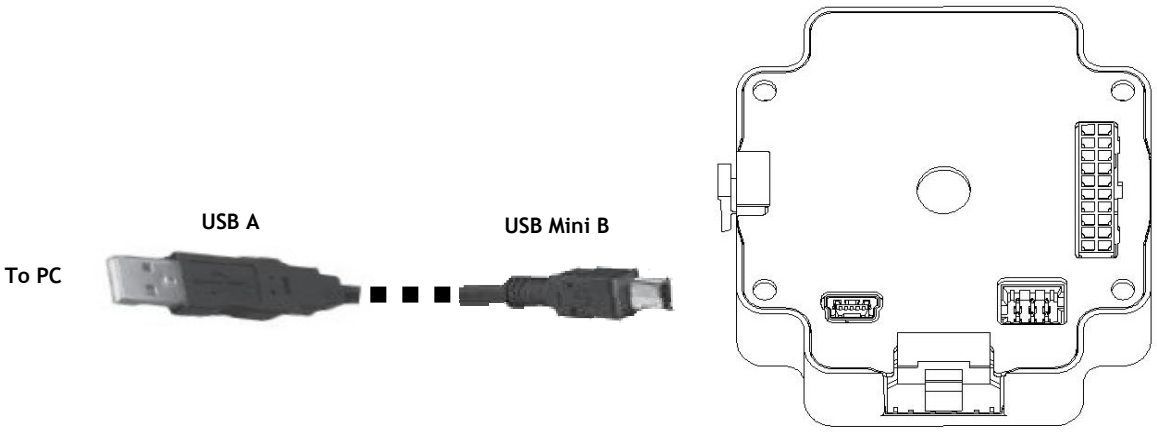
RS485 Bias Resistors

When an RS485 bus is idle all inputs are tri-stated, which means the A and B lines can float to an undefined voltage level. In some cases this may cause corruption of the communications.

If this is the case, add pull-up (B) and pull-down (A) resistors near the RS485 host to ensure valid levels are always present.

5.3 USB (Virtual COM Port)

The easiest way to connect the EvoDrive ST-23 to a PC or laptop is via a USB cable as shown below. Any standard USB-A to USB-Mini B cable can be used.



With the proper drivers installed, the USB port appears as a virtual COM port on a PC or laptop. The latest drivers are available for download from www.evarobotics.com.

The virtual COM Port allows full control of the EvoDrive when powered by an external power supply. This provides a very fast development path as well as a powerful debugging tool.

When the EvoDrive is not powered on, the unit can still be configured or programmed via USB. This is particularly useful in a production environment, or to ensure a safe means of servicing the EvoDrive in the field.

6. Digital Control

6.1 Triggered Programs

The EvoDrive ST-23 can be controlled via its digital inputs rather than serial communications.

Each digital input can be configured to perform a short (1 line) program, such as starting and stopping the motor, homing the motor, or moving to predefined positions.

The digital inputs can also be configured for safety functions such as performing a controlled shutdown, an emergency stop, or reducing the drive torque.

The rising and falling edge of each digital input can trigger a different program (8 programs total).

Programs can also be assigned to start-up (run after the EvoDrive is first powered on) and to the Index pulse of the encoder (run once per revolution).

See Triggered Programs in the EvoDrive Programmers Manual for more information.

6.2 Digital Output Status

The EvoDrive ST-23 has four dedicated digital output lines, which by default are configured as normal digital outputs.

These outputs can be configured to reflect the operating state of the EvoDrive via the I/O configuration in EvoLink. One of five status signals can be selected:

Status	Description
1	Vector Drive Enabled The output is held closed while the vector drive is enabled. This does not indicate motion or power to the motor, only that the drive outputs are enabled.
2	Motion Control Busy The output is held closed while the motor is performing a move. Note that this does not include unplanned motion, such as motion due to external forces or while under torque control.

3	Motor is Rotating The output is held closed whenever the motor shaft is rotating, whatever the cause may be.
4	Error Alarm The output is held closed while any error exists. This includes all errors other than command errors, such as incorrect command.
5	Collision Alarm The output is held closed while a collision error exists. When the collision error is cleared (by retrying a move or disabling the motor) the output is opened.

6.3 Digital Input Step Control (CNC Control)

The EvoDrive ST-23 can be configured to follow standard Step/Dir or CW/CCW digital signals used by most CNC motion controllers.

Any digital input can be assigned to be a Step, Dir, CW, CCW input via the Triggered Programs. On each digital input the positive edge, the negative edge, or both can be used to step the motor.

- **Step/Dir** control: The Step input will move the motor one step, in the direction defined by the Dir input.
- **CW/CCW** control: The CW input will move the motor one step clockwise. The CCW input will move the motor one step counter-clockwise.

The step size is defined by the RES command. For example, if the User Resolution is 400, then one edge on the control input would move the motor 1/400th of a revolution. This allows electronic gearing and replacement of legacy stepper controllers.

The maximum step update rate is 100KHz.

Configuration

The digital inputs are configured using the Triggered Program Commands. The following programs configure the inputs:

#STEP : The input edge is used to step the motor in Step/Dir mode.

#DIR : The input is used as the direction reference in Step/Dir mode. High is clockwise, Low is counter-clockwise.

#CW : The input edge is used to step the motor clockwise.

#CCW : The input edge is used to step the motor counter-clockwise.

Enabling and Recovering Step/Dir and CW/CCW Control

The programs above are only active while the EvoDrive is in a position holding mode. In other words, if the EvoDrive is maintaining a velocity, torque, or the motor outputs are disabled, then the Step/Dir and CW/CCW signals will not be followed.

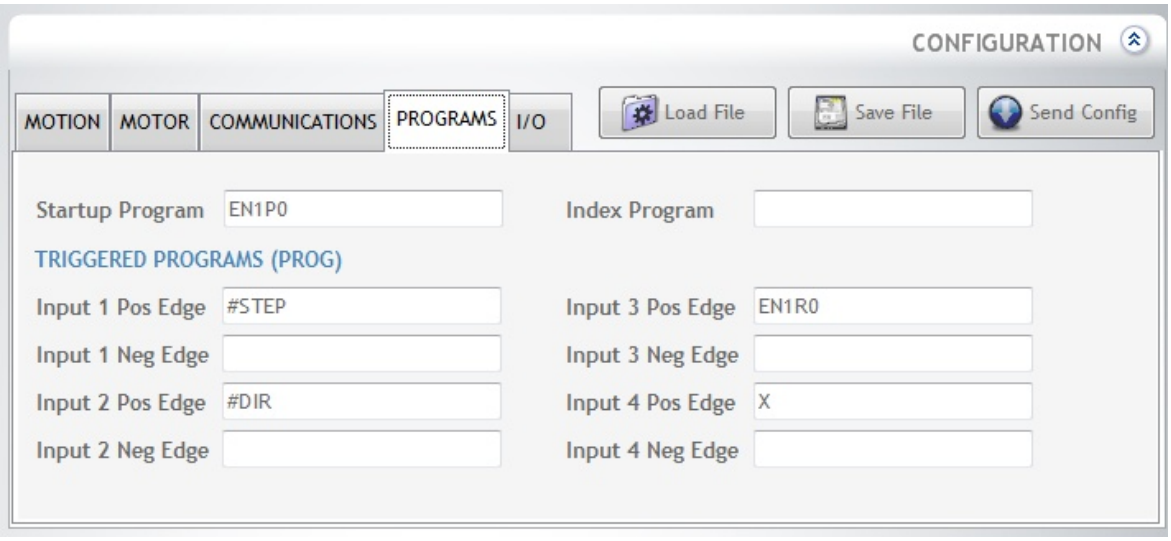
This is a safety mechanism to prevent the EvoDrive moving after a collision error. It also allows for a supervisory mode where a master can over-ride the CNC signals and move the motor with serial commands if necessary.

