Phoenix Motor Controller

User Manual

Control Solutions LLC

Table of contents

1. Phoenix Motor Controller

Online Manual Updated 02/03/2023

The Phoenix motor controller family is a fully configurable microprocessor-based controller for light- to medium-duty DC motors. The controller is ideal for use in industrial and commercial applications such as floor sweepers/scrubbers, material handling carts and personal mobility equipment. The controller family has multiple members based on optional features selected and output current requirements. Refer to the key features of the Phoenix family, or check out the Control Solutions website or your sales representative for product selection.

> **Note**
>
> All specifications stated within this document are subject to change without notice.

1.1 Hardcopy Version

Click here to download a PDF version of this manual

1.2 Disclaimer

Control Solutions LLC reserves the right to update this manual at any time without notice. This manual supersedes all previous issues, which must no longer be used. Control Solutions LLC reserves the right to change this product without any notification. Control Solutions LLC and the Control Solutions logo are trademarks of Control Solutions LLC. All other brand and product names, company names, and logos are trademarks or registered trademarks of their respective companies. All materials contained within this manual, in printed or electronic format, are protected by copyright laws and other intellectual property laws.

2. Quick Reference

2.1 CAN Bus

Status Messages

Motor Control Over CAN Bus

2.2 Connections & Wiring

2.3 Motor Configuration

2.4 Motor Operation

2.5 Phoenix App

3. Notices And References

3.1 About This Manual

Before using the Phoenix Motor Controller, please read this entire manual carefully to become familiar with the Controller's features, benefits and operation. This manual provides the information necessary to understand, connect, and successfully configure the Controller. It explains the Controller's functions, parameters, and usage, and provides general care and maintenance information as well as basic troubleshooting data. The document is intended for individuals who use the Phoenix Controller and for technicians performing maintenance.

3.1.1 Precautions

This document contains hazard statements for your safety. Hazard statements are provided where safety consequences to personnel, equipment, and operation can exist. Failure to follow these statements can have serious consequences.

Icons are used to draw your attention to the appropriate type of statement.

Note

Notes provide supporting information on installation, configuration, and use of the product. Not following the instructions given in notes or other precautions can lead to equipment failure.

Warning

A caution statement indicates the presence of a hazard that can or will cause minor injury or property damage.

Danger

Danger notices provide important information that must be followed to install, configure, and use the product safely and efficiently. Failure to follow the instructions given in a warning can potentially lead to equipment failure, damage to surrounding property, injury, or death.

3.2 Safety

Working with electric vehicles and batteries can be dangerous. Take proper precautions when setting up an electric vehicle or when working with batteries.

Warning

Malfunctions regarding operating conditions can occur when working with electric vehicles that can cause them to run. When working with or setting up an electric-powered vehicle, it is highly recommended that you support the vehicle in a safe manner with the drive wheels off the ground or disconnect the motor wires.

Warning

Short-circuiting the battery terminals or connections can cause an electric arc. Always disconnect the battery connections when installing or working with high-current vehicle batteries. It is recommended that you use insulated tools and wear safety glasses when working with high-power batteries.

Warning

Normal charging and discharging of lead acid batteries produces hydrogen gas, which is extremely flammable and explosive. Follow the battery manufacturer's safety precautions and recommendations when working with lead acid batteries. Always wear safety glasses.

3.3 Acronyms

ASIC

Application-Specific Integrated Circuit

BLDC

Brushless DC

CAN

Controller Area Network (see CAN Bus)

CSLLC

Control Solutions Limited Liability Company

DC

Direct Current

DSP

Digital Signal Processor

DSPIC

Microchip Digital Signal Processor

ECU

Electronic Control Unit (see CAN Bus)

EM

Electromagnetic

ESD

Electro-Static Discharge

FET

Field Effect Transistor

GND

Ground

GPIO

General Purpose Input/Output

HHP

Hand-Held Programmer

I2C

Inter-Integrated Circuit

I/O

Input/Output

IEC

International Electrotechnical Commission

IP

Ingress Protection

ISO

International Standards Organization

KG

Kilogram

LCD

Liquid Crystal Display

LED

Light Emitting Diode

PCB

Printed Circuit Board

POD

Power on Demand

PWM

Pulse Width Modulation

RJ

Registered Jack

RPM

Revolutions Per Minute

UART

Universal Asynchronous Receiver Transmitter

UL

Underwriters’ Laboratories

4. Features

4.1 Features

Phoenix Controllers are highly customizable, and are loosely grouped by drive capacity and intended application. New features and applications are being added all the time, so please contact your Control Solutions representative for help choosing the right model for your application.

A specific Phoenix controller is manufactured with a part number in the format: CS8xxx.yyyy

The portion to the left of the '.' is the model, and indicates the basic capabilities of the controller, as shown in the table below. The portion to the right of the '.' is the configuration, which indicates any customization or pre-loaded configuration that is installed for a particular application.

Model	Motor Type	Peak Current	Voltage	Contactor	Other
CS8101	Brushed	125A	24/36/48	Internal	IP65
CS8201	BLDC, PMAC	190A	24/36/48	Internal	UL60730, UL583, IP65
CS8202	Brushed DC	190A	24/36/48	Internal	IP65
CS8203	Brushed DC	190A	24/36/48	Internal	UL60730, UL583, IP65
CS8204	BLDC, PMAC, Brushed DC	190A	24/48/60	Internal	IP65
CS8205	Brushed DC	190A	24/36/48	Internal	IP65, Digital Input 2 Pin High
CS8301	Brushed DC	250A	24/36/48	External	IP65

Phoenix Model Summary

Unless otherwise noted, Phoenix models also include the following features:

- External EM Brake Control
- Control, Configuration, and Status monitoring via CAN Bus 2.0b
- Battery charger interlock
- Programmable Sleep (power saving) mode
- Programmable acceleration, deceleration and speed settings
- Throttle control and Auto-Drive (pre-configured) Modes
- Dual throttle support
- Programmable throttle configuration (supports analog, hall effect, and serial throttles)
- Throttle Fault Detection
- Low/high voltage shutdown
- Automatic system voltage determination at power-up
- Over-temperature protection
- Multiple current limiting modes
- Built-in diagnostics
- Diagnostic interface capability (Requires external hardware)
- ESD protection to IEC 61000-4-2 Class A
- Four quadrant, full H-bridge design
- Power on Demand — The Controller outputs the current necessary to instantly overcome obstacles such as ramps, curbs, etc.
- Anti-Rollback — Virtually no roll-back when stopping on inclines
- Multiple drive modes
- Anti-jolt on power-down
- Throttle fault detection
- High pedal disable

Info

Phoenix motor controllers are designed and manufactured in the USA

4.2 CANBUS

4.2.1 Controller Area Network (CAN)

A Controller Area Network (CAN bus) is a vehicle bus standard designed to allow microcontrollers and devices to communicate with each other in applications without a host computer. It is a standard that is used to allow Electronic Control Units (ECUs) to communicate in an efficient manner without a central computer. Messages are broadcast in a system that requires very little physical wiring, making the CAN bus low cost, robust and efficient.

Physically, a CAN Bus consists of two dedicated wires for communication. These wires are called CAN high and CAN low. When the CAN bus is in idle mode, both lines carry 2.5V. When data bits are being transmitted, the CAN high line goes to 3.75V and the CAN low drops to 1.25V.

CAN Bus documentation frequently refers to devices on a CAN Bus network as Electronic Control Units (ECU). A Phoenix Motor Controller is an example of an ECU.

CAN Bus Messages

The CAN Bus interface uses 2.0b (29-bit identifiers) for its messages. Addressing and messages are consistent with J1939 formatting and carry a variety of Phoenix status and control data as detailed below. A full description of the Phoenix CAN Bus messages is found here

Device Identification

Each controller establishes a unique identifier for its CAN Bus traffic. This ID allows other devices on the network to communicate directly with a single controller, even if multiple controllers are installed on the same bus.

At powerup, the Controller will try to establish its ID according to the J1939/81 Address Claim procedure. In a system with one Motor Controller and default configuration, the Controller will use address 0x80.

In systems with multiple devices and/or Controllers, it is often desirable to set the ID of a specific controller to a known value. This is accomplished through CAN Bus Configuration

Status Messages

Unless inhibited from doing so by status configuration, the Motor Controller periodically broadcasts a variety of status information. Details are found here.

Troubleshooting the CAN Bus Interface

The following are common issues that prevent CAN Bus communication with the Controller:

- Incorrect baud rate. Make sure the configuration of the controller matches the other devices on the network.
- Incorrectly terminated bus. CAN Bus connections require a 120 ohm terminator on each end of the network for proper operation.
- Incorrect device ID: the controller responds to its unique address as established at powerup within the constraints of the configuration. If the ID of the controller is unknown, it can be discovered using the J1939/81 request message, or by observing broadcast status messages on the network (the Controller's ID is the last byte of the 29-bit device identification identifier).

4.2.2 CAN Bus Digital Control

The Digital Control feature allows various aspects of the motor controller to be controlled via CAN Bus. These include:

- Virtual activation of 'buttons' like REVERSE, IN/OUT, or QUICKSTOP
- Virtual control of Throttle
- Virtual control of the Max Speed potentiometer

Once configured, the external control module simply sends periodic Digital Control Messages to the motor controller. It is recommended that the messages be sent periodically rather than only upon change, to allow for the possibility of a lost or missed message due to CAN Bus noise, etc. A period of 50ms is often used and provides adequate responsiveness for most applications.

Configuring Digital Control Mode

Note that depending on model, the controller may be shipped pre-configured for digital control. This section provides details for users who need to adjust or enable digital control.

SET CAN BUS CONTROL OPTIONS

The CAN Bus Digital Control Options must be set to the desired options. For example, if it is desired that motion is inhibited unless Digital Control messages are being received, set the quickstop and/or zero throttle bits of this item. As a result, unless valid Digital Control messages are being received, the motor will not move an the Reason for Stop indication will include 'Digital Stop Active'

SET MOTOR CONTROL OPTIONS

Configuration Register 0x0357 determines whether Digital Throttle is enabled, and/or Analog Throttle is enabled. Possible values for bits 2:0:

000: Allow Analog Throttle Only

001: Use Analog Throttle, but control buttons (like forward/reverse) using digital CAN Bus messages

101: Use both Analog Throttle and Digital Buttons and Digital Throttle (Mixed Throttle). Depending on the CAN Bus control Options, Digital Throttle may be set to override Analog Throttle. Or, Digital Throttle may be configured to act as a Max Speed potentiometer (gain value) for the Analog Throttle.

111: Use Digital Throttle and control buttons

Configuration Register 0x031F: If the Digital Throttle is to be used as a Max Speed potentiometer (Mixed Throttle), set bit 6.

Digital Motor Control Commands

It is possible to control the motor speed and direction over CAN Bus. By default this feature is disabled. See Digital Control Options for more information. Once the feature is enabled the motor can be run with 'as needed' commands or it can be made to stop when repeated Digital Throttle commands cease to be sent. If stopping is desired, the commands must be sent at least every 450 milliseconds by default or faster. The timeout can be changed, see Timer Configuration. When the commands stop, the Digital Throttle can be made

to go to 0 or a quickstop can be implemented. There are several options to stop the motor when commands cease to be sent. See Digital Control Options for information on how to enable or disable throttle shut off and/or quick stop.

> **Warning**
>
> Do not send CAN bus commands faster than every 20 milliseconds.

Digital Throttle

The Digital throttle is also referred to as the Digital Potentiometer. This value of 0-255 will determine the PWM of the motor from 0-100% of the max speed setting. This function (0x50), is a write only command and no response is returned unless the echo option is enabled in the Digital Control Options.

B0	[B1]	[B2]	[B3]
0x50	Digital Throttle	Digital Buttons	Digital Mode

[B#] means optional data. However, all data previous to the last value sent must be populated with meaningful data. All missing data fields after the last byte sent are ignored. Any data after the B3 byte is echoed back if echoing is enabled.

> **Note**
>
> For dual motor controllers this command only affects the motor associated with the ID used.

Digital Buttons

Note

All bits are set to 1 by default. All features are active low.

Bit Mask	Command	Description
0x01	Reserved	Set to 1
0x02	Reserved	Set to 1
0x04	Reserved	Set to 1
0x08	Reserved	Set to 1
0x10	Quick Stop	Motor stops when set to zero. The stop diagnostic byte in status FF03 will either indicate "Digital STOP" (0x03) or "Waiting for deadband" (0x0C). In either case the throttle(s) must be set to deadband or 0 to restart the motor. See Stop Diagnostics for more information on stop values.
0x20	Reverse	Set to 0 to reverse the motor if controller is in manual or mixed throttle mode. Use bits 0 and 1 if in full digital throttle mode.
0x40	Indoor/ Outdoor	Set to 0 for indoor mode. Set to 1 for outdoor mode.
0x80	Brake Release	Set to 0 to release external EM brake.

Digital Mode

Note

All bits are set to 1 by default. All features are active low.

Bit Mask	Command	Description
0x01	Seat Switch	Clear this bit to make seat active (User is sitting on seat). If throttling up of any kind is attempted the stop diagnostics byte in status FF03 will indicate "Waiting for deadband" (0x0C) The throttle(s) should be set to deadband or 0 to until this bit is set.
0x02	Horn	Set to 0 to sound horn
0x04	Reserved	Set to 1
0x08	Reserved	Set to 1
0x10	Echo 0x50 Commands	Set to 0 to make all digital throttle (0x50) commands be echoed back to the host
0x20	Reserved	Set to 1
0x40	Reserved	Set to 1
0x80	Reserved	Set to 1

Examples

Set Digital throttle to 25% PWM:

```
Command:    10EF8090 50 40        0x40 = 64 = 25% PWM
```

Set Digital throttle to zero and set buttons to run forward

```
Command:    10EF8090 50 00 FF     0x00 = 0 = 0% PWM
```

Set Digital throttle to 50% and set buttons to run reverse and mode to FF

```
Command:    10EF8090 50 80 DF FF    0x80 = 128 = 50% PWM
```

Refresh CAN Bus Timeout without changing any settings

```
Command:    10EF8090 50
```

4.2.3 CAN Bus Messages

This section summarizes the CAN Bus messages used with the Controller. See the CAN Bus Configuration page for more information about setting up the CAN Bus interface.

> **Note**
>
> The examples in this section assume the Controller's CAN Bus address is 0x80 while the Host device is 0x90. Different values must be substituted if your CAN Bus network is designed differently.

Message Format

The controller sends and receives CAN Bus 2.0b messages with 29-bit identifiers. The identifiers are formatted in the J1939 style. The controller emits status messages in the PDU2 (broadcast) range, and accepts command and control messages in the PDU1 (destination specific) format.

Control Message

The Control message allows directed (addressed) command sequences to be sent to the controllers. The payload contains up to 8 bytes, which are command-specific.

A command sent from a (source) to a (target) may be followed by a response from the (target) to the (source).

For example, a control message with priority 4, sent from device 0x90 to device 0x80 would have 0x10EF8090 as its 29-bit identifier.

The response would have identifer 0x10EF9080 as its 29-bit identifier.

The first byte of the message data in a Control message request is the 'function code', which indicates what function the controller is being asked to perform.

The first byte of the response to the Control message includes the same function code. If an error occurs (eg. unknown function code, etc), the response function code will have the most significant bit set and the second byte will contain an error code.

The error codes include

Code	Meaning
1	Unknown Function Code
2	Illegal Address
3	Illegal Data Value
4	Device Failure
5	Device Busy

For example, sending (unknown) function code 0x20 to the controller: `0x10EF8090 20`

The controller's response: `0x10EF9080 A0 01`, which has the first byte as 0x20 with the MSB set, and 01 as the error code.

The controller supports Control messages longer than 8 data bytes, via the J1939-TP protocol. This protocol is not explained here but is documented in J1939 literature.

```
PGN: 0xEF00
```

Data:	Byte 0	Byte 1 - Byte 7
Content:	{Function}	0 or more bytes of function-specific parameters

The Function is an enumeration:

Function	Selected Function
0x45	Read Parameter(s)
0x46	Write Parameter(s)
0x47	System Commands
0x50	Digital Control

READ PARAMETER(S) FUNCTION CODE

One or more bytes of configuration or status parameters can be requested from the controller using this command. It is not normally necessary to read parameters, and any use of this command should be done in collaboration with Control Solutions, since the parameters or parameter values may change depending on controller model or software version.

A Read Parameters request consists of a 16-bit address, and the number of bytes to be returned.

Example

Read the CAN Bus ID (parameter 0x0402)

```
                    FC  ADDRESS  LEN
Command:    10EF8090 45  04   02  01
Response:   1CEF9080 45  80

The response indicates that the CAN Bus ID of the unit is 0x80
```

WRITE PARAMETER(S) FUNCTION CODE

One or more bytes of configuration parameters can be written to the controller using this command. It is not normally necessary to write parameters, and any use of this command should be done in collaboration with Control Solutions, since the parameters or parameter values may change depending on controller model or software version.

Example

Write the CAN Bus ID (parameter 0x0402) to 0x81

```
                    FC  ADDRESS  Data
Command:    10EF8090 46   04 02   81
Response:   1CEF9080 46  00 (00=Success)

Notice that the parameter change did not take effect immediately
```

```
and the reponse is sent from the existing CAN Bus ID (0x80).
The new ID will take effect when the controller is reset or power cycled.
```

SYSTEM COMMAND

Example

Reset the controller

```
Command:    10EF8090 47 FB
Response:   None
```

> **Warning**
>
> Using this command while the motor is running is not recommended. An abrupt stop to the motor could harm the equipment and/or the operator.

DIGITAL CONTROL

If enabled and configured, the Digital Control message provides a proportional drive level input and/or control of direction via CAN Bus. Refer to Digital Control for more details.