To place the EvoDrive into a position holding mode, a P command (Absolute Position) or an R command (Relative Position) should be sent.

For CNC applications it is recommended to change the start-up program (S0) to **EN1P0** . This means the EvoDrive is in the correct mode after power-up.

It is also advisable to add the triggered program **EN1R0** to one of the digital inputs. This input will then act as a reset switch that recovers the EvoDrive out of any error state (e.g. Collision alarm etc).

For simplicity, the following example shows a typical CNC configuration in EvoLink.



The startup program will ensure the EvoDrive is in a position holding mode immediately after power on.

Input 1 is used for the STEP signal. Only the positive edge is used therefore 1 STEP pulse = 1 step.

Input 2 is used for the DIR signal.

Input 3 is wired for a reset input – this will re-enable the drive and place it in a position holding mode after collision errors etc.

Input 4 is wired as an emergency stop.

7. Power Supply Selection

The power supply design is a critical part of any drive system. Not only does it provide power when needed, but it also protects system components from surges, back EMF, and electrical noise. Power supplies must source and sink large amounts of energy whilst maintaining a steady voltage rail for consistent performance.

Voltage Rating

Generally speaking, a higher supply voltage allows for a higher maximum motor speed. However it is very important to factor in the effects of back EMF and allow margin for this. See the discussion on Back EMF below.

The maximum input voltage of the EvoDrive ST-23 is 50VDC, so the recommended supply voltages for most applications is 24 or 48VDC.

A regulated power supply is more expensive than an unregulated linear supply, but it will be better at maintaining a constant output while the load of the motor changes. This is important for two reasons

1. It helps prevent the supply voltage from dropping below the minimum working voltage of the EvoDrive.
2. It helps prevent the supply voltage from exceeding the maximum input voltage of the EvoDrive, potentially damaging the EvoDrive.

Current Rating

The current rating of the power supply must be greater than the desired drive current of the motor.

If the current rating of the power supply is larger than this then the power supply will be able to handle fluctuations in load better, and will *generally* produce less EMC emissions.

Obviously the current draw of all EvoDrive units must be added together to get the total current load of the power supply. For example if a product has three EvoDrive units, one driving at 1 Amp and two driving

at 1.5 Amps then the power supply should be rated to 4 Amps plus a healthy margin (20 – 50 %).

Back EMF

Whenever a stepper motor is spinning it is generating a voltage that opposes the power supply. This voltage is called the Back EMF.

The Back EMF determines how quickly current can be established in the motor windings. For example, when using a 24V supply at low speeds, the back EMF is small, let's say 2V. That means there is 22V of potential to generate current in the windings. The current control is fast and responsive.

But at high speeds the Back EMF can approach the supply voltage, let say 20V. Now there is only 4V of potential to produce the required current. The current control is slow and becoming insufficient. This speed is often called the 'base' speed of the motor and effectively limits the top speed of the motor.

When all is well, the back EMF is not visible. That is, the power supply will regulate to its supply voltage despite changes in Back EMF.

However, fast deceleration or sudden changes in speed cause the motor currents to suddenly change polarity. This means the power supply voltage is suddenly added to the back EMF, and it is possible to exceed the maximum input voltage of the EvoDrive which will permanently damage the product.

The severity of the surge is dependant on the motor speed, deceleration, and inertia of the load.

This can be better understood by realising that the power supply must sink the energy stored in the system in order to slow it down. If the motor is driving a large load, then slow decelerations and torque changes are required to let the power supply remove energy from the system whilst still regulating the voltage. Of course if there is a lot of friction or viscous damping in the system, then a lot of the energy will be dissipated in the mechanics and the load on the power supply is reduced.

It is recommended that when tuning the motion profiles of the system the supply voltage is monitored to ensure no dangerous spikes or surges are being generated.

Protection

In a fault mode, the motor windings are shorted and current recirculates through the motor. In this way Back EMF is contained to the motor and dissipates into heat as the motor slows. This protects the power supply and the EvoDrive from sudden voltage surges.

But in situations described above, when the power supply must actively remove energy from a moving system through deceleration, it is possible that the power supply voltage will increase significantly.

It is recommended that a power supply with over and under voltage protection be selected. These usually shut down the power supply if the output voltage exceeds a certain amount (eg 15% rated voltage).

This prevents voltage surges from exceeding the maximum safe input of the EvoDrive and will help protect the EvoDrive from damage.

Where the power supply cannot be relied upon to manage the surge voltage, a surge suppression device such as a TVS Diode should be placed as close to the EvoDrive as possible. Radial TVS devices can be crimped directly into the power connector of the EvoDrive. The TVS should be rated for as much power as possible (several KW at least).

7.1 Cabling Recommendations

These recommendations are some rules-of-thumb that are simple to implement and should reduce the risk of EMC/EMI problems with the final product. However the recommendations are made without any knowledge of your systems architecture, power distribution topology or regulatory requirements.

Power Distribution

- The power supply to each EvoDrive should be fused to 3 amps (fast blow).
- The power supply should be twisted pair cabling of a gauge suitable for the expected current draw (see table below).
- Ideally, each EvoDrive should have a separate power cable that connects it to the power supply.
- Where surges are possible, add a TVS diode to the EvoDrive power connector. See previous section

RMS Current (Amps)	Minimum Gauge (AWG)	Minimum CSA (mm^2)
2	20	0.5
3	20	0.5
5	18	0.8
7	16	1.3
10	14	2.0

Communications

- Logic and communications signals should be run separately to the power supply.
- The cables should be twisted or shielded (or both) to prevent EMI issues. If shielded, the shield should be grounded at the host end and left floating at the EvoDrive end.

Daisy Chains

If the system is cabled in a daisy chain rather than a star topology, there are some further considerations that should be made.

If at all possible, run the communications cables separately to the power supply. A dual twisted pair cable may also be used.

If the cable is shielded, ensure the shield is not broken at each EvoDrive. Likewise the shield should not be connected to the ground at each EvoDrive. The shield should continue as an unbroken conductor along the entire daisy chain.

8. Motor Selection

The EvoDrive ST-23 can drive any bipolar or unipolar stepper motor with up to 3 amps winding current.

Obviously your application will place size and power constraints on the stepper motor selection and that will normally determine the motor you will use. Within those bounds however, the following considerations may help you select the right stepper motor.