Byte	Length	Parameter	Description
0	1 byte	Function	0x50 indicates Throttle Control message
1	1 byte	Digital Pot	Unsigned 0-255, indicates a proportional level. For example, to be used as a throttle value.
2	1 byte	Digital Buttons	Note: bits are active low (0=Active) Bit 0: Reserved, set to 1 Bit 1: Reserved, set to 1 Bit 2: Reserved, set to 1 Bit 3: Reserved, set to 1 Bit 4: 0=Quickstop. Behavior depends on quickstop configuration Bit 5: 0=Reverse Bit 6: 0=Indoor Mode Bit 7: Reserved, set to 1
3	1 byte	Digital Mode	Bit 0: 0=Seat Empty. If the Seat Switch function is enabled, clearing this bit prevents motion Bits 1-7: Reserved, set to 1

Example

```
Set Digital throttle to 25%
(0x40 = 64 = 25% throttle)
Command:    10EF8090 50 40 FF
```

```
Set Digital throttle to zero and set buttons to run forward
(0x00 = 0 = 0% throttle)
Command:    10EF8090 50 00 FF
```

```
Set Digital throttle to 50% and set buttons to run reverse and mode to FF
(0x80 = 128 = 50% throttle)
Command:    10EF8090 50 80 DF FF
```

```
Refresh CAN Bus Timeout without changing any settings
Command:    10EF8090 50
```

Status Messages

Status messages are emitted by the controller at periodic intervals. Specific messages can be inhibited by configuring them. If status message are inhibited, they can be manually requested using a J1939 PGN request message using PGN 0x0nFF00.

PGN Request Example:

```
Request status FF01
The first data byte is the status message number 0-7. The
number must be followed by 0xFF and 0x00 with no other data bytes.
Command:    10EA8090 01 FF 00
Response:   10FF0180 0E 62 00 00 00  00  00  00
```

Message definitions can vary according to Controller Model. Refer to the model-specific bus definition for exact field definitions.

FF00 MOTOR DRIVE STATUS MESSAGE

```
PGN:                0xFF00
Default Priority:   6
Interval:           100ms
```

Byte	Length	Parameter	Description
0	1 byte	Reserved	
1	1 byte	Output Current	Measured output current in Amps
2	1 byte	PWM Output	Unsigned 0-255. Indicates proportion of output PWM (255=100%)
3	1 byte	Reserved	
4	1 byte	Active current limit	Uses the same format as cur_lb and cur_ub.
5	3 bytes	Reserved	

FF01 MONITOR STATUS MESSAGE

```
PGN:                0xFF01
Default Priority:   6
Interval:           1000ms
```

Byte	Length	Parameter	Description
0	1 byte	Temperature	Measured Controller temperature (C)
1	1 byte	Supply Voltage	Measured supply voltage(V) multiplied by 4
2	1 byte	Reserved	
3	1 byte	State Of Charge	The state of charge based on compensated voltage compared to the values of register 0x0327 and register 0x0328. A value of zero indicates the battery state of charge is at or below the Undervoltage warning threshold. A value of 100(decimal) indicates state of charge is at or above the Top Segment configured level.

FF02 CUSTOM STATUS MESSAGES 0-7

```
PGN:                0xFF02
Default Priority:   6
Interval:           500ms
```

Byte	Length	Parameter	Description
0	8 bytes	Reserved	These eight bytes can be programmed to do read any RAM or EEPROM location. The values can be read once at power up or continuously. See Custom Status Configuration for more info.

FF03 SYSTEM STATUS MESSAGE

```
PGN:                0xFF03
Default Priority:   6
Interval:           1000ms
```

Byte	Length	Parameter	Description
0	1 byte	System State	Bitmapped state codes. See System State for more information.
1	1 byte	Motor State	Enumerated state codes. See Motor State for more information.
2	1 byte	Communications Alarms	Bitmapped state codes: All 0's = Normal Bit 0: CAN Bus RX errors > 127 Bit 1: CAN Bus TX errors > 127 Bit 2: Reserved Bit 3: Reserved Bit 4: Interprocessor comm error Bit 5: CAN Bus RX Silent for > 1 second Bit 6: Digital Throttle command timeout Bit 7: Incoming R/W Overload
3	1 byte	Charge Mode	When a compatible charger is attached, this byte indicates what the charger is doing. 0x00 = Not Charging 0x01 = Precharge 0x02 = Bulk Charge 0x04 = Balancing 0x08 = Float 0x80 = Just changed from charge mode to drive mode. Key cycle or power cycle is required to clear this bit.
4	1 byte	Fault Code	Active fault (0=None) See Faults for specific fault codes.
5	1 byte	Miscellaneous Diagnostics	See Miscellaneous Diagnostics for more information.
6	1 byte	PWM Limited	See PWM Diagnostics for more information.
7	1 byte	Stop Cause	See Stop Diagnostics for more information.

FF04 THROTTLE STATUS MESSAGE

```
PGN:                0xFF04
Default Priority:   6
Interval:           100ms
```

Byte	Length	Parameter	Description
0	2 bytes	Throttle 1 Analog	Unsigned (LSB, MSB) value which corresponds to the measured throttle voltage. 0=0V, 65535=5V
2	1 byte	Throttle 1 Command	Unsigned 0-255. Indicates proportion of scaled throttle (255=100%)
3	1 byte	Reserved	
4	2 bytes	ANALOG IN Voltage	Unsigned (LSB, MSB) value which corresponds to the measured throttle voltage. 0=0V, 65535=5V. Note: resolution of the measurement is 12 bits and the input is not factory calibrated.
6	2 bytes	Reserved	

FF05 SPEED STATUS MESSAGE

```
PGN:                0xFF05
Default Priority:   6
Interval:           250ms
```

Byte	Length	Parameter	Description
0	2 bytes	Actual RPM	Unsigned (LSB, MSB). Measured motor speed in RPM. Only used in brushless system.
2	2 bytes	Target RPM	Unsigned (LSB, MSB). Only used for Brushless motor in speed control mode, target motor speed in RPM
4	4 bytes	Reserved	

FF06 DIGITAL CONTROL STATUS MESSAGE

```
PGN:                0xFF06
Default Priority:   6
Interval:           250ms
```

Byte	Length	Parameter	Description
0	1 byte	Reserved	
1	1 byte	Reserved	
2	1 byte	Reserved	
3	1 byte	Reserved	
4	1 byte	Miscellaneous Status	Bit 0: Reserved Bit 1: 0=Indoor 1=Outdoor Bit 2: 1=Low Volts Bit 3: 1=Brake Release Bit 4: 1=Quick Stop. Bit 5: Seat Switch Active Bit 6: Reserved Bit 7: Reserved
5	1 byte	Aux	Bit 0: Reserved Bit 1: Reserved Bit 2: Reserved Bit 3: Reserved Bit 4: Reserved Bit 5: Reserved. Bit 6: 1=Forward Bit 7: 1=Reverse

FF07 CUSTOM STATUS MESSAGES 8-15

```
PGN:                0xFF07
Default Priority:   6
Interval:           500ms
```

Byte	Length	Parameter	Description
0	8 bytes	Reserved	These eight bytes can be programmed to do read any RAM or EEPROM location. The values can be read once at power up or continuously. See Custom Status Configuration for more info.

5. Installation

5.1 Installation

The Phoenix Motor Controller may be supplied with or without an enclosure for protection against moisture and dust/dirt.

Use the following guidelines when wiring your motor controller.

5.1.1 General Wiring Guidelines

Cabling

- Keep cables as short as possible.
- Make sure the cabling you use can withstand the environment and stress points.
- Avoid using damaged cables; they can cause a fire.
- Avoid contact with flammable material.
- Install cables in such a way that users cannot reach them.
- If possible, do not route cables near the motor case.
- The wire size must be as large as possible. This reduces the resistance and electrical loss associated with the cable. Refer to the wiring sections for minimum wire sizes.
- Do not use wire sizes smaller than 0.5mm2/AWG20 for low current signals. Such wiring is not strong enough.
- Avoid wire loops, particularly loops of single wires instead of multiple wires.
- Run wires in pairs or bunches. Note that wires can come in bundles of two or three wires.

Connections

- The controller and speed setting potentiometers must be mechanically connected to the vehicle frame.
- The vehicle frame must not be used as the earth return. International safety standards prohibit any electrical low-resistance connection to the frame as a safety risk.
- Avoid the exposure of electrical connections. Insulate exposed connections.
- Use only the supplied terminal screws or nuts to make electrical connections.
- For CAN Bus connections, refer to additional guidelines found here

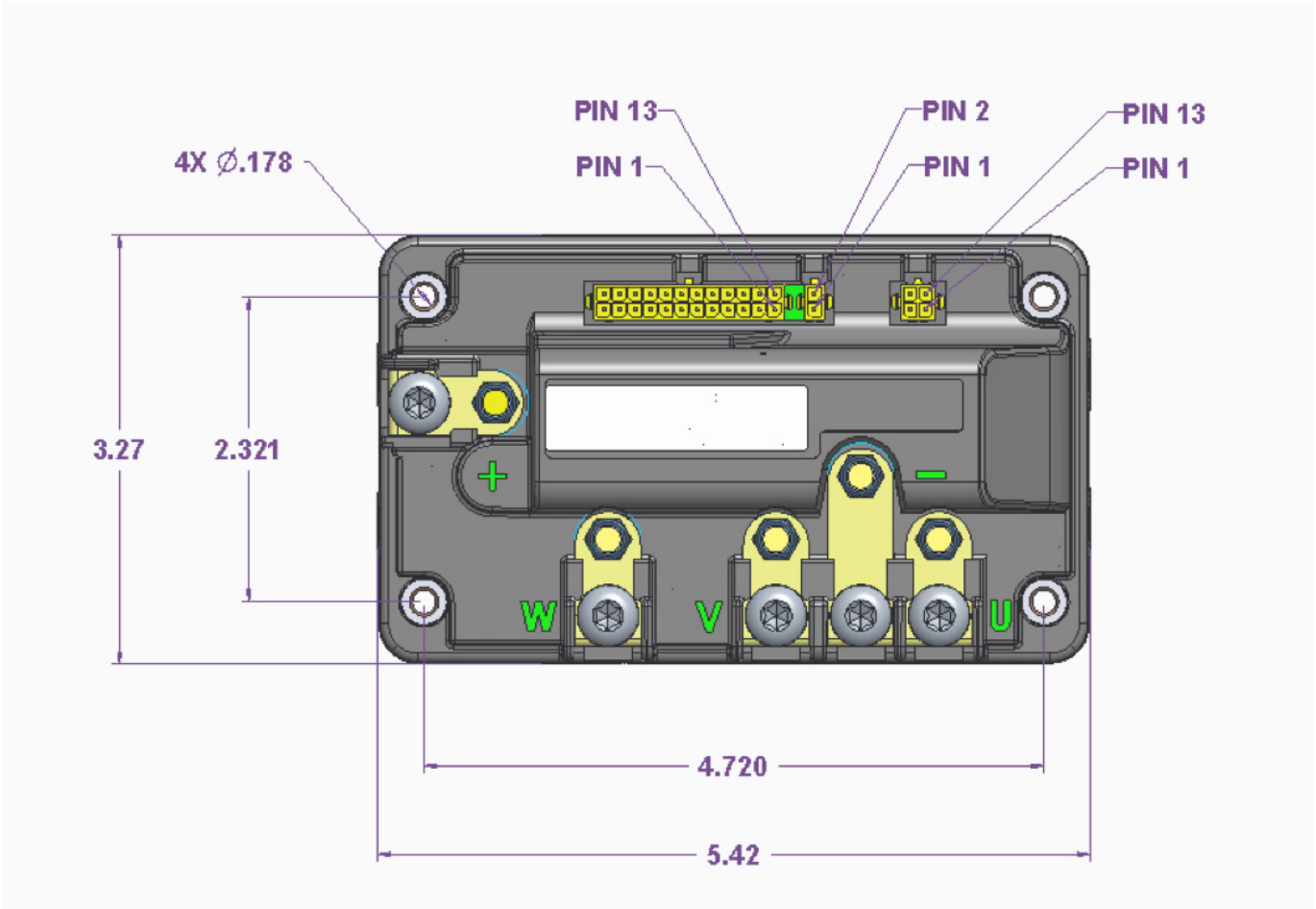
Warning

- Cable routing: When routing cables, you must route them in such a way as to prohibit water entry or undue stress or strain on the cables. Also, make sure the cables do not extend beyond the vehicle, and that they are not inhibited by a seat raise or other moving parts.
- Unit replacement: Before replacing or moving the motor controller, disconnect all the cables of the vehicle at the powered end.
- Service manual: The documentation that accompanies your end product should specify inspection and maintenance requirements for connectors and cables.
- Safety: The installer must make sure that the finished wiring is installed correctly and safely.
- Security: Disable the vehicle before making changes to the connections by: disconnecting the motor or batteries, or placing the drive wheels up off of the floor, or placing the battery circuit breaker in the open position.
- ISO requirements: Cover the battery and motor connectors with a cover that cannot be removed without certain tools, or otherwise install them such that they cannot be adjusted.

5.1.2 Mounting the Controller and Enclosure

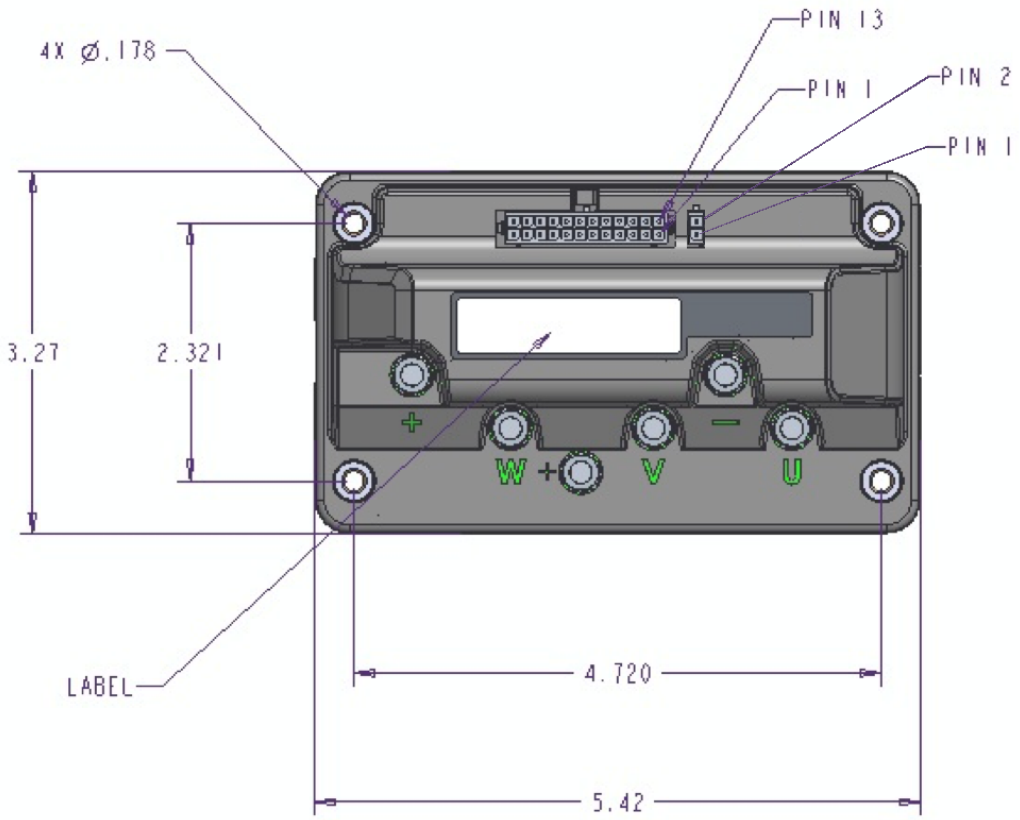
Phoenix motor controllers are equipped with four mounting holes, typically located at the corners of the unit. The mounting holes are sized for a #8 screw. The amount of torque on the mounting screws depends on the type of screw used. Consult the screw manufacturers specifications for torque information. The controller can be oriented in any position. It is recommended that the unit be positioned in a manner to keep it away from excessive dirt and moisture in order to prevent damage. Additionally, the installation location should have proper airflow to keep the ambient temperature below 45° C.

P125/P190 Mounting



Motor and power connections should be made with properly sized wires and terminals, torqued to about 40-45 inch-pounds.

P250 Mounting



Motor and power connections should be made with properly sized wires and terminals, torqued to about 40-45 inch-pounds.