- The EvoDrive can drive up to 3 amps. However this does not restrict you from using stepper motors with other current ratings. Smaller current ratings can be configured, and higher current ratings can still be driven up to 3 amps.
- Currents at the stepper motor current rating will usually saturate the motor magnetic circuit. For best performance, try running the stepper motor at 80% of its current rating.
- Stepper motors are optimised for low-speed torque, and so is the EvoDrive. A motor with a high stall-torque value will provide the smoothest and quietest motion control.
- The motor step size is a trade-off between speed and accuracy when driving in open-loop mode. When in closed-loop mode, the accuracy is set by the encoder, so there is less need for a small step size. In fact larger step sizes will provide a better servo response.
- A dual shaft motor is very convenient when using an encoder for closed loop control.
- The EvoDrive tuning is optimised for high-torque stepper motors. Other motors may produce a high-pitch ‘squeal’ or operate with a jerky motion. Use the Motor Calibration function in EvoLink to auto-tune the EvoDrive to these motors.

Note that these are guidelines only and may not reflect the requirements of your application. If you would like more specific assistance, please contact EVA Robotics.

8.1 Encoder

A key question when commissioning a new design is whether to use closed loop or open loop control.

Below are some advantages and disadvantages to consider when choosing a control mode.

Open Loop

- Open loop is cheaper since there is no need for an encoder.
- The EvoDrive ST-23 will implement a quiet and smooth open loop control.
- Little to no tuning is required to achieve tight, accurate control.
- It is very inefficient because the maximum drive current is used all the time.
- The motor and controller may run hot.
- If the drive current cannot overcome obstacles, the motor will lose sync with a sudden loss in torque.
- The motor must be driven much more conservatively to avoid losing sync.
- Collisions are not detected.

Closed Loop

An encoder is required for closed loop control. The advantages over open-loop control are:

- More accurate position control.
- The motor will run smoother and quieter.
- The motor has greater dynamic range (it can achieve greater speeds and apply more torque at high speed, than in open-loop).
- The motor and controller runs much cooler and more efficiently.
- Torque output can be monitored and/or controlled.
- The motor will not lose sync – it will attempt to push through obstacles.
- Collision detection is possible.
- Less safety margin is required when selecting a motor.
- Tuning may be required to achieve a desired system performance. Though the default tuning is usually suitable.

Encoder Resolution

Any quadrature encoder can be used as long as it has a resolution greater than 8192 counts per revolution.

The encoder provides two resolutions that define the control performance:

Position resolution: This is equal to half the encoder resolution. So with a 8192 count encoder the output can be controlled to ± 0.044 degrees.

Control resolution: This is the torque resolution available to the control loop to control the motor. An 8192 encoder provides a control resolution of ± 2.5% on a 1.8 degree motor.

The control resolution doesn't sound very accurate but this is actually more than enough for most applications. Because the control is closed loop, as long as you have enough torque overhead the motor will follow the trajectory profile at a much finer resolution than in open loop.

As the encoder resolution increases so does the control resolution. For example a 16 384 count encoder has a torque resolution of ± 1.2% and will satisfy the most demanding torque control applications.

9. EvoLink

EvoLink is control and diagnostics software for the EvoDrive ST-23. It can be used during product development to help develop and tune applications. It can also be used in a production or service environment for configuration or debugging.

EvoLink provides easy access to the EvoDrive's command set and should be used with reference to the EvoDrive Programmers Manual.

9.1 Installation

The latest version of EvoLink can be downloaded from www.evarobotics.com.

EvoLink is distributed as an executable installer. Running the installer will install EvoLink and the USB drivers required to communicate with the virtual COM port.

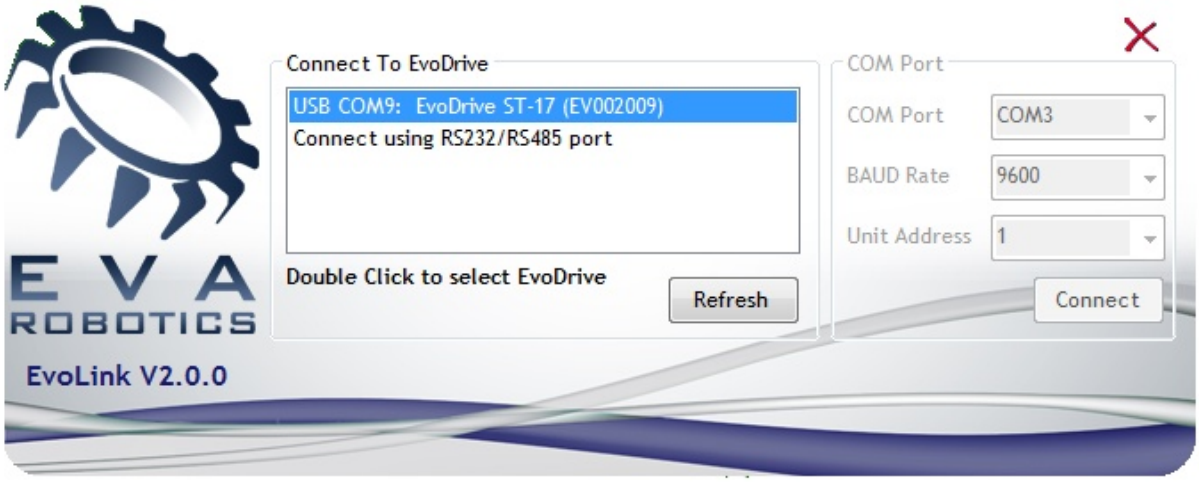
EvoLink requires the .Net Framework V3.5 or higher. A separate installer for the .Net Framework V3.5 is included in the EvoLink installation. Alternatively the latest .Net Framework can be downloaded from Microsoft or requested from EVA Robotics.

9.2 Connect Page

When EvoLink is first launched the connection options are presented.

If the EvoDrive is connected to the PC via USB, then it will be listed in the **Connect To EvoDrive** panel. To connect to the EvoDrive double click on the line that identifies the EvoDrive.

To connect to an EvoDrive over RS232 or RS485, select **Connect using RS232/RS485 port**. Then enter the connection details into the **COM Port** panel and press **Connect**.



9.3 Main Page

The main page provides access to all the EvoDrive functions and features.