5.1.3 Connectors and Pinouts

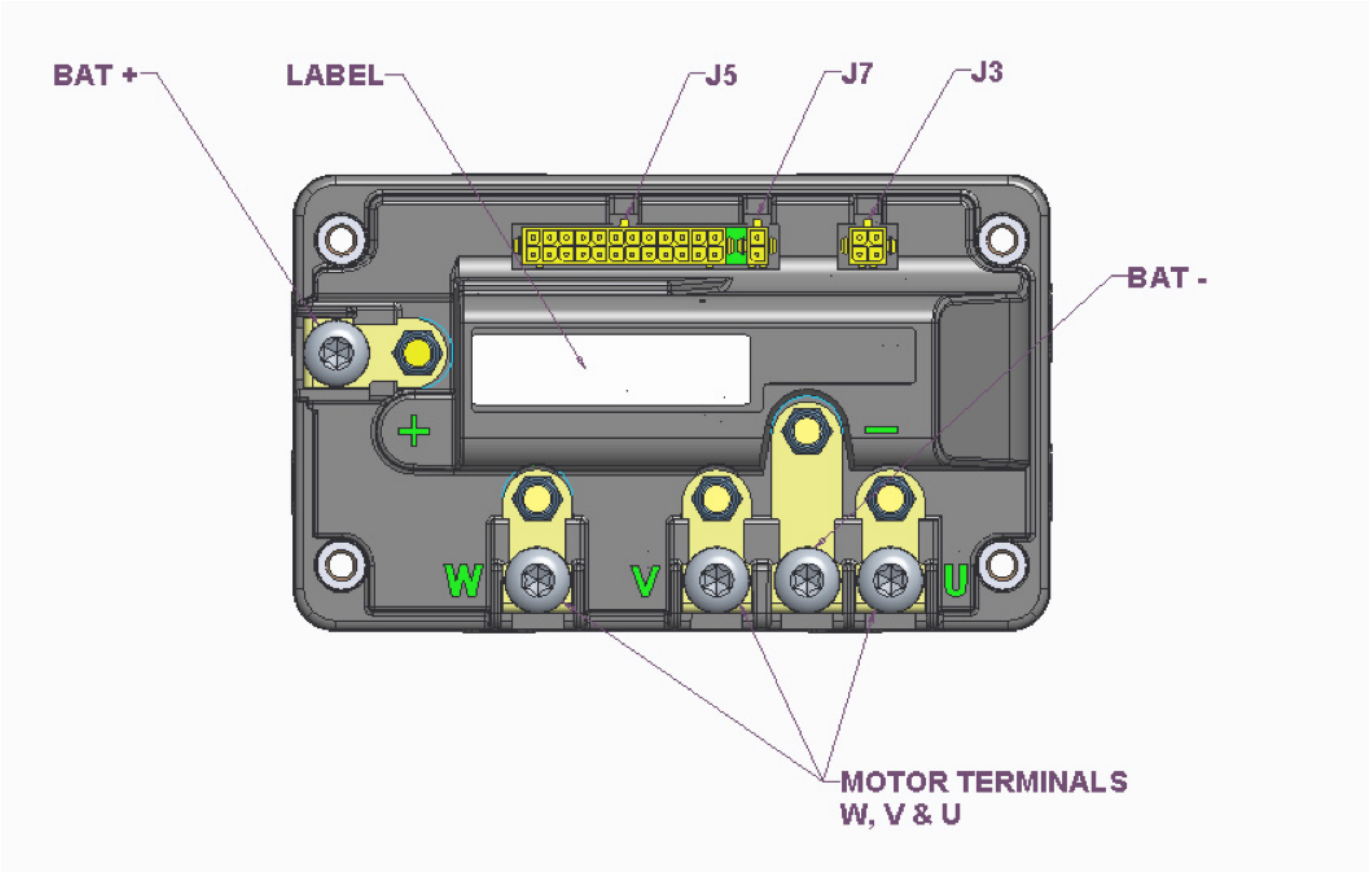
Electrical connections vary among the various Phoenix models. Refer to the information below, or the custom specifications supplied with your controller.

P125/P190 Style Pinouts

P250 Style Pinout

5.2 P125/P190 Pinout

5.2.1 Connectors and Mates



Label	Type	Function	Part Number	Mate
J7	2 Pin TE Micro MATE-N-LOK	EM Brake	TE 3-794630-2	TE 794617-2
J3	4-Pin TE Micro MATE-N-LOK	Charging	TE 3-794630-4	TE 794617-4
J5	24-pin TE Micro MATE-N-LOK	Control and Status I/O	TE 5-794630-4	TE 2-794617-4
+ (Battery +)	STUD M6 X 1 8MM	Positive voltage input		
– (Battery -)	STUD M6 X 1 8MM	Negative voltage input		
W (Motor W)	STUD M6 X 1 8MM	High current connection to motor		
V (Motor V)	STUD M6 X 1 8MM	High current connection to motor		
U (Motor U)	STUD M6 X 1 8MM	High current connection to motor		

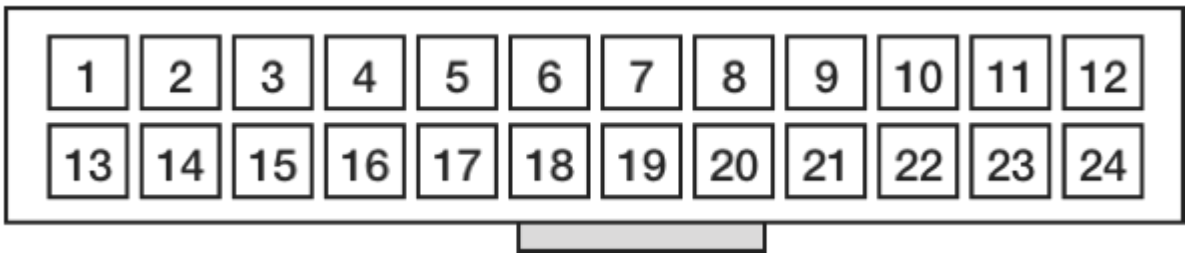
5.2.2 J7 Brake

Pin	Name	Description	Typical Use
1	EMBRK+	VIN	EM Brake High Voltage
2	EMBRK-	< .4V , 1.25 A Max	EM Brake Ground

5.2.3 J3 Charging

Pin	Name	Description	Typical Use
1	Raise Charge	Active < 0.8VDC	
2	Charging	Active > 2VDC	
3	Batt -	<0.02VDC	Charger Battery -
4	Batt +	>28.7VDC @3A	Charger Battery +

5.2.4 J5 Control and Status I/O



Pin	Name	Description	Typical Use
1	THROTTLE LOW	Throttle Pot Low (~0V): Low potentiometer reference for an analog throttle.	Throttle potentiometer
2	CAN-H	CAN Bus High (5 volt differential)	Status/Configuration
3	CAN-L	CAN Bus Low (5 volt differential)	Status/Configuration
4	DIGITAL INPUT 2 (GP_DIN2)	Digital Configurable Input 2	Seat Switch
5	NC		
6	DIGITAL INPUT 1 (GP_DIN1)	Digital Configurable Input 1	Fault Input (Quickstop)
7	DIGITAL OUTPUT 1	Open Collector Output. Active > 2 V, Inactive = open circuit	
8	I2C SDA	I2C Data	Status/Configuration
9	I2C SCL	I2C Clock	Status/Configuration
10	THROTTLE POT HIGH	Throttle Pot High (~5V): High potentiometer reference for an analog throttle.	Throttle potentiometer
11	5V SUPPLY	Regulated 5V Supply	Motor Hall Sensor Power
12	15V SUPPLY	Regulated 15V Supply	Motor Hall Sensor Power
13	THROTTLE POT CENTER	Throttle Pot Center (0-5VDC)	Throttle potentiometer
14	KEY SWITCH LOW	Active < .8V, Inactive = open circuit	Keyswitch, see also KEY SWITCH HIGH
15	ANALOG IN	Analog Configurable Input	Temperature Sensor or Max speed pot
16	DIGITAL OUTPUT 3	Digital output. Requires mezzanine board customization to use this signal	Typically used as "Raise Charge" signal
17	DIGITAL OUTPUT 4	Digital output. Requires mezzanine board customization to use this signal	Typically used as "Brake Release"
18	GND	< 0.2 v with respect to GND	System Logic Ground
19	HALL W	Sensor position	Motor Hall Sensor W
20	HALL V	Sensor position	Motor Hall Sensor V
21	HALL U	Sensor position	Motor Hall Sensor U
22	KEY SWITCH HIGH	Active > 2 V, Inactive = open circuit	Keyswitch, see also KEY SWITCH LOW
23	DIGITAL INPUT 4 (REVERSE)	Digital Configurable Input 4	Forward/Reverse Control
24	BATT LOW POWER	~VIN+, <1A. Current Protected Battery (+) Output	Used for KEY SWITCH HIGH

5.2.5 Battery Connections

The P125/P190 battery connections are made using the supplied M6, Torx T30 screws. A ring terminal such as TE Connectivity part number 321598 can be used to terminate the leads. Connections should be torqued to 40-45 inch-lbs.

Warning

Do not overtighten the terminal connections. Torque to 20 inch-pounds. Overtightening may cause damage to the controller.

5.2.6 Motor Terminals

The P125/P190 motor connections are made using the supplied M6, Torx T30 screws. A ring terminal such as TE Connectivity part number 321598 can be used to terminate the leads. Connections should be torqued to 40-45 inch-lbs.

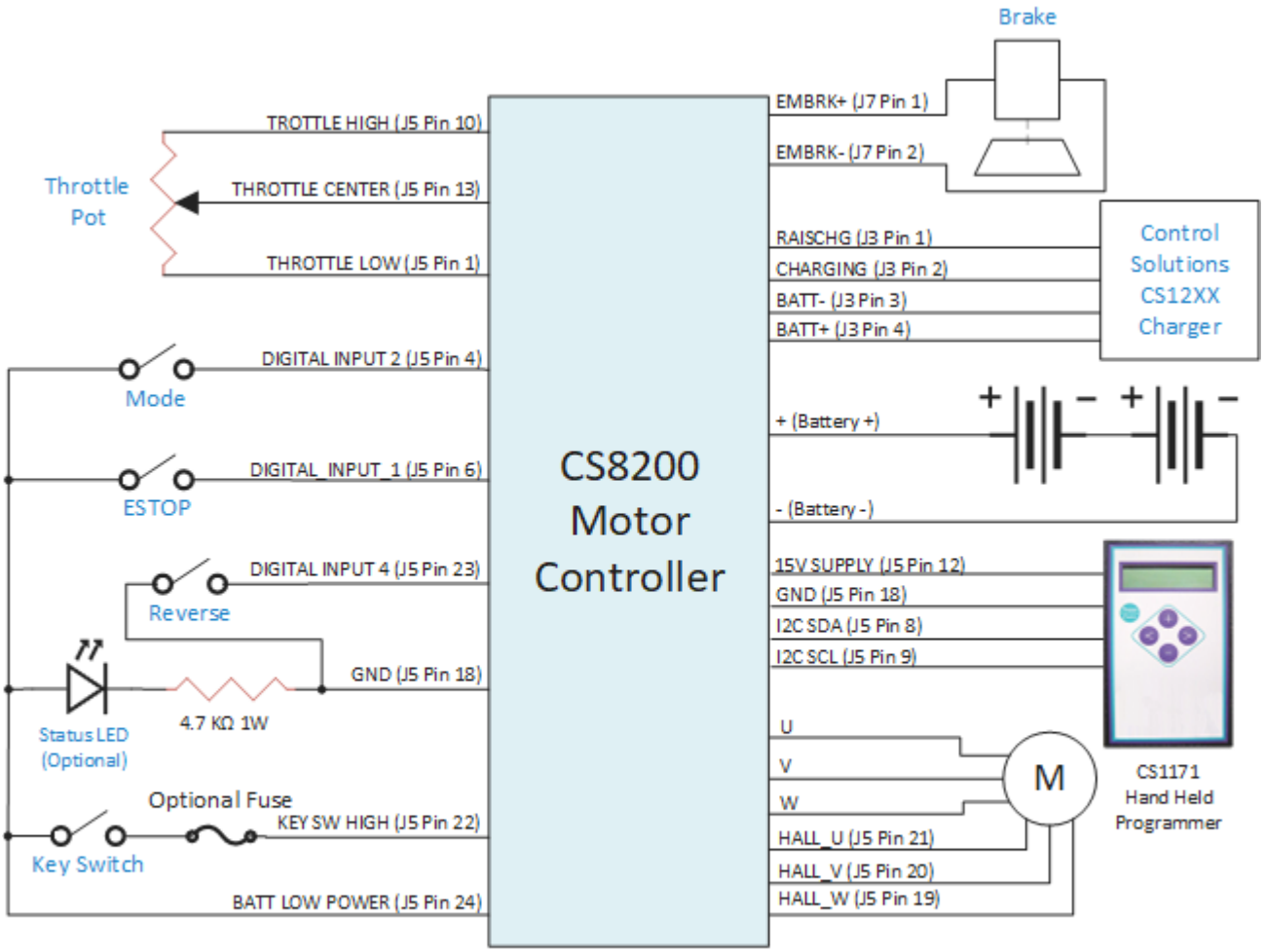
Note

For a Brushed motor with only two motor connections, use the 'W' and 'U' connections

Warning

Do not overtighten the terminal connections. Torque to 20 inch-pounds. Overtightening may cause damage to the controller.

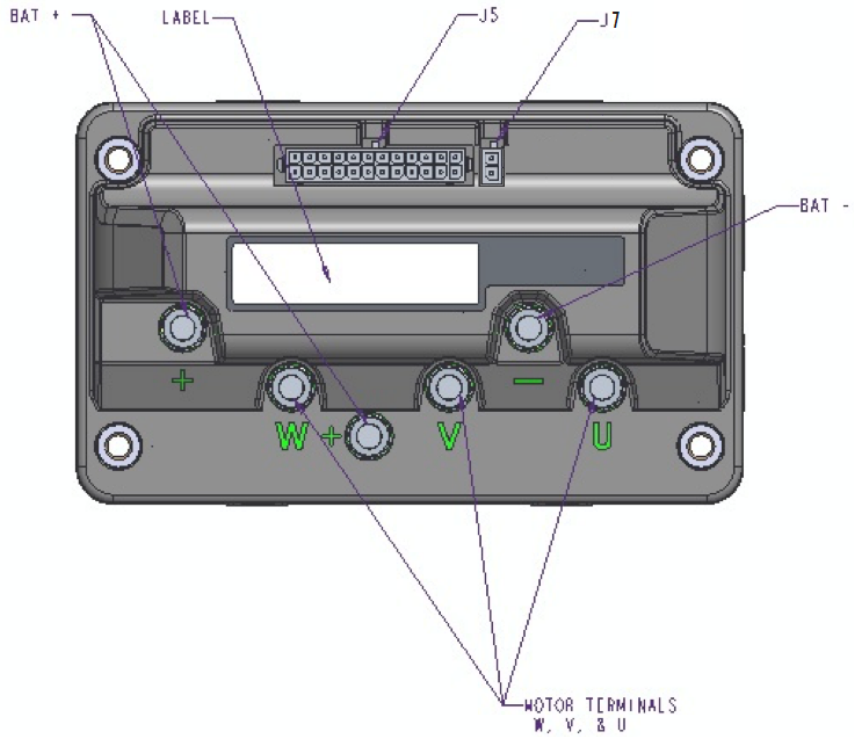
5.2.7 P125/P190 Typical Connections



NOTE: The Configuration shown is for a BLDC motor. For a brushed motor the hall sensors are not used and only W &U or W & V are used for the motor leads.

5.3 P250 Pinout

5.3.1 Connectors and Mates

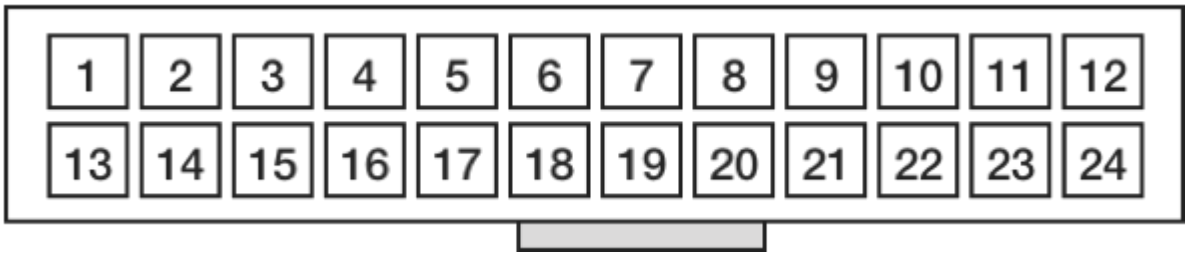


Label	Type	Function	Part Number	Mate
J7	Two-pin	EM brake		
J5	24-pin TE	Control and Status I/O	TE Connectivity 5-794630-4 Micro MATE-N-LOK	TE Connectivity P/N 2-794617-4
+ (Battery +)	STUD M6 X 1 8MM	Positive voltage input		
– (Battery -)	STUD M6 X 1 8MM	Negative voltage input		
W (Motor W)	STUD M6 X 1 8MM	High current connection to motor		
V (Motor V)	STUD M6 X 1 8MM	High current connection to motor		
U (Motor U)	STUD M6 X 1 8MM	High current connection to motor		

5.3.2 J7 Brake

Pin	Name	Description	Typical Use
1	EMBRK+	VIN	EM Brake High Voltage
2	EMBRK-	< .4V , 1.25 A Max	EM Brake Ground

J5 Control and Status I/O



Pin	Name	Description	Typical Use
1	THROTTLE LOW	Throttle Pot Low (~0V): Low potentiometer reference for an analog throttle.	Throttle potentiometer
2	CAN-H	CAN Bus High (5 volt differential)	Status/Configuration
3	CAN-L	CAN Bus Low (5 volt differential)	Status/Configuration
4	DIGITAL INPUT 2 (GP_DIN2)	Digital Configurable Input 2	Seat Switch
5	EXT RELAY (P250 Only)	Open drain output	Used to drive external protection relay
6	DIGITAL INPUT 1 (GP_DIN1)	Digital Configurable Input 1	Fault Input (Quickstop)
7	DIGITAL OUTPUT 1	Open Collector Output. Active > 2 V, Inactive = open circuit	
8	I2C SDA	I2C Data	Status/Configuration
9	I2C SCL	I2C Clock	Status/Configuration
10	THROTTLE POT HIGH	Throttle Pot High (~5V): High potentiometer reference for an analog throttle.	Throttle potentiometer
11	5V SUPPLY	Regulated 5V Supply	Motor Hall Sensor Power
12	15V SUPPLY	Regulated 15V Supply	Motor Hall Sensor Power
13	THROTTLE POT CENTER	Throttle Pot Center (0-5VDC)	Throttle potentiometer
14	KEY SWITCH LOW	Active < .8V, Inactive = open circuit	Keyswitch, see also KEYSW_HIGH
15	ANALOG IN	Analog Configurable Input	Temperature Sensor or Max speed pot
16	DIGITAL OUTPUT 3	Digital output. Requires mezzanine board customization to use this signal	Typically used as "Raise Charge" signal
17	DIGITAL OUTPUT 4	Digital output. Requires mezzanine board customization to use this signal	Typically used as "Brake Release"
18	GND	< 0.2 v with respect to GND	System Logic Ground
19	HALL W	Sensor position	Motor Hall Sensor W
20	HALL V	Sensor position	Motor Hall Sensor V
21	HALL U	Sensor position	Motor Hall Sensor U
22	KEY SWITCH HIGH	Active > 2 V, Inactive = open circuit	Keyswitch, see also KEY SWITCH LOW
23	DIGITAL INPUT 4 (REVERSE)	Digital Configurable Input 4	Forward/Reverse Control
24	BATT LOW POWER	~VIN+, <1A. Current Protected Battery (+) Output	Used for KEY SWITCH HIGH

Battery Connections

Use a properly-sized ring terminal to connect the battery leads.