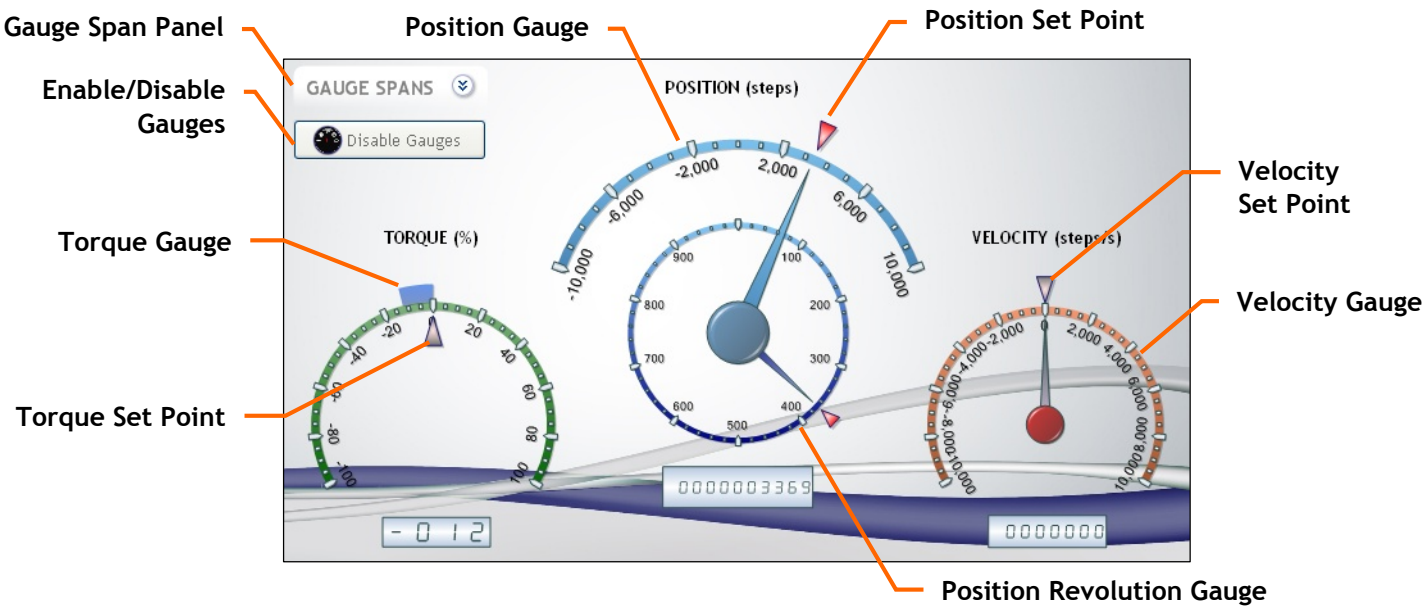
Most functions are grouped onto expandable panels that allow easy access to different EvoDrive functions on the fly. Panels can be opened or closed in any order and at any time to customise the available information.

The main panels and features are summarised below:

- **Emergency Stop.** This button will immediately disable the EvoDrive ST-23 outputs and couple the motor windings together.
- **Information Panels.** These provide status information on the EvoDrive ST-23 including I/O states and error conditions.
- **Quick Set Points**. This is an easy way to set the EvoDrive set-points while the **Commands** panel is closed.
- **EvoDrive Configuration**. This panel allows the EvoDrive configuration to be modified, backed up, and restored.
- **EvoDrive Commands.** This panel provides access to some common functions as well as the ability to send any command string or script file.
- **Chart**. This panel allows real time data such as position or torque to be plotted, saved, and exported.
- **Gauge Controls**. The gauges provide real time torque, position, and velocity data from the motor. They also allow the torque, position, and velocity set-points to be set graphically.

9.4 Control Gauges

The control gauges provide an intuitive method of controlling the EvoDrive while providing real time feedback.



The gauges provide real time feedback for motor torque, position, and velocity. Each gauge has a numerical and a graphical readout which are updated approximately 10 times per second.

Each gauge also has a set point marker which will be either red or grey. The set point markers can be selected by clicking once on the triangular marker, and dragged to create a new set point. The active set point is coloured red while the inactive set points are grey.

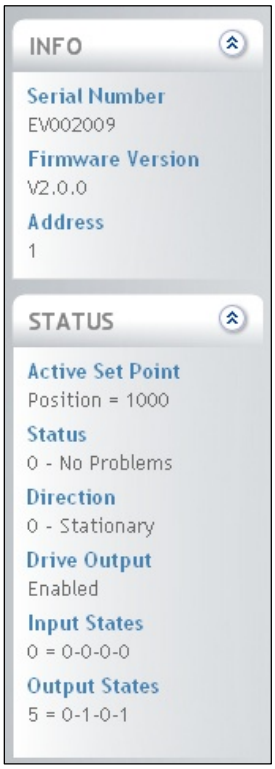
Note: Double clicking on any set point marker will change the set point to 0.

The position gauge has a smaller scale with its own pointer and set point marker. This gauge represents the position within the current motor revolution. Changing the set point on this gauge allows the position to be fine tuned within one revolution of the current position.

The gauge spans can be adjusted by opening the **Gauge Spans** panel in the upper left corner. Setting the gauge span to actual limits as defined by your application allows quick and intuitive control of the motor during development.

9.5 Information Panels

Info Panel



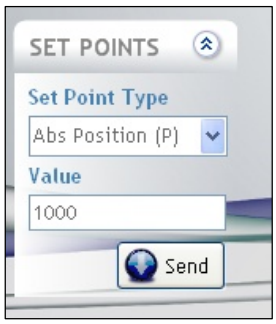
The **Info** panel contains the EvoDrive's serial number, firmware version, and bus address.

Status Panel

The **Status** panel provides real time status information on the EvoDrive. This information is updated twice per second.

- **Active Set Point**: Displays the current set point type and value.
- **Status**: Displays the current status code and a short description.
- **Direction**: Displays the current direction code and description.
- **Drive Output**: Shows the status of the vector drive – **Enabled** or **Disabled**.
- **Input States**: Shows the decimal value returned by the DI command, and a bit value for each input (Input4 ➔ Input 1).
- **Output States**: Shows the decimal value returned by the DO command, and a bit value for each output (Output 4 ➔ Output 1).

9.6 Quick Set Point Panel



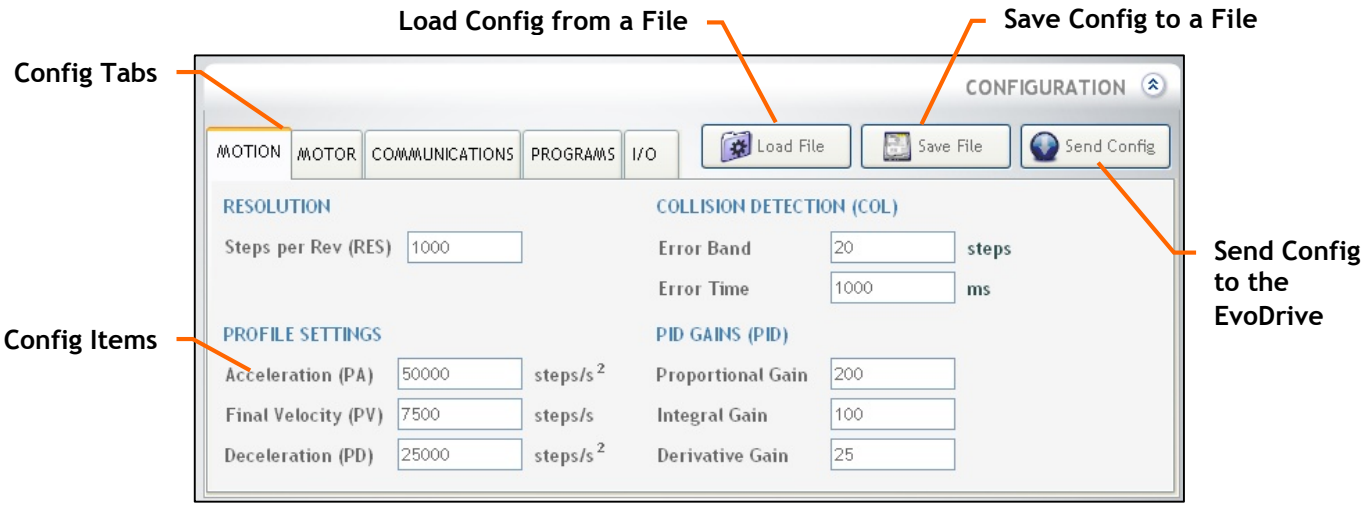
The **Quick Set Points** panel provides another simple interface for changing the set points. It is useful while using the **Chart** panel or to send an exact set point to the EvoDrive.