Danger

Electrical charge may still be present on the battery connections even after the battery has been disconnected or power switched off. This stored charge will dissipate in a few minutes, but take care not to short the + terminal to a ground point because an electrical arc and possible damage to the controller may result.

Warning

Do not overtighten the terminal connections. Use a maximum torque of 20 inch-pounds. Overtightening may cause damage to the controller.

Motor Terminals

The P250 motor connections are made using the supplied M6, Torx T30 screws. A ring terminal such as TE Connectivity part number 321598 can be used to terminate the leads. Connections should be torqued to 40-45 inch-lbs.

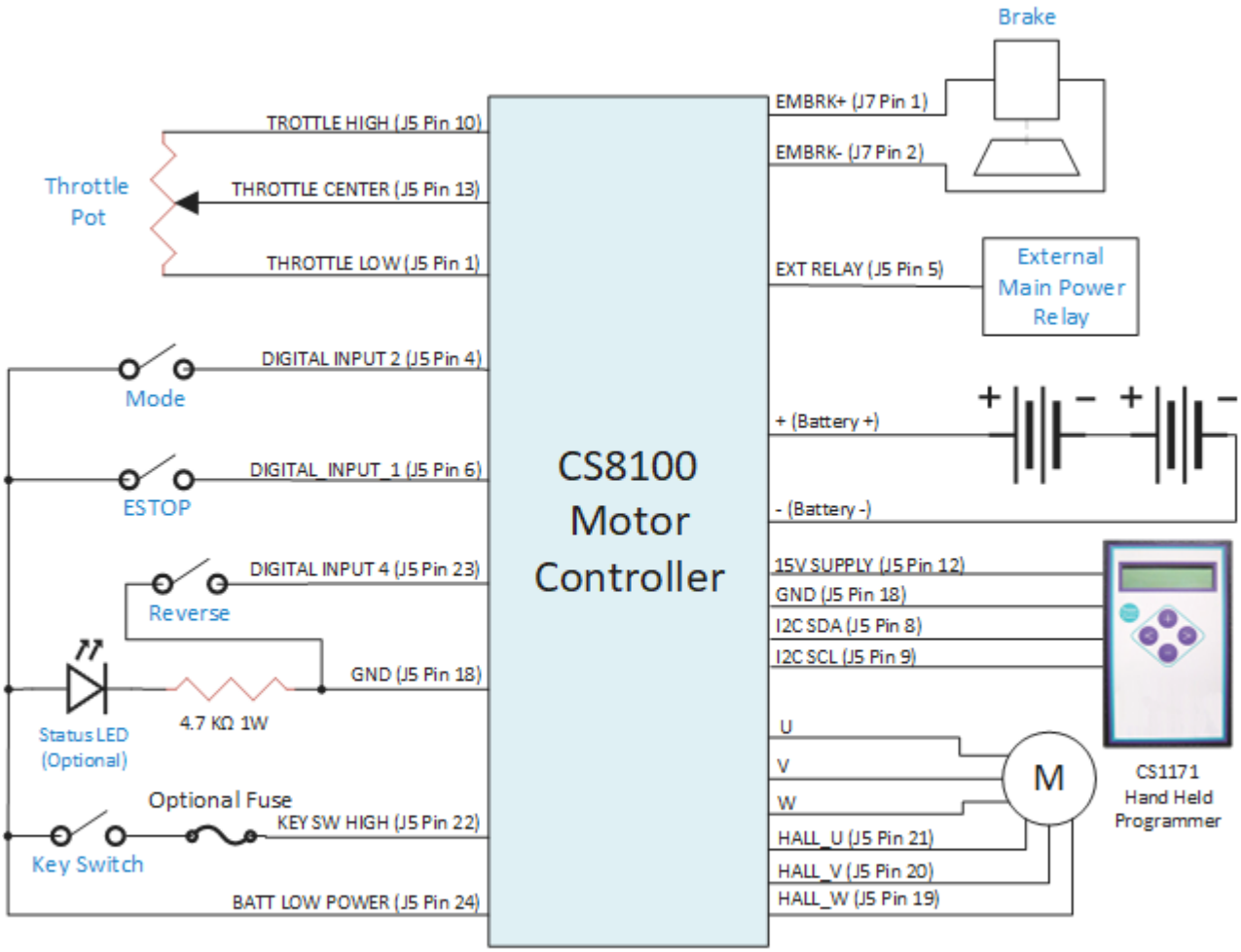
Note

For a Brushed motor with only two motor connections, use the 'W' and 'U' connections

Warning

Do not overtighten the terminal connections. Torque to 20 inch-pounds. Overtightening may cause damage to the controller.

5.3.3 P250 Typical Connections



NOTE: The Configuration shown is for a BLDC motor. For a brushed motor the hall sensors are not used and only W &U or W & V are used for the motor leads.

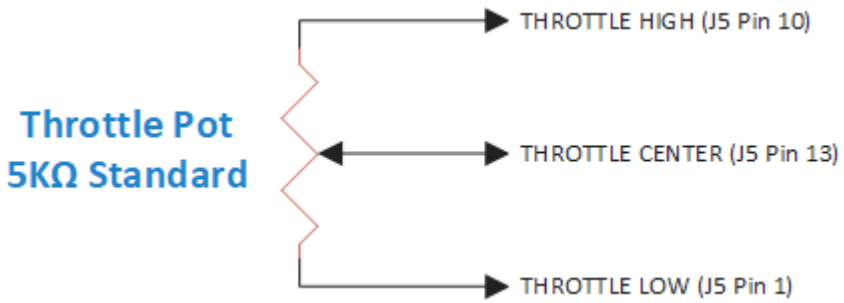
5.4 Throttle Wiring

> **Note**
>
> The controller's throttle settings must be properly adjusted. See the Throttle Configuration section

> **Danger**
>
> Adjusting or changing throttle connections can cause unexpected movement of the motor and/or vehicle/system. Always secure the machine before making adjustments to the throttle

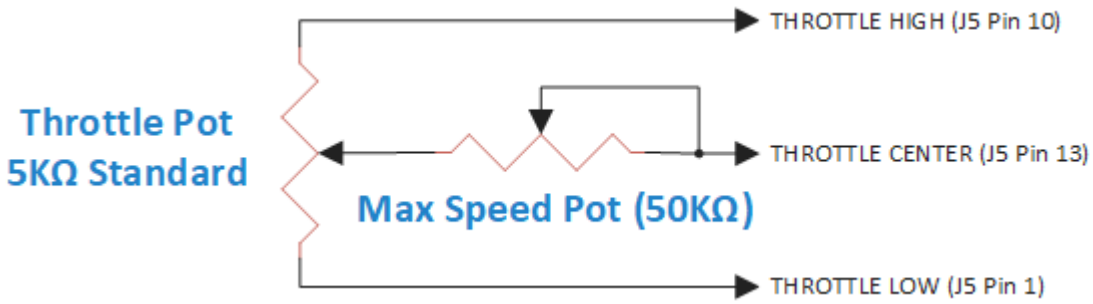
5.4.1 Three-wire Potentiometer

A three-wire potentiometer throttle can be used to control the motor speed. The figure below shows how to wire a throttle potentiometer for a standard configuration.



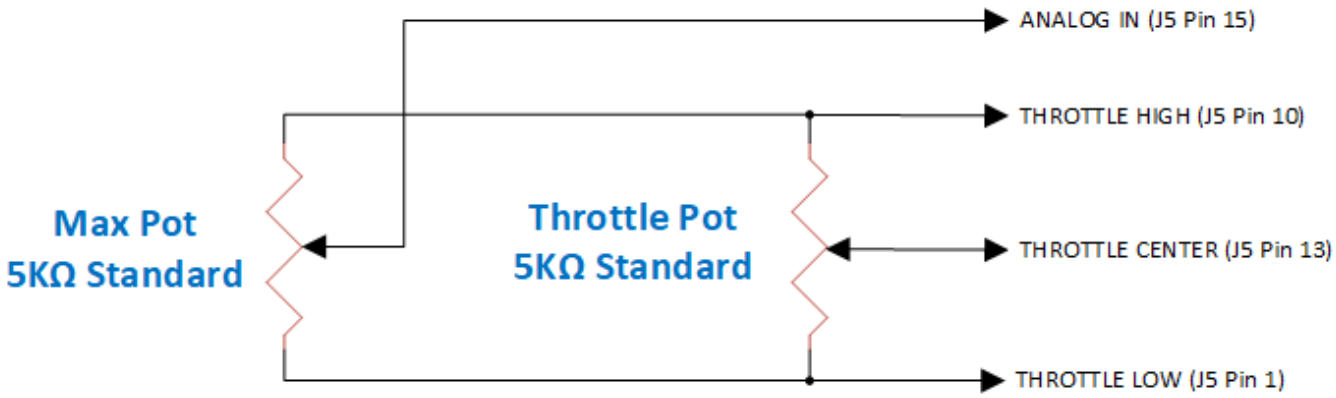
5.4.2 Potentiometer with Max Speed Pot

In this configuration, a second potentiometer is used to scale the throttle and limit the maximum speed.



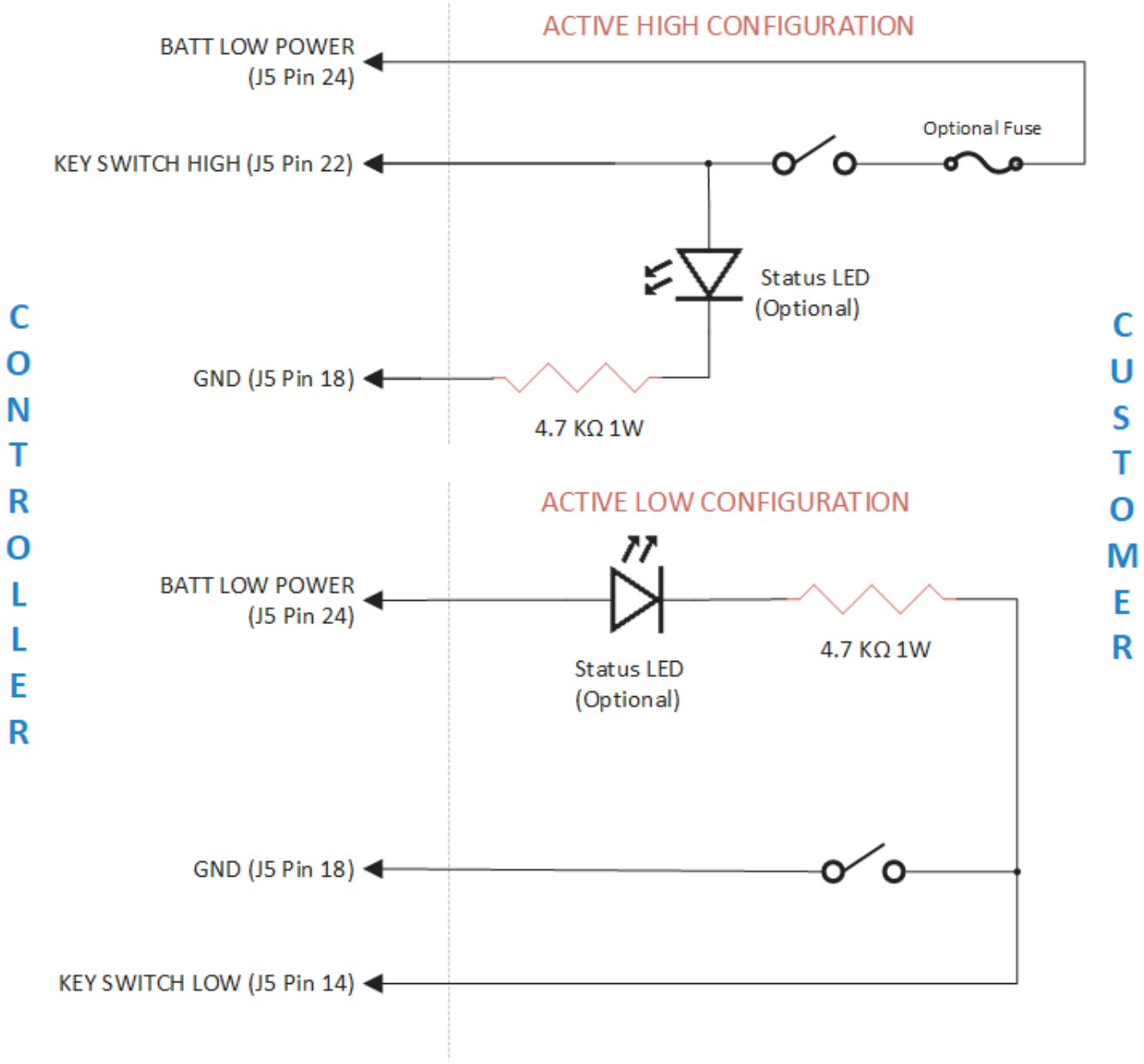
5.4.3 ANALOG IN Max/Min Potentiometer

This configuration uses the ANALOG IN voltage input to limit the maximum speed.



5.5 Keyswitch Wiring

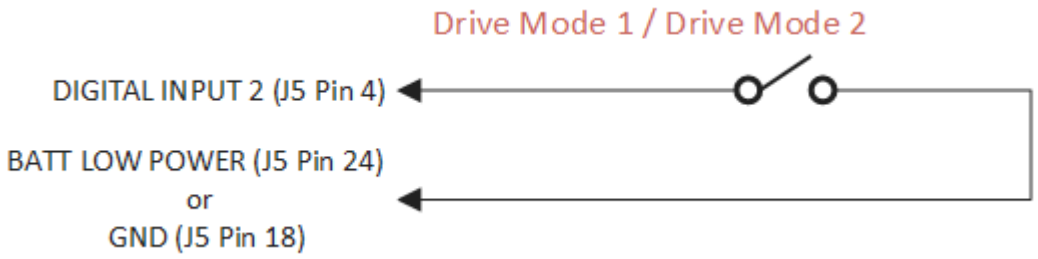
The figure below shows two options to wire a key switch to the controller. When the switch is closed, the controller is powered on. When the switch is open, the controller is powered off. The value of R is 4.7kΩ.



5.6 Wiring Digital Inputs

5.6.1 Drive Mode Selector Switch Wiring

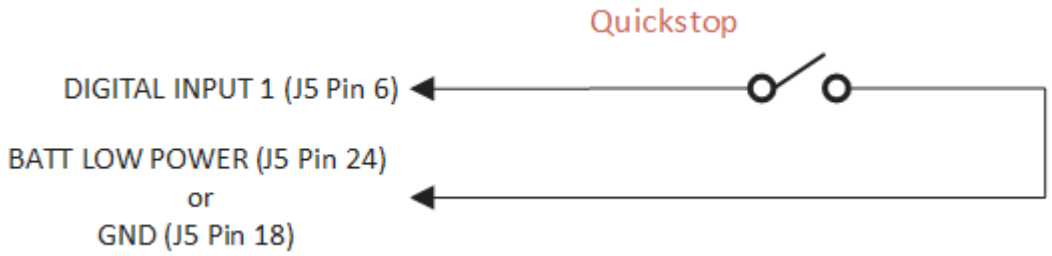
The figure below shows how to wire a drive mode selector switch to the controller. The drive mode selector switches between Mode 1 and Mode 2 (which are also referred to as Indoor and Outdoor). These modes can be individually programmed to provide different max speeds, accelerations, etc. When the switch is open, the controller is in Drive Mode 1; when the switch is closed, the controller is in Drive Mode 2.



5.6.2 Quickstop Switch Wiring

Depending on the module configuration, quickstop can be wired as active (+5 V) or passive (GND). The figure below shows how to wire a passive quickstop configuration. When the switch is closed, quickstop is activated. When the switch is open, quickstop is inhibited.

> **Note**
>
> In addition to the wired configuration there is a Qstop hi parameter that determines whether the Quickstop input is considered active high or active low. This parameter must be set correctly in order for the controller to function as expected. See Register 0318 for more information.



5.6.3 Forward/Reverse Switch Wiring

The figure below shows how to wire a Forward/Reverse switch to the controller. The forward/reverse switch changes the motor's direction.

NOTE: On DSP models the input is active high as shown below.

5.7 Configuration and Diagnostic Software

Phoenix controllers are supported by the Phoenix Diagnostics PC software that allows loading, editing, and saving of configuration parameters, as well as diagnostic status reporting.

In order to use this software, it must be connect to a controller using a supported USB CAN Bus adapter or a CS1816 Bluetooth dongle.

5.7.1 Connection Methods

USB CAN Bus Adapter

- **PEAK-System PCAN-USB** (website)
  - Windows: Download and install driver from PEAK-System's website. Note that Windows 7 requires an older version (4.1.x) of the driver.
  - macOS: No driver installation is necessary.
- **Kvaser Leaf Light V2** (website)
  - Windows: Download and install driver from Kvaser's website.
  - macOS: This CAN adapter is not supported

Other PEAK-System or Kvaser USB CAN adapters that use the same drivers may also work with Phoenix Diagnostics, but have not been tested.