9.7 Configuration Panel

The **Configuration** panel allows the EvoDrive ST-23 configuration to be read, modified and saved.

The EvoDrive configuration is all the non-volatile drive parameters. All configuration items are set programmatically. Where a configuration item is associated with a particular command, that command is shown in brackets ().

For more information on individual configuration items see the EvoDrive Programmers Manual.



When the **Configuration** panel is opened the EvoDrive configuration will be uploaded for display.

All configuration items are shown in UserStep units (defined by **Steps per Rev**). Changing the **Steps Per Rev** value will automatically change all other values that are dependant on it.

Modifying Configuration Items

Changing the value of a configuration item does not change the value on the EvoDrive. All changes remain local until the **Send Config** button is pressed.

When **Send Config** is pressed all values are saved to non-volatile memory on the EvoDrive. Most take affect immediately.

Some values, such as the BAUD rates, require the EvoDrive to be reset before the changes take effect. If a reset is required you will be prompted before resetting the EvoDrive.

Backing up Configuration

The EvoDrive configuration can be saved to a configuration backup file (.evo) by pressing the **Save File** button. A browse window will be opened to allow you to select a location and filename for the backup.

Restoring Configuration

Pressing the **Load File** button will prompt you to select a configuration backup file (.evo).

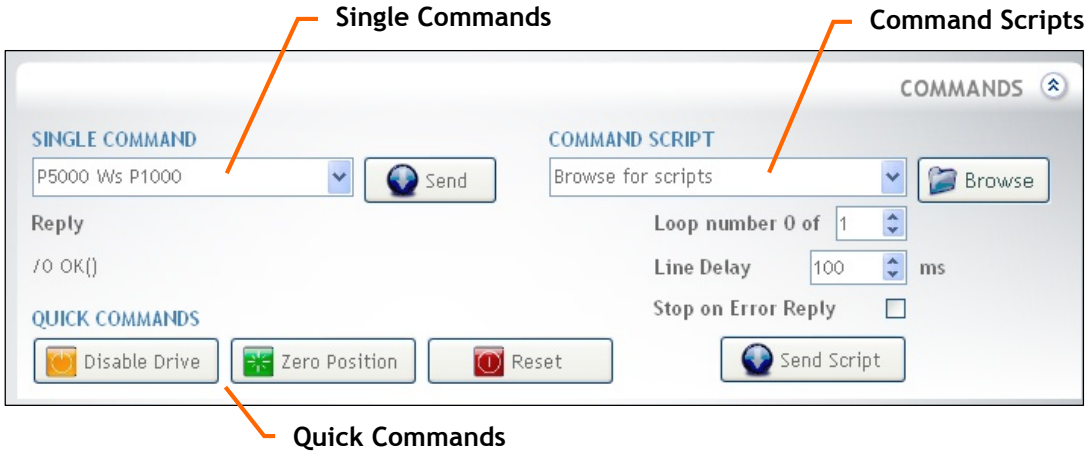
Selecting a file will load the values from the backup onto the screen. Press the **Send Config** button to save these values to the EvoDrive.

Note that restoring the configuration will not change the EvoDrive serial number or firmware.

Once overwritten the EvoDrive configuration cannot be recovered.

9.8 Commands Panel

The commands panel provides an interface for sending raw commands directly to the EvoDrive. The three functional areas of the Command panel are shown below.



Quick commands

These buttons allow quick access to three common commands used during development:

- **Enable**/Disable the vector drive (EN command)
- **Zero** the current position (Z command)
- **Reset** the EvoDrive (Reset() command)

Single Command String

Single command lines can be sent directly to the EvoDrive by typing the command into the text box and pressing the **Send** button.

Note that the header (/), the address, and the terminating (**CR**) characters do not need to be included in the command, these will be added automatically.

The text box is the top of a drop down list which contains a history of all sent commands. Previous commands can be selected from the drop down list and resent by pressing the **Send** button.

The reply from the EvoDrive is displayed under the **Reply** heading.

Command Script Files

A script file is a text file containing multiple commands. An example is shown below.

```
# Example Script File
# EvoDrive ST-23

Prompt(Watch out! The EvoDrive is about to spin)

V5000
Pause(3000)
Prompt(Well… I told you.)
```

Each line in the text file is a new command. The commands will be sent to the EvoDrive one line at a time. For each command the EvoDrive reply will be shown under the **Reply** heading.

Script files are sent to the EvoDrive according to the following options:

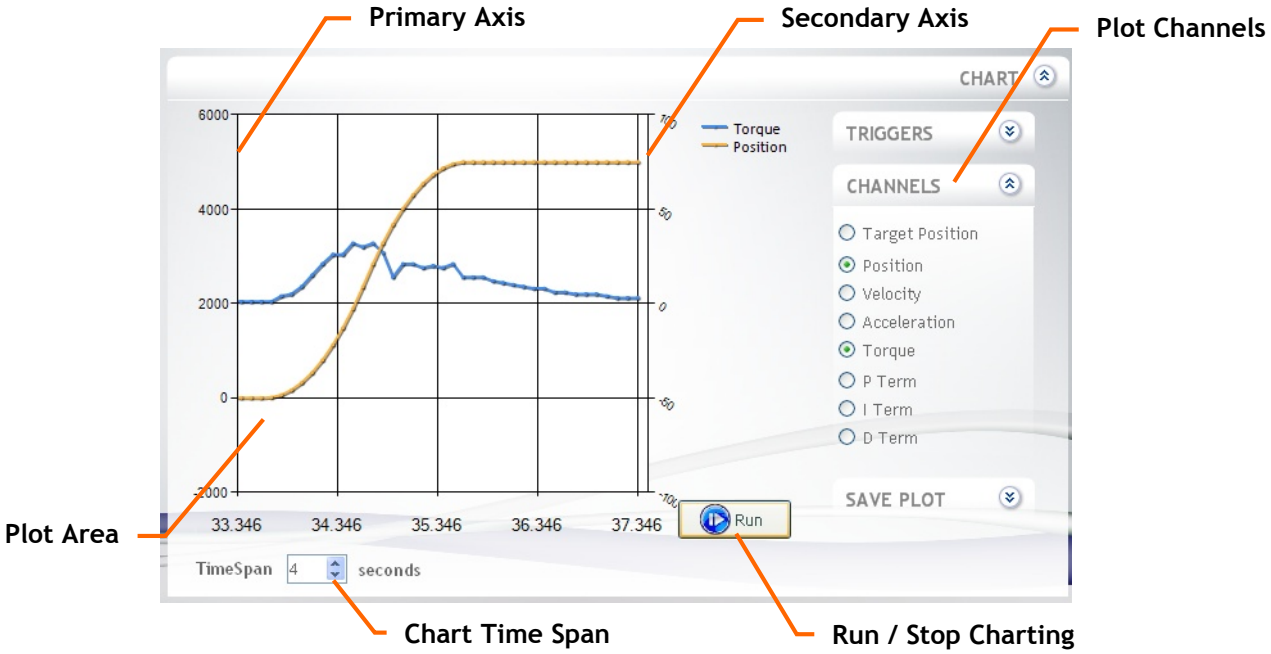
- **Loop Number**: This sets how many times the script file should be repeated.
- **Line Delay**: The line delay is the time in milliseconds between each line in the script file being sent. The default is 100ms.
- **Stop on Error Reply**: If this is set then the script file will be aborted if the EvoDrive returns an error reply.