Bluetooth Dongle

A Control Solutions **CS1816 Bluetooth dongle** can be used to connect to the Phoenix controller's legacy programming interface.

REQUIREMENTS

- Windows 10 version 1703 or later [1]
- A computer with a Bluetooth adapter that reports Link Manager Protocol Version 6 or higher. See Microsoft's support article What Bluetooth version is on my PC? for instructions on how to check this version using Device Manager.
- Phoenix Diagnostics 3.6.3 or later

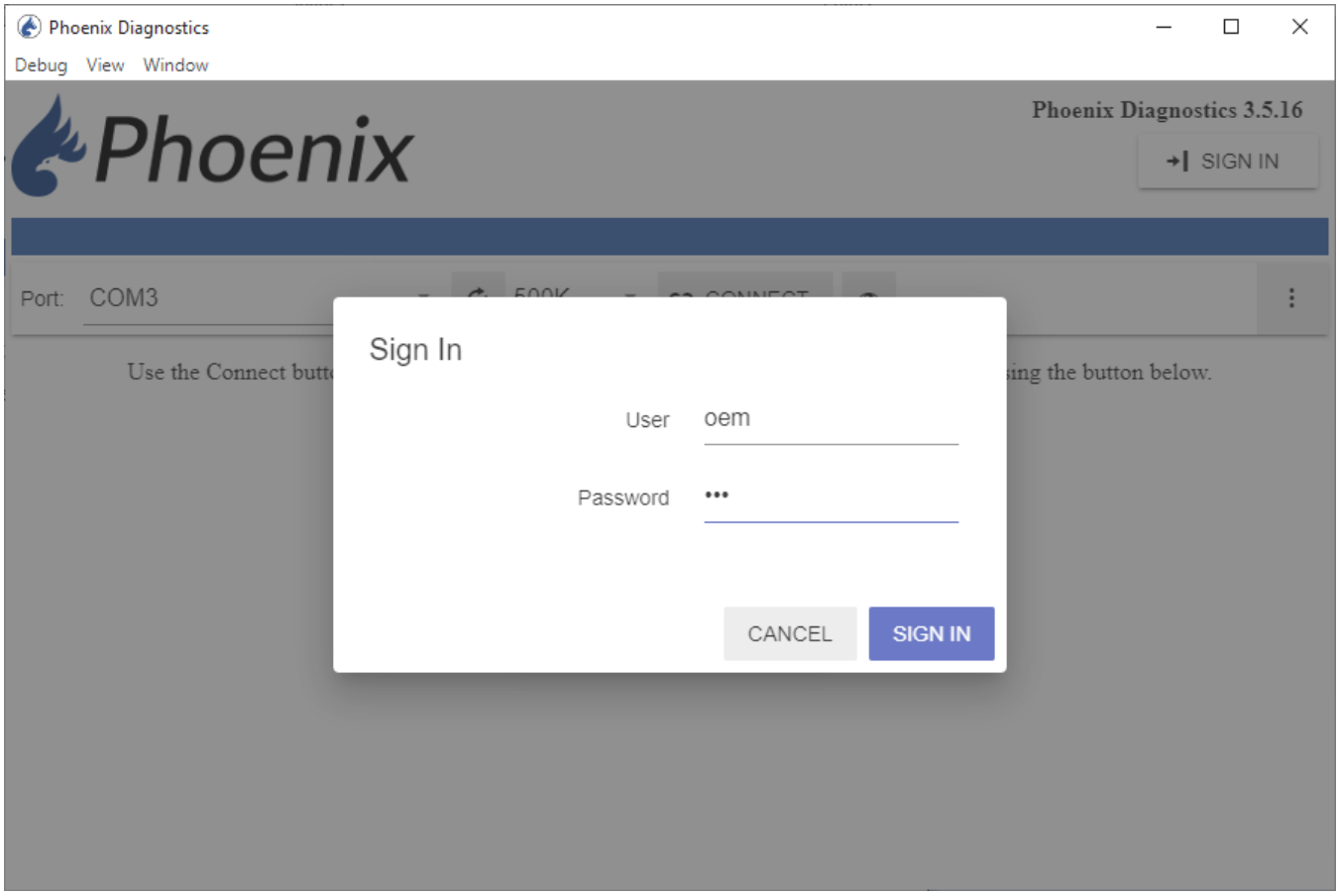
5.7.2 Installation

1. If using a USB CAN bus adapter, install its drivers and plug it in to a USB port, and restart the computer
2. Download and install the Phoenix Diagnostics App
   - Windows 7 and later
   - macOS 10.15 and later

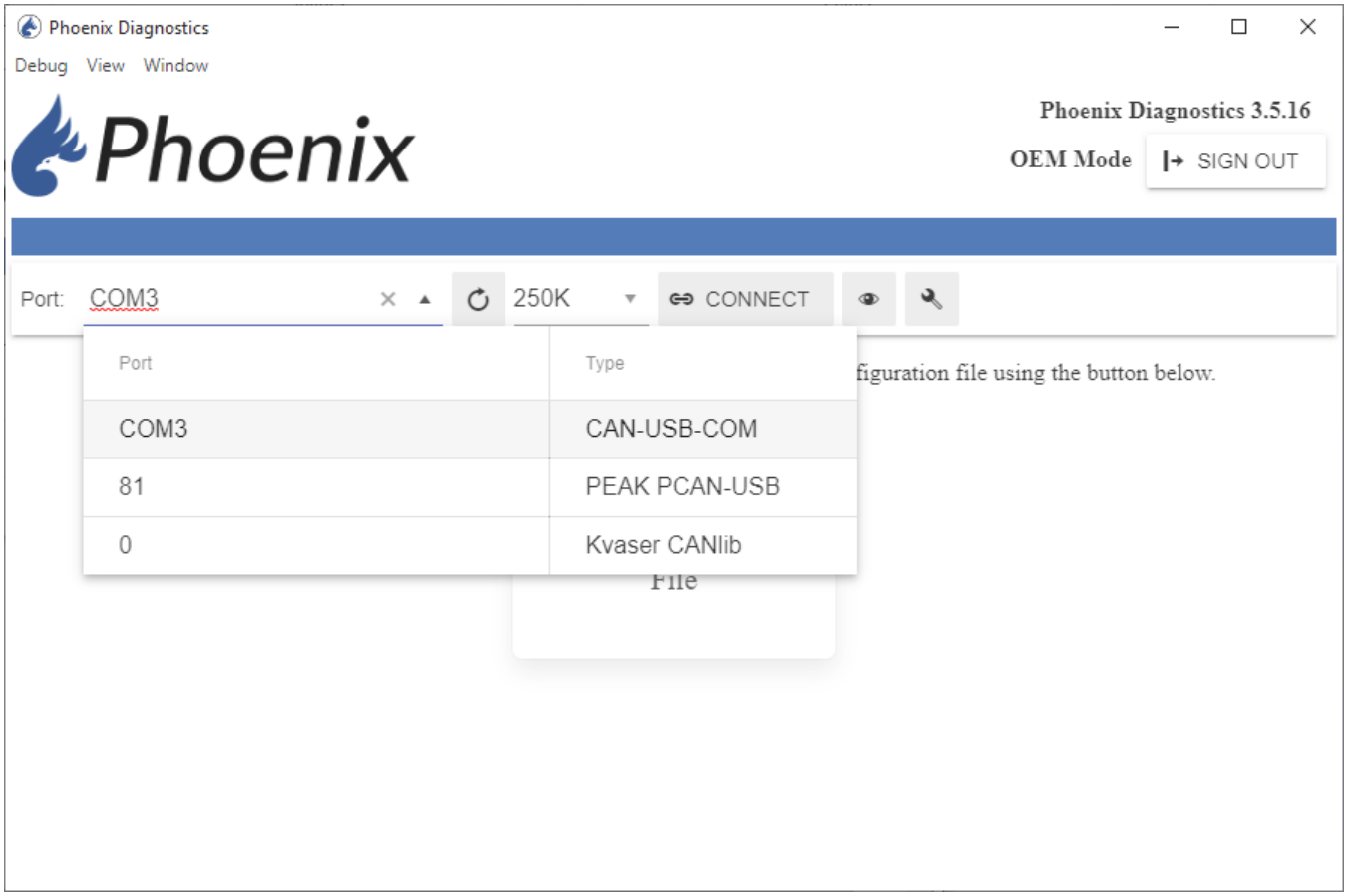
5.7.3 Using Phoenix Diagnostics

With a USB CAN Bus Adapter

1. Connect the USB CAN adapter to the computer and motor controller.
2. Launch Phoenix Diagnostics.
3. If the app does not show OEM Mode under the version, sign in. Click the "SIGN IN" Button and enter either your personal username and password, or use `oem` in both the user and password fields. The app will restart.



4. Select the CAN Bus port. If none are listed try clicking the Refresh button. If that does not work, double check that the CAN adapter is detected by the operating system and that its drivers are installed.



5. Select the CAN baud rate.

6. Click the "CONNECT" button and the dashboard screen should appear after several seconds. If it does not appear, try a different baud rate and verify that the CAN Bus is terminated properly.

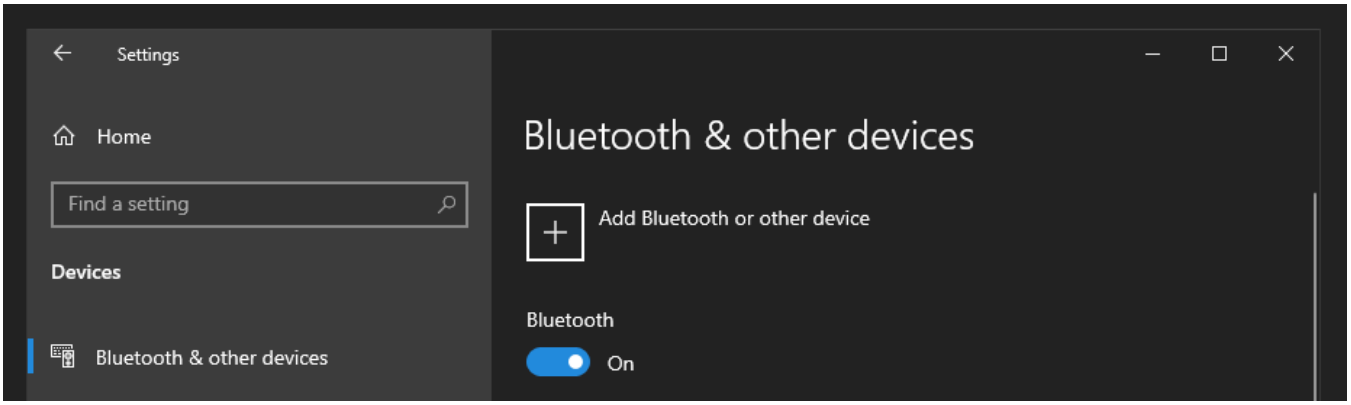
TROUBLESHOOTING

See Troubleshooting the CAN Bus Interface.

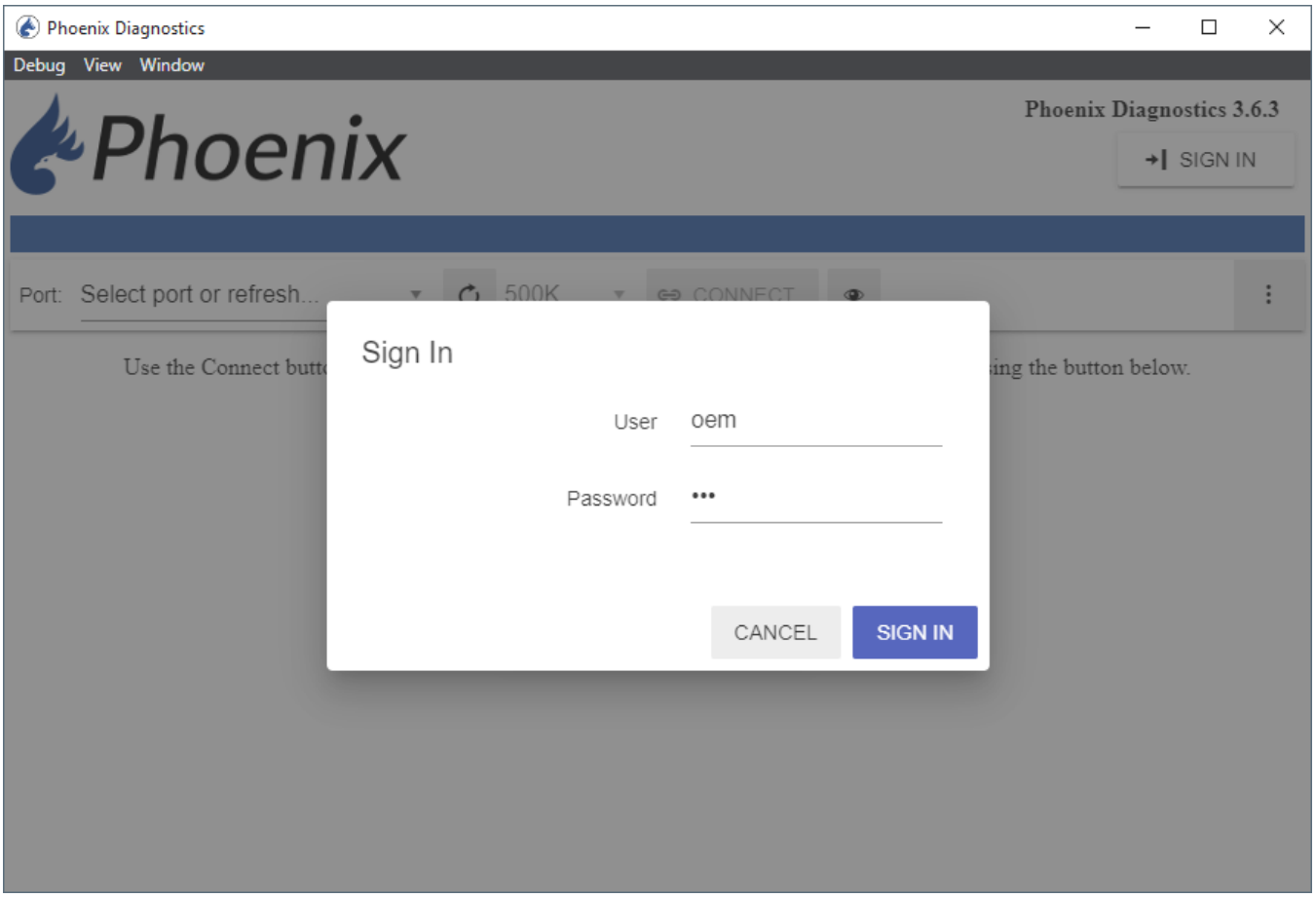
With a Bluetooth Dongle

The CS1816 Bluetooth Dongle is a Bluetooth Low Energy device. As such, it must not be paired in Windows. If it is paired, Phoenix Diagnostics may fail to find the dongle or connect to it.

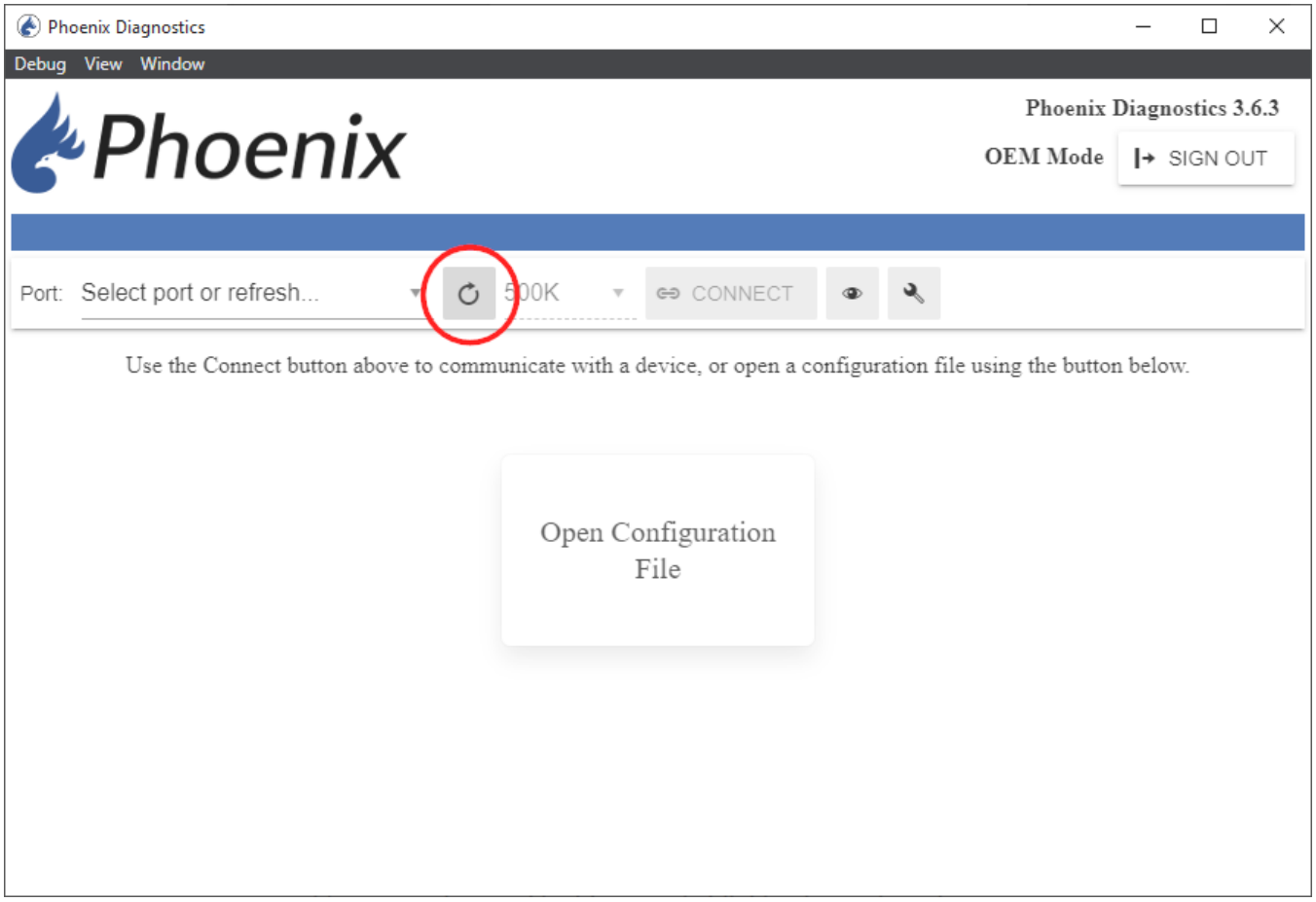
1. Connect the Bluetooth dongle to the motor controller, turn on power to the system, and turn on the controller's keyswitch. The dongle's blue LED should light up solid for a few seconds as it starts up, then blink intermittently to indicate it's ready for a connection.
2. Ensure Bluetooth is turned on in Windows using its Settings app or notification area.