There are three special commands which will not be sent to the EvoDrive:

- **#** : Denotes a comment line
- **pause(x)** : Will pause the script for x milliseconds
- **prompt(x)** : Will cause a message box to be displayed to the user with the message x. This message must be acknowledged before continuing the script.

9.9 Chart Panel

The **Chart** panel allows certain EvoDrive parameters to be plotted against time. This is a very useful tool during development to view motion profiles, torque levels or while tuning the PID gains.



Plotting Data

The **Channels** panel contains the data available for plotting. Up to 5 channels can be selected at any one time.

Press the **Run/Stop** button to start and stop the chart. Data will be streamed from the EvoDrive at the maximum rate allowed by the BAUD rate. The data will be plotted immediately and the plot area will scale itself to contain all data.

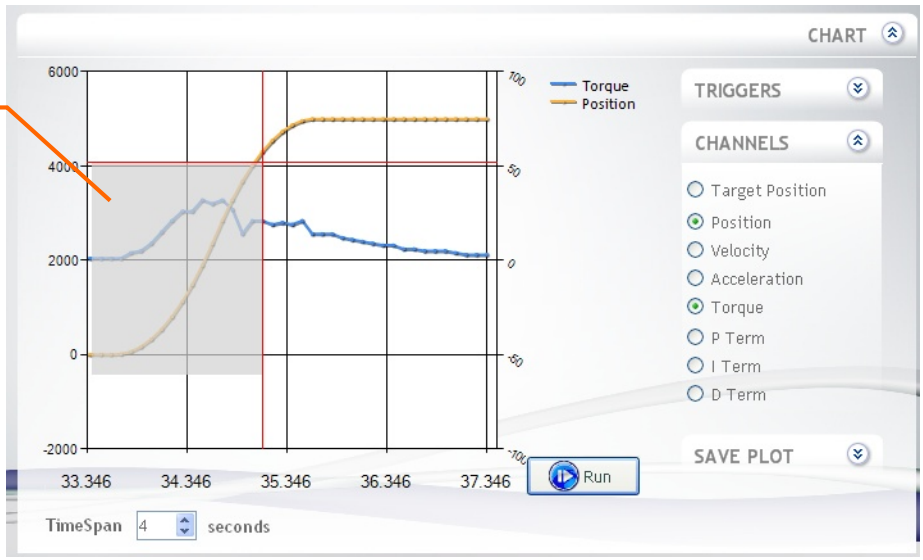
Changing the **TimeSpan** value will change the span of the X (time) axis. A value of 0 will display all data. All other values will display the latest **TimeSpan** seconds of data as a rolling plot.

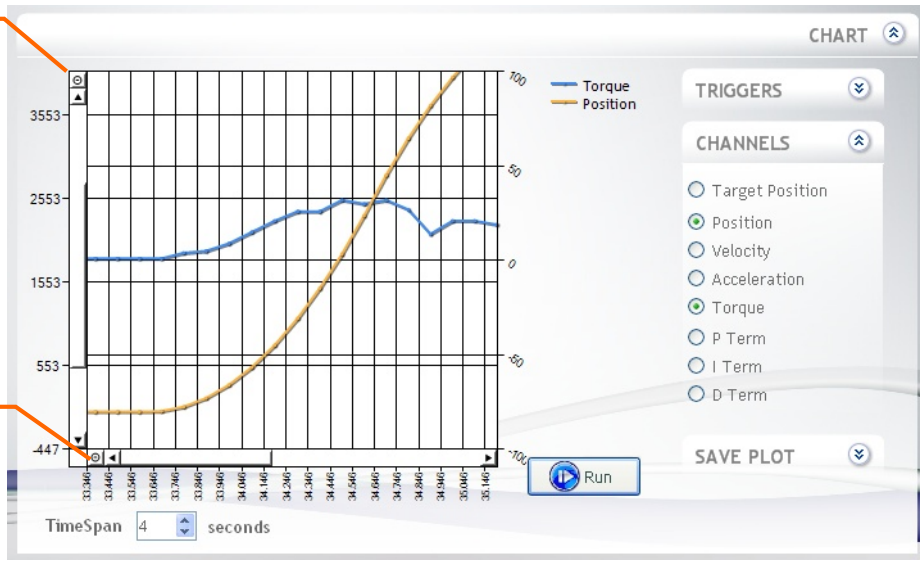
The **Position**, **Velocity** and **Acceleration** channels will be plotted against the primary axis. **Torque** and **PID Terms** will be plotted against the secondary axis.

Viewing Data

After stopping the data capture, the data view can be expanded by selecting an area on the plot.

Select the area by clicking and dragging the mouse over the area of interest.

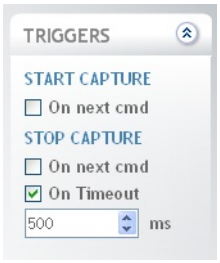




Zooming in on the data will enable scroll bars on the X and Y axes which allow the selected area to be adjusted in each axis.

At one end of each scroll bar is a small reset button which will return the axis to its original scale.

Capture Triggers



The **Triggers** panel contains options for starting and stopping the chart.

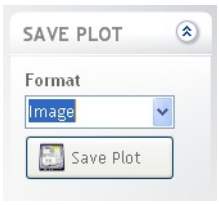
When the **Start On Next Command** option is selected, pressing the **Run** button will arm the chart. But the chart will not start to capture data until another command has been sent to the EvoDrive. Any command will trigger the chart to begin.

When the **Stop On Next Command** option is selected, the chart will stop the next time a command is sent to the EvoDrive.

If both **Start On Next Command** and **Stop On Next Command** options are selected, then the chart will begin on the first command, and it will stop on the second command.

If the **Stop On Timeout** option is enabled, the chart will stop *x* milliseconds after the chart was started, *x* being the value shown under the **Stop On Timeout** option.

Saving Data



The Save Plot panel provides options for exporting the data.

Image will save the plot area to an image file. Several different formats are supported including JPG, BMP and GIF.

Data will save the raw data to a .csv (Comma Delimited) text file. This file can then be opened in Excel or other spreadsheet/graphing software for further analysis and presentation.

9.10 Motor Calibration

To get the best performance out of any motor/encoder combination, EvoLink can be used to automatically calibrate the hardware.