3. Launch Phoenix Diagnostics.
4. If the app does not show OEM Mode under the version, sign in. Click the "SIGN IN" Button and enter either your personal username and password, or use `oem` in both the user and password fields. The app will restart.

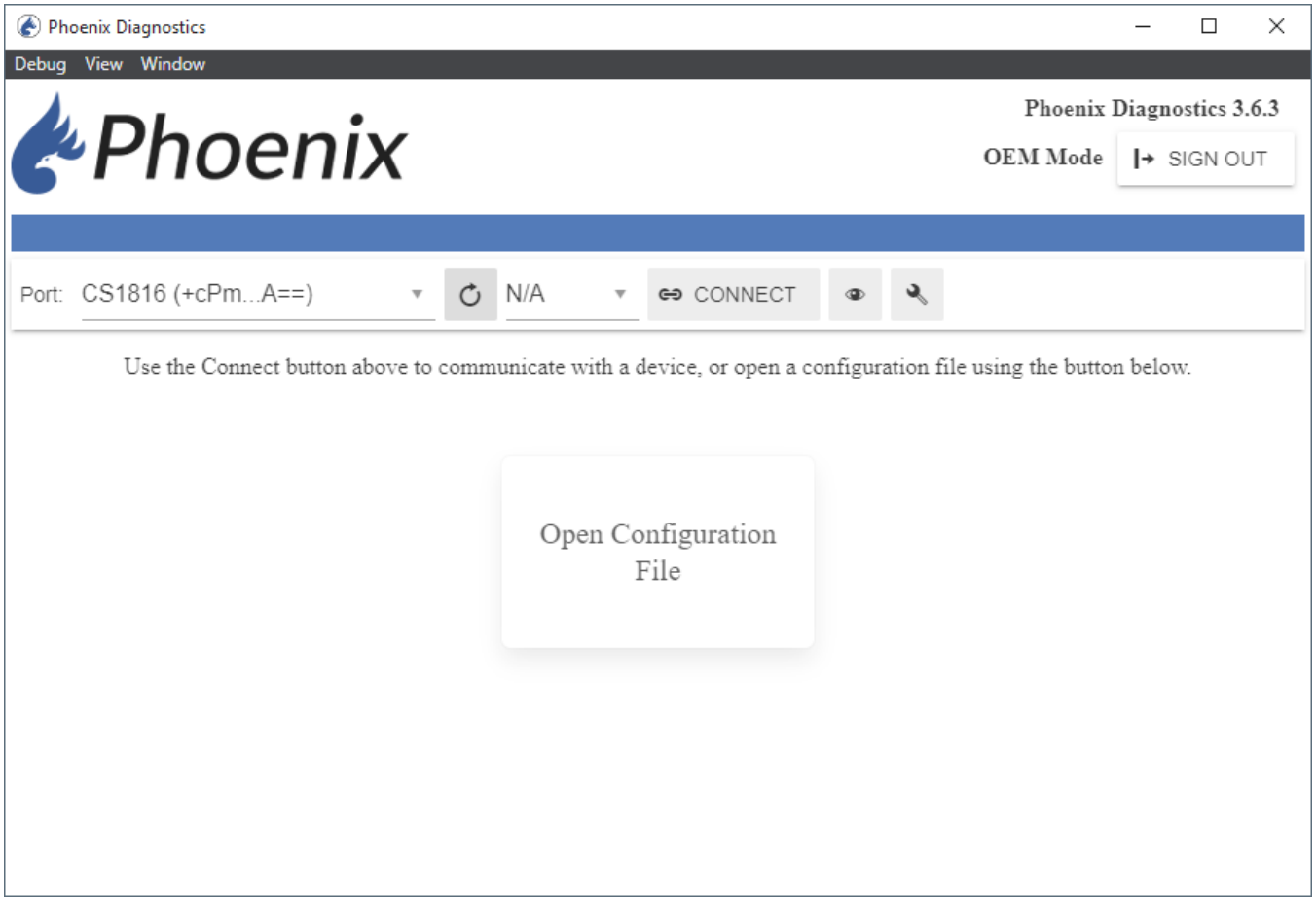


5. Click the Refresh button to scan for Bluetooth devices.



6. If a CS1816 Bluetooth dongle is found, it will be added to the port list. Click the "CONNECT" button to connect to the dongle. The dongle's blue LED should turn solid on, and the dashboard screen should appear

after about 10 seconds.



TROUBLESHOOTING

If the Bluetooth dongle is not found by Phoenix Diagnostics at all:

- Ensure the Bluetooth dongle is not paired in Windows
- Ensure the motor controller's keyswitch is turned on
- Ensure it's powered on and its blue LED is blinking intermittently

If Phoenix Diagnostics finds the Bluetooth dongle, but the connection fails with an error:

- Ensure the Bluetooth dongle is not paired in Windows
- Turn Bluetooth off and back on again in Windows
- Cycle power to the motor controller and Bluetooth dongle

---

1. https://blogs.windows.com/windowsdeveloper/2017/01/13/new-bluetooth-features-in-creators-update-gatt-server-bluetooth-le/

5.8 Updating Controller Firmware

Phoenix controllers are supported by PC software that allows updating the firmware in the controllers.

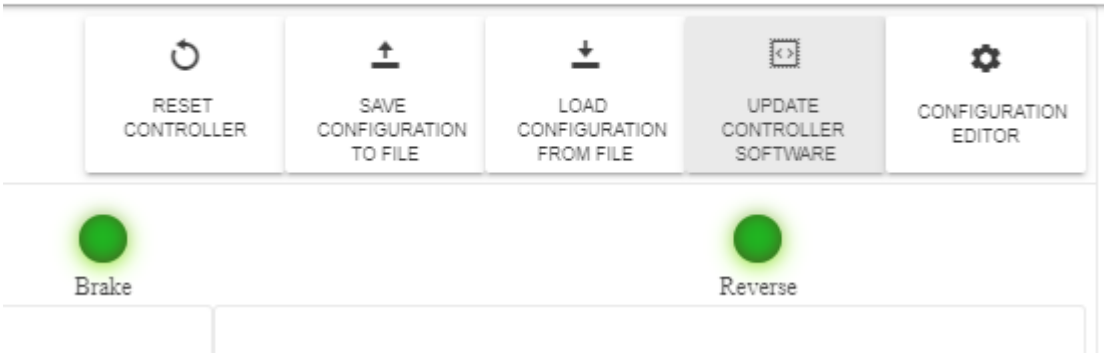
In order to use this software to update a controller, it must be connected to the controller using a supported CAN Bus/USB adapter:

If you have not installed the Phoenix Diagnostics application see Installation

5.8.1 Updating the Software

After installation run the Phoenix Diagnostics App.

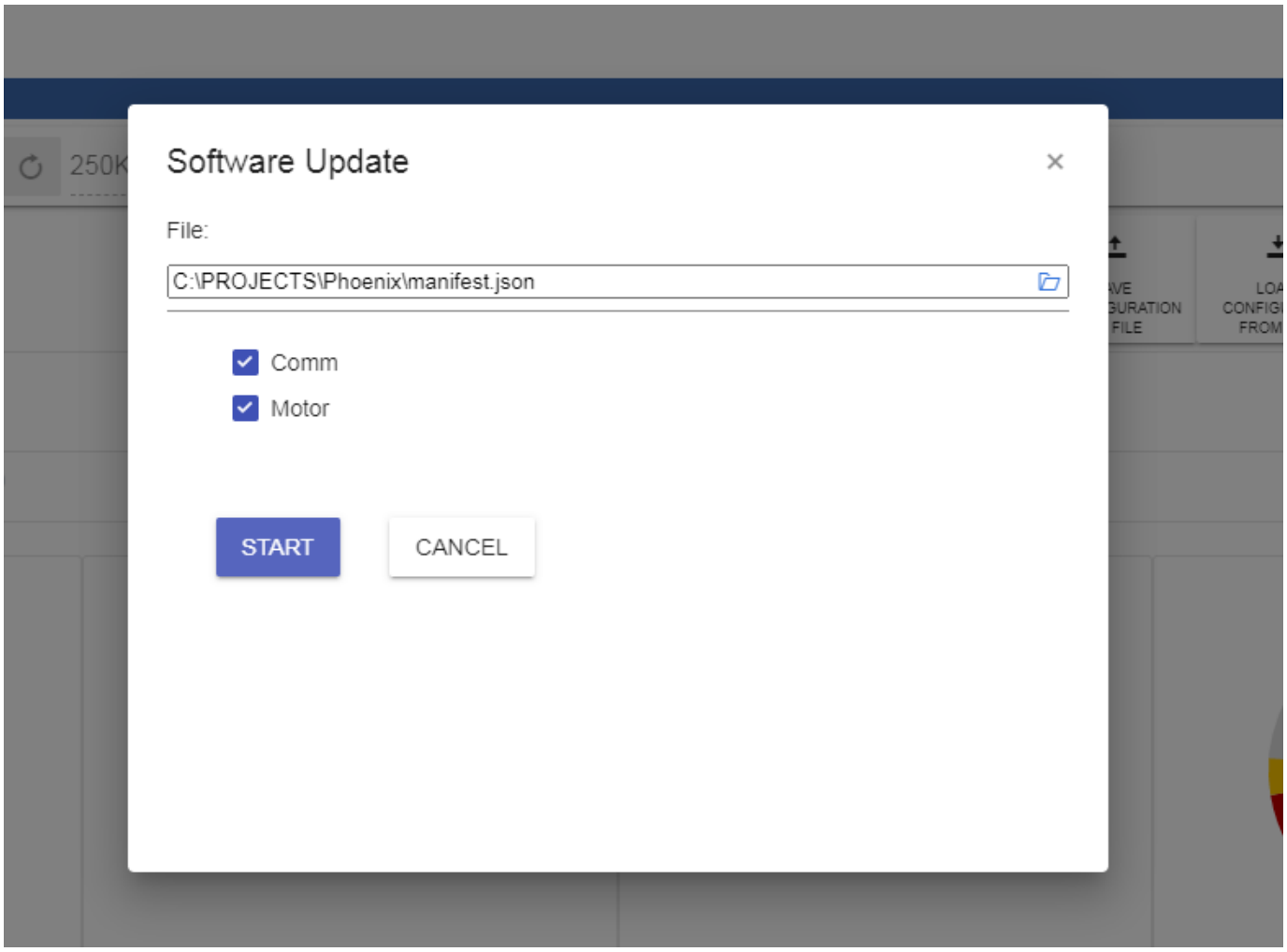
Click on "Update Controller Software button.



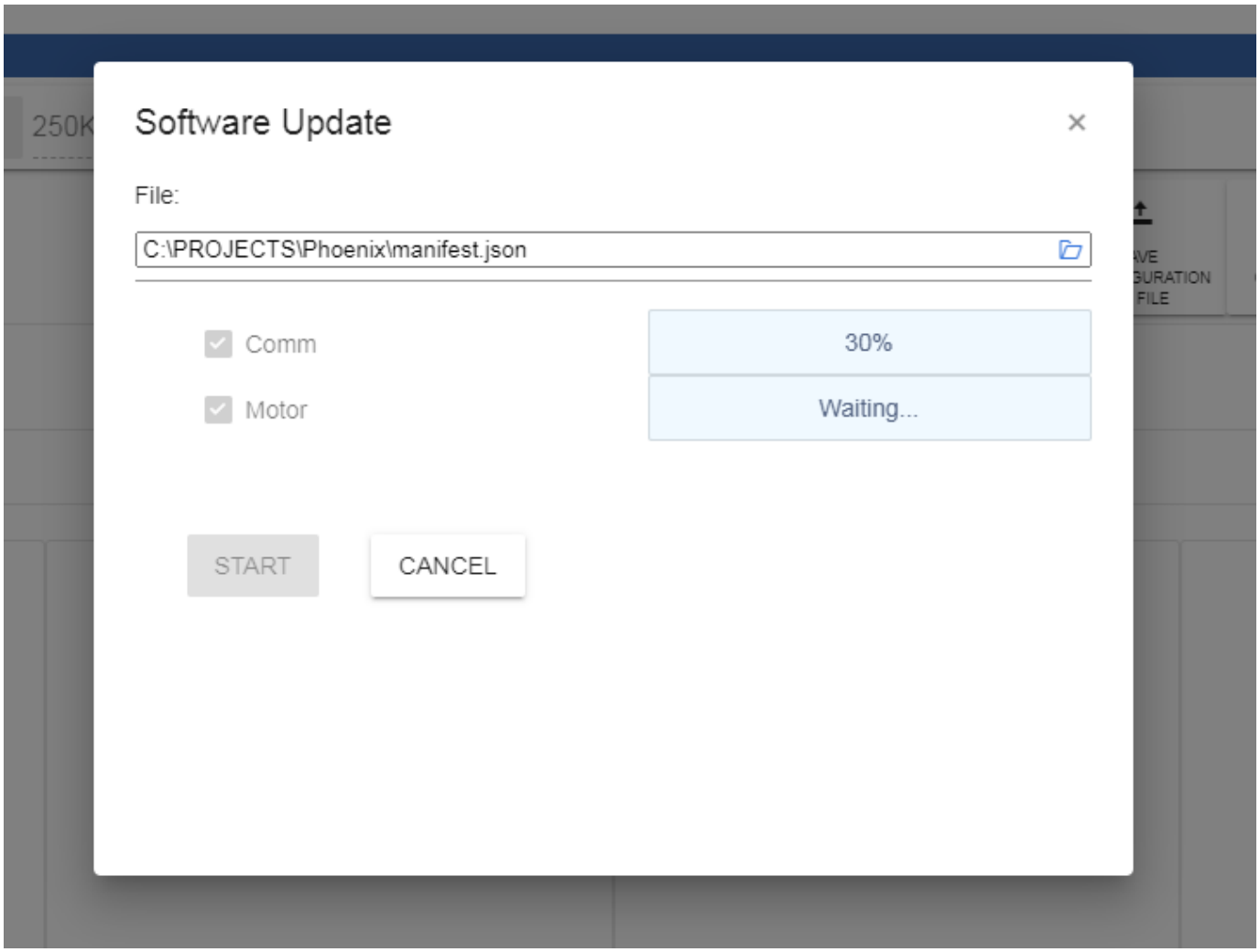
The "Software Update" window will appear. Select the desired targets to update. The P190, P250 and dual motor controllers have the "Comm" processor which is the CAN bus interface and the "Motor" which is the motor control processor. NOTE: On dual motor controllers updating the "Comm" on both motors is not necessary because it updates the same chip. Click "START" to begin the update.

Warning

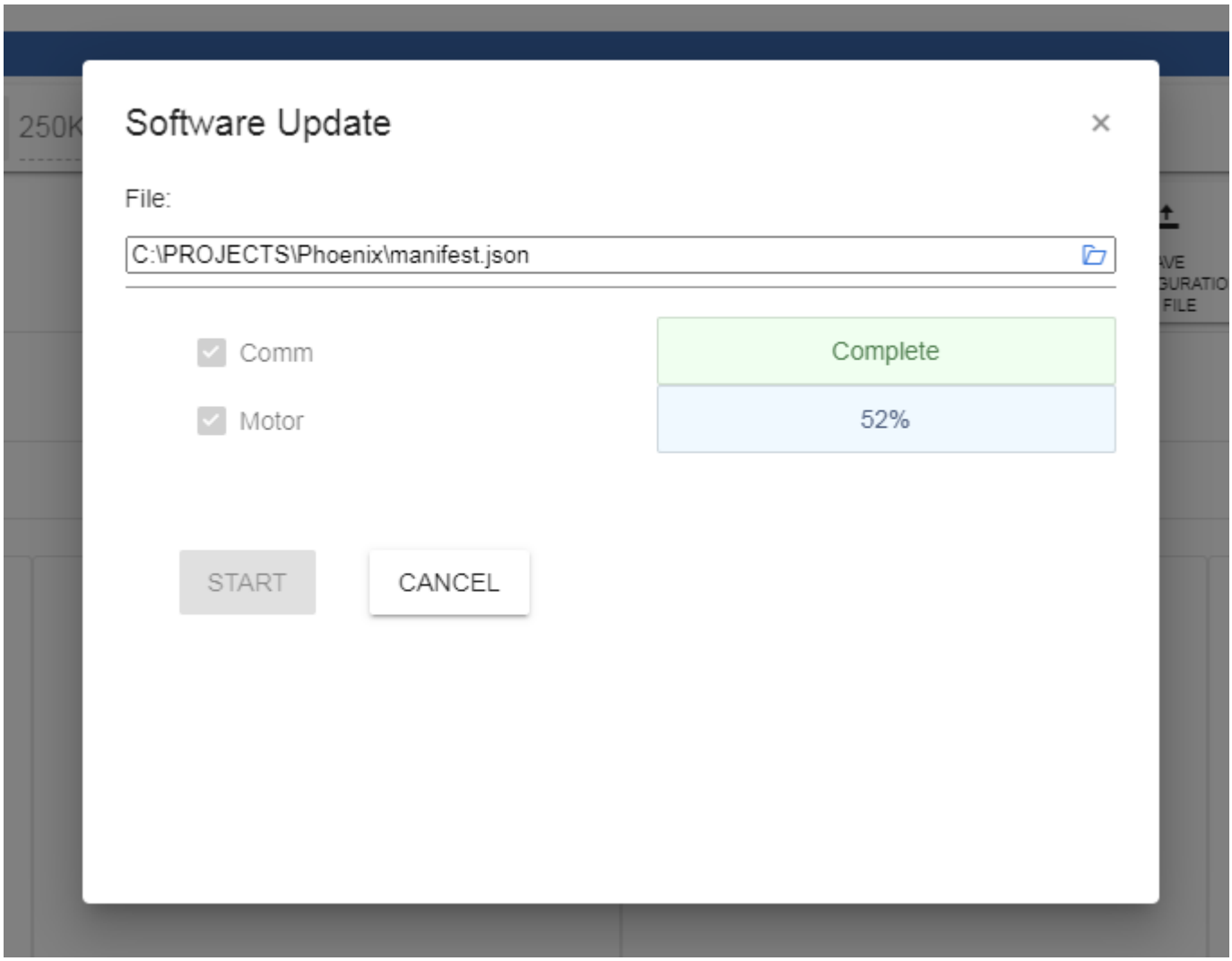
Do not turn off the power during an update of the motor controller. This will brick the motor processor. If the update is interrupted just retry the update without cycling the power.