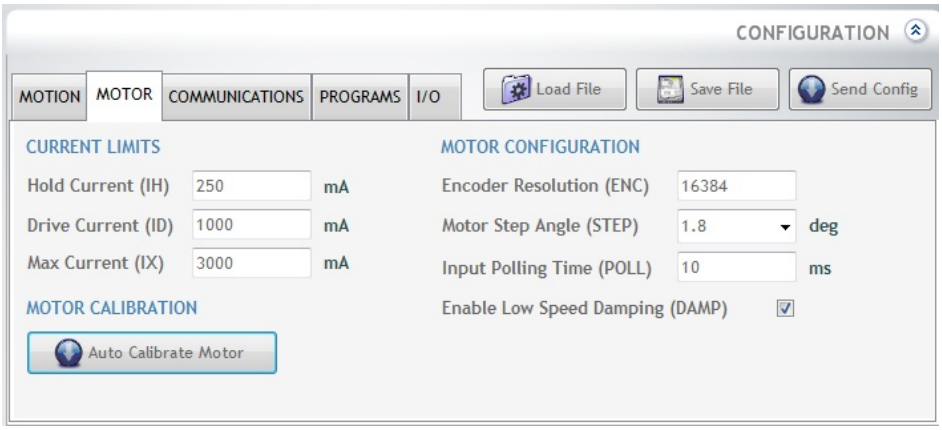
The calibration will detect the winding parameters of the motor. It will also detect any small errors between the motor position and encoder feedback. These errors may be due to manufacturing tolerances in the motor or non-linearity in the encoder, or a combination of both.

Calibration is specific to a particular motor and encoder combination. Calibration values cannot be moved from one EvoDrive to another. If a motor or encoder is replaced, or even taken apart and then re-assembled, the calibration may need to be performed again.

Starting Calibration

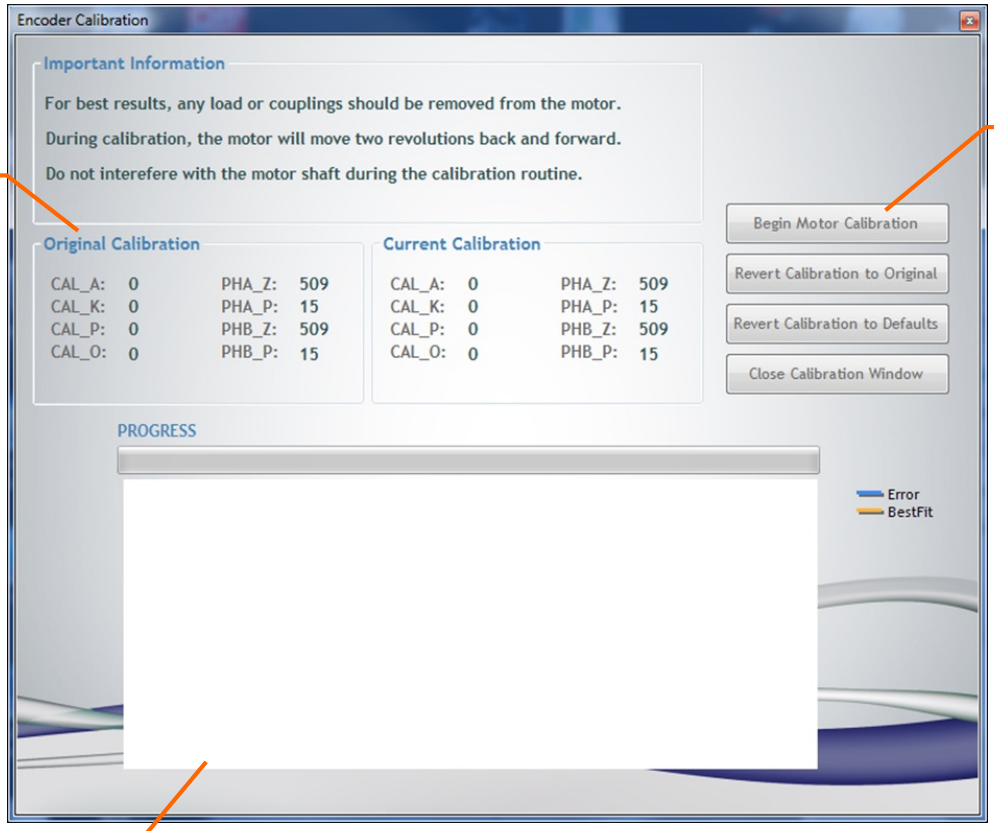
Before calibrating the motor, ensure power is connected to the EvoDrive, and disconnect the motor from any loads to ensure the motor shaft can move freely.

Open the Configuration Panel. On the **Motor** Tab, press the **Auto Calibrate Motor** button.



If there is no encoder attached (and configured) on the EvoDrive, then the motor will be calibrated immediately. This will produce a short beep or hiss from the motor, then a prompt will appear to say the calibration is complete.

If there is an encoder attached, then the following window will be displayed.



This window shows the original calibration values currently stored in the EvoDrive. You can reset the calibration values to default settings by pressing the **Revert Calibration to Defaults** button.

To begin the motor/encoder calibration, press the **Begin Motor Calibration** button.

The motor will turn 1-2 full revolutions clockwise and then counter-clockwise. While the motor is turning, the position error is displayed on the graph. The error is in degrees. This error will be compensated for by the EvoDrive after calibration.

Once the motor has finished moving, the actual and a best-fit error curve are plotted together in the results window. The **Current Calibration** group shows the updated calibration values.

To cancel the calibration and return to the original calibration values press the **Revert Calibration to Original** button.

Otherwise, to save the new calibration values and exit, press the **Close Calibration Window** button.