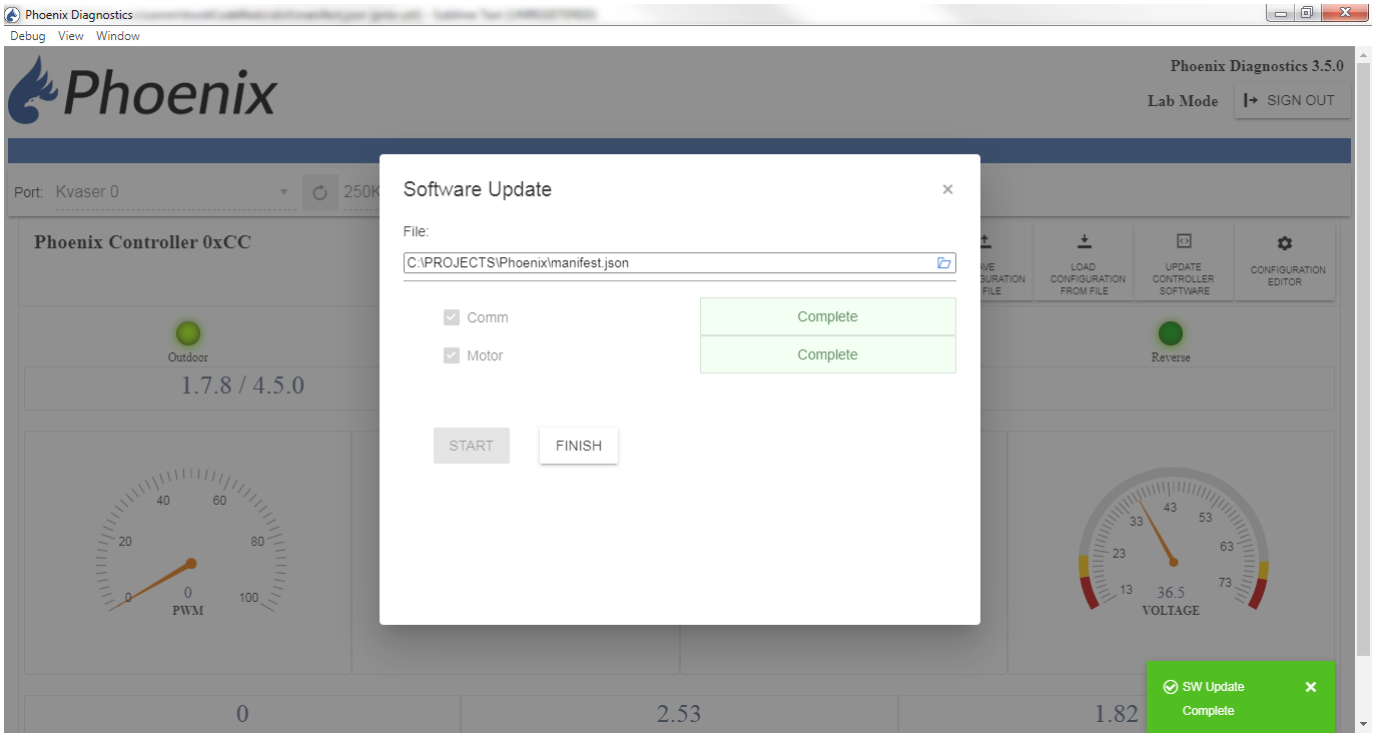
The "Comm" processor updates first.



Then the motor software updates.



When it is complete click "Finish".



6. Configuration

6.1 Configuration

Danger

Before performing the setup procedures, it is important that you support the vehicle on jacks or blocks to prevent the drive wheels from touching the ground, allowing them to spin freely without obstruction. Doing so will prevent unattended dangerous vehicle movement.

Double-check all wiring to ensure there are no shorts and that everything is properly wired.

Be sure to wear proper eye protection in case of lead acid battery failure.

Note

There are multiple ways to configure Phoenix controllers, including loading of parameters via CAN, a handheld programmer, and/or a PC/mobile application. Refer to the Programmer instructions for details on using the specific Programmer and navigating its menus.

6.2 Calibration

6.2.1 Factory Calibration

There are several EEPROM values that are programmed at the factory. These values affect the accuracy of the current, temperature, and battery voltage measurements.

> **Warning**
>
> EEPROM addresses 0305-0314 should not be modified. These values will vary from unit to unit so they should not be copied from one unit to another.

6.3 Identity

6.3.1 Model Number

Each hardware variant of the Phoenix controllers has a specific Product ID. This 16-bit value is stored at address 03F9-03FA.

6.3.2 SWEE

The "Software EEPROM" or SWEE file that was used to configure the unit at the factory has a specific number and letter revision. The 16-bit part number is stored at address 03F3-03F4. The revision letter is stored at 03F5.

6.3.3 Serial Number

Each unit has a unique 32 bit serial number. This 32 bit value is stored at address 03FB-03FE.

6.3.4 Software Version

See Software Version

6.4 Input/Output Configuration

> **Note**
>
> The available IO pins vary by controller model. For details, refer to the model specifications. This section describes the most common setup choices.

6.4.1 KEY SWITCH HIGH and KEY SWITCH LOW

The KEY SWITCH HIGH and KEY SWITCH LOW signals are used to switch the controller on and off. Configuration options for the keyswitch include:

- Key off deceleration: controls how quickly the controller stops after a key-off or quickstop event
- Shutdown time: configurable period of time after the key-off event before the controller turns off.
- Idle Timeout: a period of time after which the controller will automatically shut down if not used.

6.4.2 THROTTLE POT CENTER Input

This is a proportional, analog voltage that represents the user's throttle input. Refer to the Throttle page for configuration details.

6.4.3 ANALOG IN Input

The ANALOG IN is a second proportional input. Depending on configuration, it can be used to:

- Scale the main throttle input (Max Speed Pot),
- Accept a voltage from a motor temperature sensor.

6.4.4 DIGITAL INPUT 1

DIGITAL INPUT 2 has a configurable function:

- Quickstop/Fault input

6.4.5 DIGITAL INPUT 2

DIGITAL INPUT 2 has a configurable function:

- Seat switch/Motion Inhibit

6.4.6 DIGITAL INPUT 4

DIGITAL INPUT 3 has a configurable function:

- Reverse

6.4.7 DIGITAL OUTPUT 1

DIGITAL OUTPUT 1 is an open-collector output that can be used for:

- Fault indication

6.4.8 DIGITAL OUTPUT 3

Currently not connected. Internally used as raise charge signal.

6.4.9 DIGITAL OUTPUT 4

Currently not connected. Internally used as brake release signal.

6.5 Motor Configuration

There are several configuration items that relate to the type and specifications of the connected motor.

> **Note**
>
> Certain controller models are compatible with certain motor types. For instance, some Phoenix controllers are for use with brushed motors, while other controllers are designed for use with brushless motors.

6.5.1 Brushless DC (BLDC) Motors

When using a brushless DC motor, the controller performs the electrical commutation of the rotor. In order to do this, it must be able to sense the position of the rotor so it can manipulate the electrical fields appropriately.

This sensing is performed either using dedicated hardware (sensors) or by measuring the back EMF on the rotor windings. In order to interpret these signals correctly, the following parameters can be set:

Motor Type

The motor type describes the characteristics of the motor and sensors:

- Number of motor pole pairs
- Physical arrangement of sensors
- Whether sensors A and C should be swapped in software (to match actual wiring of the system)
- Whether the sensor signal is active high or low

Motor Compensation (motor comp)

Motor compensation is used to adjust the motor's performance based on varying terrain. This feature, also known as Power On Demand (POD), helps in fine-tuning the motor behavior to ensure optimal performance. Setting this parameter correctly ensures that the vehicle maintains consistent performance whether on flat surfaces or hilly terrain.

6.5.2 Electromagnetic Brake Control

Many Phoenix controllers incorporate circuitry to control an electromagnetic brake. The controller energizes the brake when appropriate to allow the motor to spin. Parameters that can be configured for the electronic brake include:

- Disabling the EM Brake feature
- Brake delay: the delay after decelerating before the EM brake is de-energized.

6.5.3 Troubleshooting

- Verify correct wiring

- Verify that throttle input is at an appropriate level
- Check for fault codes (depending on model, may be indicated by a flashing LED or reported by diagnostic software).
- Check for Stop Diagnostics reported by CAN Bus 10FF03 status message. Also see System Status Message and Special Diagnostic Commands.

6.6 Input/Output Configuration

> **Note**
>
> The available IO pins vary by controller model. For details, refer to the model specifications. This section describes the most common setup choices.

6.6.1 Electromagnetic Brake Control

Many Phoenix controllers incorporate circuitry to control an electromagnetic brake. The controller energizes the brake when appropriate to allow the motor to spin. Parameters that can be configured for the electronic brake include:

- Disabling the EM Brake feature
- Brake delay: the delay after decelerating before the EM brake is de-energized.

6.7 Throttle Configuration

The throttle is a proportional input signal, typically between zero and +5VDC; however for CAN Bus-capable controllers, it is also possible to provide the proportional input digitally.

The throttle input is conditioned, scaled, and limited according to the controller's settings. The output of throttle processing is a scaled digital value that represents the desired target drive level.

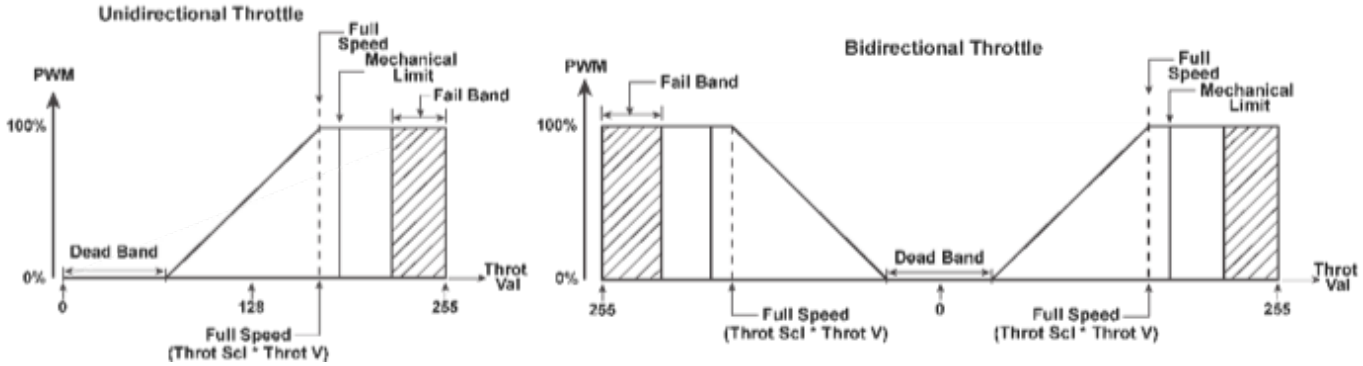
This target drive level is interpreted according to the Throttle Mode. For example, the throttle may target speed (RPM) or torque (PWM).

Properly setting up the throttle on a vehicle will ensure that you obtain peak performance and control of speed on the vehicle. The steps involved in setting up the throttle are:

1. Setting basic throttle configuration
2. Adjusting the throttle deadband
3. Adjusting the throttle scale
4. Adjusting the throttle failband

> **Note**
>
> If there is a potentiometer that sets the maximum speed on the vehicle, make sure it is adjusted to the maximum speed setting before configuring the throttle.

You should perform these procedures in the order they appear in this manual. When done properly, the vehicle will perform smoothly throughout the entire throttle range and provide the highest resolution of throttle control. The figure below shows the Throttle Deadband, Throttle Scale, and Throttle Failband for Unidirectional and Bidirectional Throttles.



6.7.1 Basic Throttle Configuration

THROTTLE POT CENTER Input

The Throttle Pot (THROTTLE POT CENTER) is a 0-5V input, measured on the THROTTLE POT CENTER pin. Various configuration parameters allow the behavior of the throttle to be customized. Other interfaces, such as ANALOG IN or Digital Throttle, can be used to limit or scale the THROTTLE POT CENTER throttle.

The THROTTLE POT CENTER interface is enabled by configuration register 0x0357.

ANALOG IN Input

The Analog-In (ANALOG IN) input is a 0-5V input, which can be configured for a number of functions. For example, it can be used as a Max Speed pot to modify the THROTTLE POT CENTER input.

Digital Throttle Input

The digital throttle accepts a proportional throttle value. It does not apply deadband, failband, or throttle scaling processing, since the system providing the digital command will determine under what conditions the motor should run.

In order to use digital throttle, the digital control feature and the digital throttle bits must be enabled in configuration register 0x0357.

Additionally, the Digital Control Options allow customization of the digital throttle behavior.

If enabled, the digital throttle input may also be used as a Max Speed Pot (Mixed Throttle) in combination with THROTTLE POT CENTER, by enabling the appropriate bit in configuration register 0x031F.

Uni-or-Bidirectional Throttle

A unidirectional throttle ranges from 0 to 100% with one direction of mechanical deflection. Its deadband region is at one end of the electrical range, and the failband is at the other.

A bi-directional throttle normally rests in the middle of the mechanical deflection range and scales from 0 to 100% in either direction. Its deadband region is in the middle of the electrical range, and the failbands are at the extremes.

Use the Programmer to set the Uni- or Bidirectional throttle, and to set the neutral position of the throttle. See Motor Configuration Register for information on registers 0x0317 and 0x0323.

Inverted Throttle

Enable this setting to invert the polarity of the throttle input (for instance, a unidirectional throttle will have its deadband region near the 5V end of the electrical range, and failband near 0V). See Motor Configuration Register for information on register 0x031F.

Throttle Offset

To ensure maximum range and resolution of the throttle, the throttle should mechanically rest at the neutral position (0V for unidirectional, and 2.5V for bi-directional). Mechanical variation of the resting throttle position can be compensated by adjusting the throttle deadband (see below). If there is a bias (offset) in the throttle's resting position, the throttle offset can be used to compensate for it.

1. Locate the throttle at its resting position.
2. Observe the throttle voltage reported by the Programmer.
3. Adjust the Throttle Offset parameter until the Programmer reads the desired throttle voltage (e.g. 2.5V).

See Motor Configuration Register for information on register 0x035F.

Ramp Shape

The throttle ramp shape parameter sets the shape of throttle curves, determining the ratio of linear to logarithmic shape on the throttle curve. This value helps create a smoother acceleration profile or a more aggressive throttle response based on the application needs. A higher ramp shape value results in a more progressive throttle response when changing throttle inputs. Setting this value too high can roll off low-end throttle response too far and is generally not recommended.

6.7.2 Adjusting Throttle Deadband

The first step in setting up the throttle is adjusting the Throttle Deadband. Throttle Deadband sets the range of the neutral zone in the throttle input.

1. Move the vehicle’s throttle to the position where you want the vehicle to start moving. It is recommended that the throttle position not be too far from the neutral position.
2. While holding the throttle in the position where you want it to engage, adjust the value of Deadband up until you hear the relays click on the controller.
3. Release the throttle mechanism.
4. Throttle Deadband setup is complete.

See Configuration Register for information on register 0x0319.

6.7.3 Adjusting Throttle Scale

The throttle scale is a linear gain value that determines the throttle potentiometer voltage required for full speed. Under-adjusting the throttle scale will result in failure to reach full speed. Over-adjusting the throttle scale will result in reaching full speed too soon, and a reduction of speed control. To adjust the throttle scale, use the following procedure:

1. Adjust the throttle scale value to its lowest setting
2. Fully depress the throttle mechanism.
3. Monitor the Scaled Throttle status and adjust the throttle scale setting until the Scaled Throttle status reads the maximum value.
4. When complete, the Scaled Throttle status should read zero when the throttle is in its neutral position, and full value when the throttle is in its fully active position.
5. If a bi-directional throttle is used, check the Scaled Throttle value for the other direction as well.

See Motor Configuration Register for information on register 0x031D.