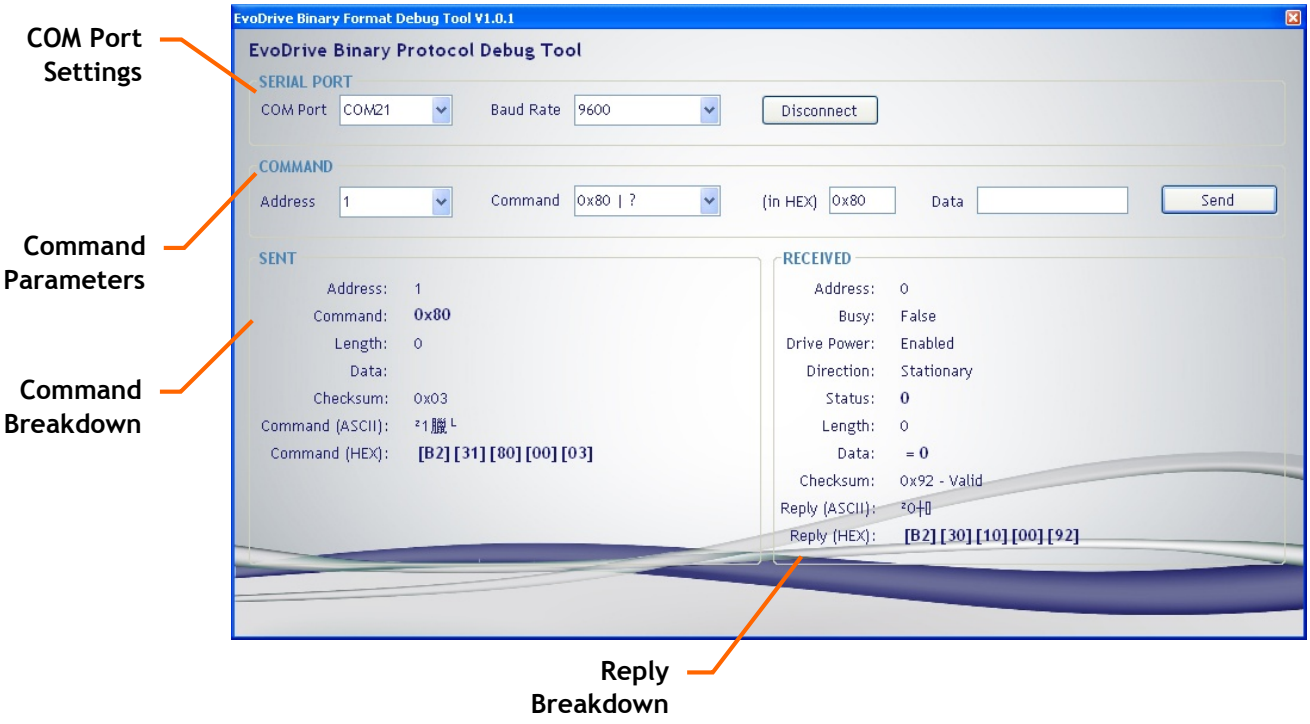
10. Binary Command Format Tool

The binary protocol debug tool is a software application that allows commands to be sent to the EvoDrive ST-23 using the binary command protocol.

The software displays a component breakdown of the command and the reply. It also shows the commands in both their extended ASCII and Hex formats.

The software helps developers build their binary interface faster, and helps to validate that their drivers are interpreting EvoDrive binary replies correctly.

For more information on the binary protocol, see the EvoDrive Programmers Manual.



11. Specifications

Absolute Maximum Ratings

Power Input	52V DC
Motor Output	52V DC
Peak Motor Current	7.1 A
Encoder Signal Inputs	5.5V DC
USB Supplied Voltage	5.5V DC
I/O Connector – I/O pins	25V DC
I/O Connector – RS232 pins	± 25V DC
I/O Connector – RS485 pins	± 10V DC

Vector Drive

Power Input	12 – 50V DC (24VDC Typical)
Drive Current	2.2A RMS 3.1A Peak
Maximum Drive Speed	Motor dependant (Up to 3000 RPM)
Maximum Resolution	102 400 steps per revolution
Motor Compatibility	Bi-Polar Stepper Motors. Any step size (0.9° ➔ 7.2° steps).

Communications

Independent Channels	2
Channel 1 Interfaces	RS232 Virtual RS232 over USB
Channel 2 Interfaces	RS485
USB	USB V2.0 Mini-B Connector
RS232 Maximum BAUD Rate	115 200 bps

RS485 Bus Maximum BAUD Rate	230 400 bps
RS485 Bus Maximum Nodes	34
Max Command Buffer	128 Characters

Digital I/O

General Purpose Inputs	4
General Purpose Outputs	4
Digital Control Modes	Step/Dir CW/CCW
Maximum pulse frequency	90KHz
Digital Output Type	NPN, Active Low 200mA max current sink
Digital Input Low Voltage Levels	0 – 0.9 VDC
Digital Input High Voltage Levels	1.4 – 24 VDC
Power rails provided	3.3 VDC (100mA max) 5.0 VDC (250mA max)

Triggered Programs

Number of Programs	9, 1 per trigger source
Program Length	64 Characters

Encoders

FW-A202 Resolution	8,192 Counts per Rev
FW-A209 Resolution	16,384 Counts per Rev
Encoder Compatibility	Quadrature Encoders Resolution of 8,192 counts after quadrature or greater. 3.3V or 5V supply.

Environmental

Operating Temperature	10°C – 55°C
Operating Relative Humidity	8% - 80% non-condensing
Storage Temperature	-40°C – 120°C
Storage Humidity	5 – 95% non-condensing
Environmental Conditions	Indoor use, up to 2000m altitude Rated Pollution Category II

Regulatory

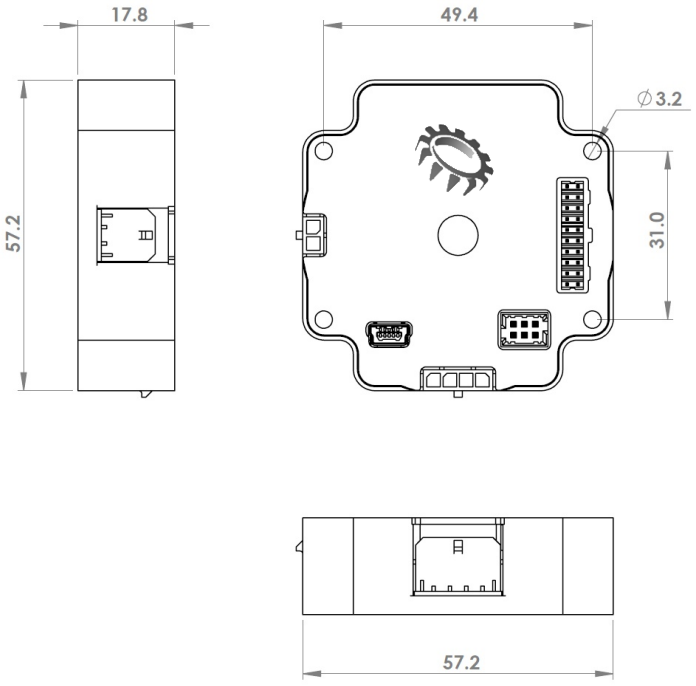
Circuit Ratings	All circuits are SELV

11.1 Mechanical Specifications

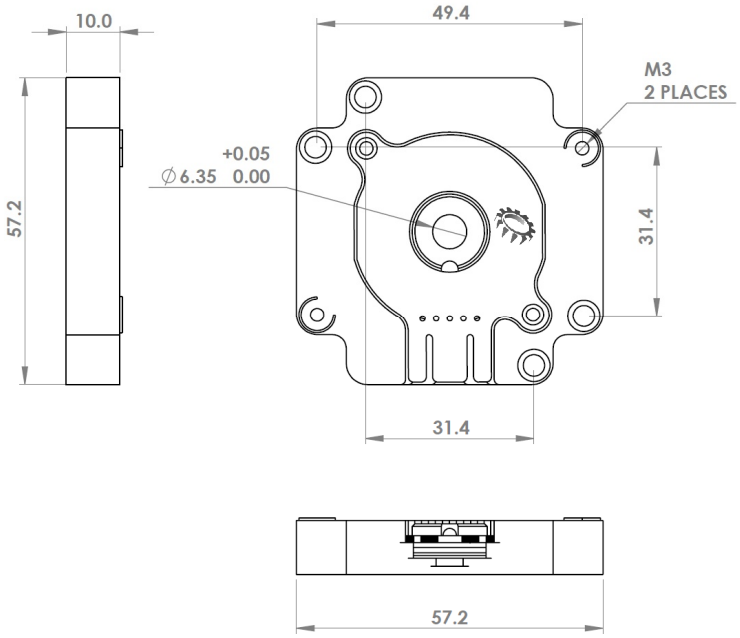
Note: These drawings show the standard EvoDrive ST-17 components without mating connectors. Allowances should be made for connectors and cable bending radius.

All dimensions are in mm.

EvoDrive (FW-A201)



Encoder (FW-A209)



EvoDrive ST-23 Integrated Stepper Servo (FW-A206)

Stacked EvoDrive + Encoder + High Torque Motor