> **Note**
>
> To compensate for mechanical tolerance and ensure that Scaled Throttle always reaches 100%, throttle scale should be padded by a value of 1 or 2. This will cause the Throt val to reach 100%, just shy of the nominal mechanical limit. In addition to compensating for mechanical tolerance, padding the throttle scale helps ensure constant full speed when the user has to hold the throttle at the maximum position for extended periods. Without the padding, the user may experience speed fluctuations as their grip on the throttle relaxes slightly over time.
>
> Experiment with the padded throttle scale value to achieve desired results.

6.7.4 Adjusting Throttle Failband

The Throttle Failband is an area beyond the full speed throttle voltage that disables the motor. Throttle Failband provides a safety feature to protect against throttle shorts or open circuits, which could lead to undesired movement of the vehicle.

> **Note**
>
> Perform this procedure only after properly adjusting the Throttle Deadband and Throttle Scale

1. Change the failband setting to its highest value (which disables the failband).
2. Actuate the throttle mechanism on the vehicle to the full mechanical limit.
3. Decrease the failband setting until the motor stops.
4. Increase the failband setting by a small amount (e.g., 5-10 units) to allow additional tolerance.
5. Because the failband fault has been activated during the adjustment process, you will need to cycle the keyswitch before the motor will run.

See Motor Configuration Register for information on register 0x031B.

High/Low Failband

If the Failband is configured to be less than the deadband value for a unidirectional throttle, the controller interprets this special case and applies the failband to both the upper throttle limit as well as the lower throttle limit. The resulting ranges are:

- [0 .. Failband]: Throttle fail (low)
- [Failband ... Deadband] Throttle deadband
- [Deadband ... (255-Failband)]: Throttle active
- [above (255-Failband)]: Throttle Fail (high)

After the failband value is determined for the upper throttle limit, the correct value for High/Low Failband is (255-failband).

6.8 Performance Settings

The controller contains parameters that control many characteristics of a vehicle's performance. Using these parameters allows the controller to be programmed for a wide variety of applications. After setting up the throttle, it is recommended that you set up the maximum speed and acceleration/deceleration characteristics of the vehicle.

> **Note**
>
> If there is a potentiometer that sets the maximum speed on the vehicle, make sure it is adjusted to the maximum speed setting before configuring the performance settings.

6.8.1 Maximum Speed

The controller allows you to configure separate maximum speeds for forward and reverse directions. The Forward Speed and Reverse Speed parameters set the percentage of maximum speed allowed to the motor when the throttle is in the full position, and the speed adjustment potentiometer (if used) is set to full. To adjust the maximum speeds:

1. Drive the vehicle forward and adjust the Forward Speed Forward Speed parameter in the EEPROM until the vehicle travels at the desired maximum speed at full throttle.
2. Place the vehicle in reverse.
3. Drive the vehicle backwards and adjust the Reverse Speed parameter in the EEPROM
4. until the vehicle travels at the desired maximum speed at full throttle.

6.8.2 Minimum Speed

Sets the minimum speed for forward/reverse throttle when the throttle exits the deadband region. Some systems may not move at all for very small drive values; this setting allows the drive output to be set to a minimum level that will cause motion.

6.8.3 Acceleration and Deceleration

> **Note**
>
> The controller stores two sets of accel and decel tuning parameters. The correct set of parameters are activated using the 'Mode 1/2' or 'Indoor/Outdoor' selections. When adjusting settings, make sure the mode selection is in the correct position.
>
> It will be necessary to perform the acceleration and deceleration tuning steps twice for vehicles that use both Modes.

The acceleration and deceleration parameters give you control of how smoothly the vehicle accelerates and decelerates. Fast acceleration and deceleration rates will give the vehicle quick performance but will discharge the batteries at a higher rate.

1. From a stopped position, press the throttle to the full throttle position to check the acceleration rate.
2. Adjust the Forward Accel parameter in the EEPROM until the vehicle accelerates smoothly at the desired rate.
3. After you have adjusted the forward acceleration rate, drive the vehicle forward at full throttle.
4. Release the throttle and observe how fast the vehicle decelerates to a stop. Adjust the Forward Decel parameter in the EEPROM until the vehicle decelerates smoothly at the desired level.
5. Place the vehicle in reverse and make sure there are no hazards behind the vehicle.
6. From a stopped position, press the throttle to the full throttle position to check the reverse acceleration rate
7. Adjust the Reverse Accel parameter in the EEPROM until the vehicle accelerates smoothly in reverse at the desired rate.
8. After you have adjusted the reverse acceleration rate, drive the vehicle in reverse at full throttle.
9. Release the throttle and observe how fast the vehicle decelerates to a stop. Adjust the Reverse Decel parameter in the EEPROM
10. until the vehicle decelerates smoothly at the desired level.
11. The Rev->Fwd Decel setting adjusts how quickly deceleration occurs when changing direction. A good starting point is the standard Reverse Decel setting, and fine-tuning the parameter to achieve the desired effect.
12. Likewise, the Fwd->Rev Decel setting adjusts how quickly deceleration occurs when changing direction. A good starting point is the standard Forward Decel setting, and fine-tuning the parameter to achieve the desired effect.

For more information on setting acceleration and deceleration parameters see Configuration Registers for information on registers 0x0336 - 0x0341.

6.9 Limits

> **Note**
>
> Limits are typically set to protect the controller hardware, the motor, or other system elements from damage. They should only be changed by a knowledgeable system engineer. It is usually best to change them incrementally and observe the result before continuing.

6.9.1 Voltages

The following should be considered when setting up a new system:

- Nominal battery voltage
- Undervoltage warning limit
- Severe undervoltage (shutdown) limit. Note that the controller will not power on unless input voltage is at least as high as the shutdown limit.
- High Voltage Limit determines when the controller protects itself against unsually high input voltage.

6.9.2 Temperatures

The controller can cut back power to protect the hardware from damage due to over-temperature. Refer to:

- Controller Temperature Limiting for the on-board sensor
- Motor Temperature Limiting for the optional motor temperature sensor input

6.9.3 Controller Temperature Limiting

An onboard sensor measures the temperature of the controller near the drive electronics. As the temperature rises near the limit, the controller will indicate a high temperature condition and automatically reduce power. When the temperature decreases, output power will be restored and the high temperature indication will clear.

The temperature threshold is set in configuration register 0x0316

If the temperature increases to the limit, a fault code 0x31 is reported.

Power cutbacks start when the temperature is 8 degress C below the limit, unless Early Temperature Cutback is enabled, in which case the cutback starts 32 degrees below the limit.

6.9.4 Motor Temperature Limiting

> **Applies to**
>
> Version 1.7.2 and higher

When wired to a temperature sensor in the motor, the controller's ANALOG IN input monitors the sensor. There are two temperature thresholds. The first one causes the motor current to be reduced when the threshold is exceeded. The second (higher) limit will cause the motor to stop, report a fault, and require a key switch cycle before the motor will run again.

Configure the following registers to enable the temperature sensor.

1. EEPROM Address 0x0392.0x92 Set to 0x60 to configure ANALOG IN (GPIO2) as an analog input
2. EEPROM Address 0x0323 Bit 7: (motor_therm) 1 = ANALOG IN determines current limit threshold (cur_lb or cur_ub)
3. EEPROM Address 0x034E (cur_time) Persistance / ramp time for cur_lb / cur_ub transitions, 40ms resolution.
4. EEPROM Address 0x0321 (cur_lb) Lower current limit threshold
5. EEPROM Address 0x0322 (cur_ub) Upper current limit threshold
6. EEPROM Address 0x0315 (hi_tcol) ANALOG IN voltage for current limit change, 19.5mV resolution
7. EEPROM Addr 0x035E (cfr_opts9) Bit 0: ANALOG IN invert. 0 = excessive temperature when ANALOG IN voltage is less than threshold 1 = excessive temperature when ANALOG IN voltage is greater than threshold
8. EEPROM Address 0x035C (ina1_type) set upper nibble to '1' to enable ANALOG IN as a temperature 'stop' signal
9. EEPROM Address 0x039B (ANALOG IN_temp_stop) ANALOG IN voltage for 'stop' functionality, 19.5 mV resolution. When ANALOG IN is configured as a 'stop', the fault code 0x32 will be generated upon assertion of 'ANALOG IN stop'. This condition is 'latched' and will require a key switch to recover.

6.9.5 Motor Current Limiting

> **Applies to**
>
> Version 1.7.8 and higher

Setting limits on the output current of the controller can prevent damage to the motor or other parts of the system. The system often is designed with a 'continuous' current rating, which is the amount of current that the drive can accept for long periods of time, and a shorter 'peak' current that provides extra power, for example, when starting up the motor. The key configuration parameters are described below.

Current Limit Lower Bound

The 'LB' is typically set to the desired continuous-current rating of the system. See Current Lower Boundary for more information.

Current Limit Upper Bound

The 'UB' is typically set to the desired 'surge current' rating of the system. See Current Upper Boundary for more information.

Current Limit Time and Units

The 'CT' represents the transition time between UB and LB, and can be set in seconds or minutes. The way the CT affects the current limit transitions depends on the Current Limiting Mode as described below. See Over_Current Timeout for more information.

Current Limit Mode

The Mode determines how the Lower Bound (LB), Upper Bound (UB), and Time (CT) are used to manage the motor current. In 'Step' modes, the transition between states (bounds) happens immediately. In 'Incremental' modes, the transition happens over a period of time. See Current Limit_Config for more information.

STEP MODE 0

At the start of drive, current is limited to UB for the duration of CT, then the limit drops to LB until throttle is idle.

STEP MODE 1

Limit to UB unless it exceeds LB/2 for CT, then limit to LB but linearly recover toward UB over several seconds.

STEP MODE 2

Limit to UB unless it exceeds LB/2 for CT, then limit to LB but linearly recover toward UB over a period equal to 2 x CT.

MOTOR TEMPERATURE

Limit to UB unless motor temperature is above the threshold for CT, then step the limit to LB but linearly recover toward UB over a period equal to 2 x CT. See section "External Motor Temperature".

INCREMENTAL MODE 0

Limit to UB unless current exceeds LB/2, then decay toward LB at a rate of 1/CT and recover toward UB over several seconds.

INCREMENTAL MODE 1

Limit to UB unless current exceeds LB/2, then decay toward LB at a rate of 1/CT and recover toward UB at a 30 minute rate.

INCREMENTAL MODE 2

Limit to UB unless current exceeds LB/2, then decay toward LB proportional to (excess measured current / CT) and recover toward UB at over several seconds.

INCREMENTAL MODE 3

Limit to UB unless current exceeds LB/2, then decay toward LB proportional to (excess measured current / CT) and recover toward UB at a 30 minute rate.

INCREMENTAL MODE 4

Limit to UB unless current exceeds LB/2 for CT, then decay toward LB proportional to (excess measured current / CT) and recover toward UB at a 30 minute rate.

INCREMENTAL MODE 5

Limit to UB unless current exceeds LB/2 for CT, then decay toward LB proportional to (excess measured current / CT) and recover toward UB at a 30 minute rate.

STEP STOP MODE

Limit to UB unless current exceeds LB for CT, then stop the motor until throttle returns to deadband.

IN/OUT MODE

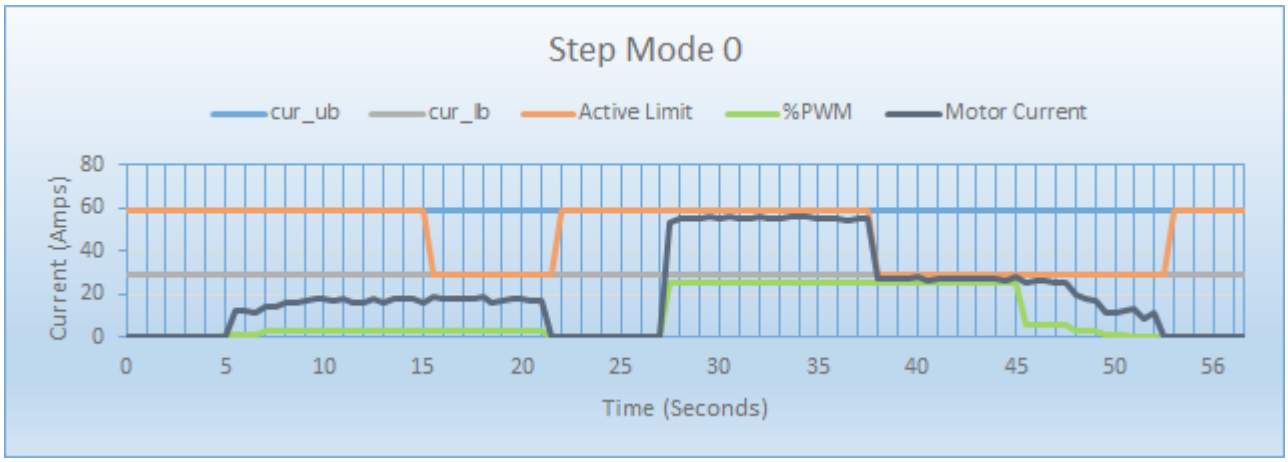
LB applies when controller is in "Indoor" mode; UB applies when controller is in "Outdoor" mode.

6.9.6 Current Limiting Examples

The graphs below show the behavior of the various current limiting modes, using a Lower Bound of 29 amps and an Upper Bound of 59 amps. Current Limit Time was set to 10 seconds except for Incremental mode 0 & 1 which used 20 seconds.

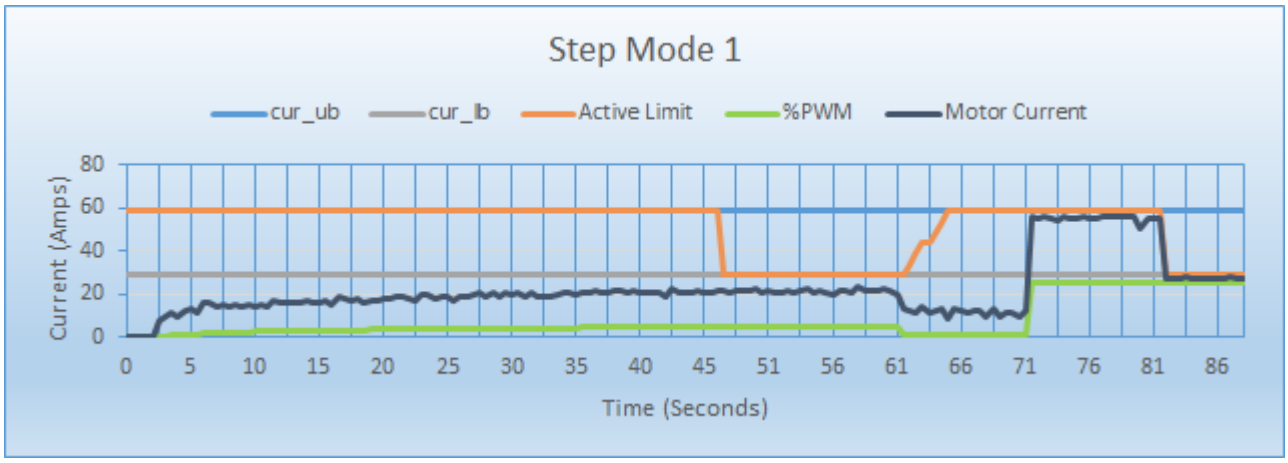
Step Mode 0

The current limit is UB for the duration of CT, then the limit switches to LB regardless of how much current is being used. The limit stays at LB until the motor is stopped. The orange line shows that the limit drops to LB after the time limit regardless of how hard the motor runs. The second time the motor was run much harder and the the current was held to UB for 10 seconds then it was reduced to LB.



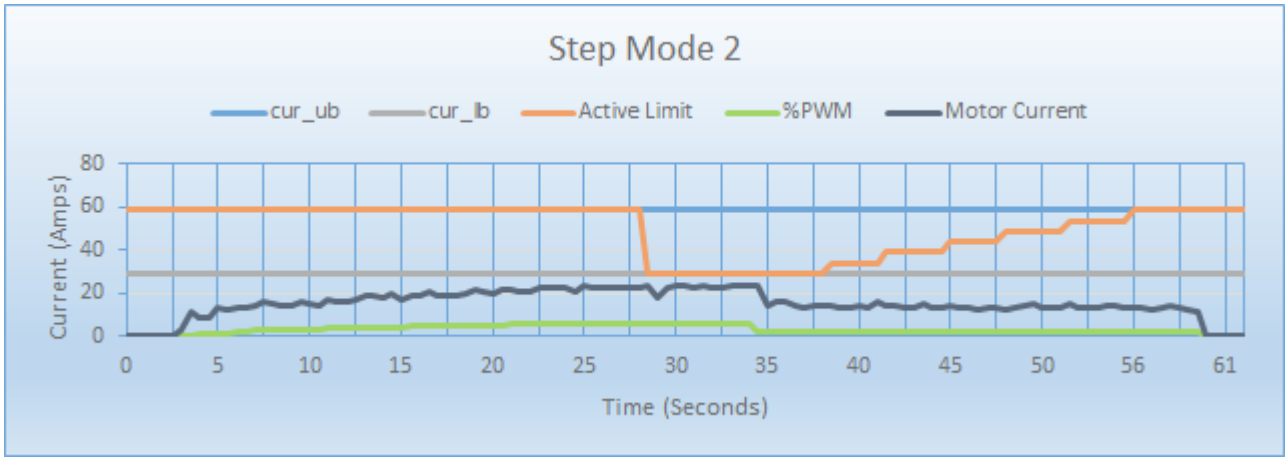
Step Mode 1

This mode will switch to LB when the current is > LB/2 for CT. The recovery is a fast linear recovery of .64 seconds per step from LB to UB. Notice how the current recovers in about 3.84 seconds. In these examples the number of steps from LB to UB is 6 and the rate is .64 seconds per step.



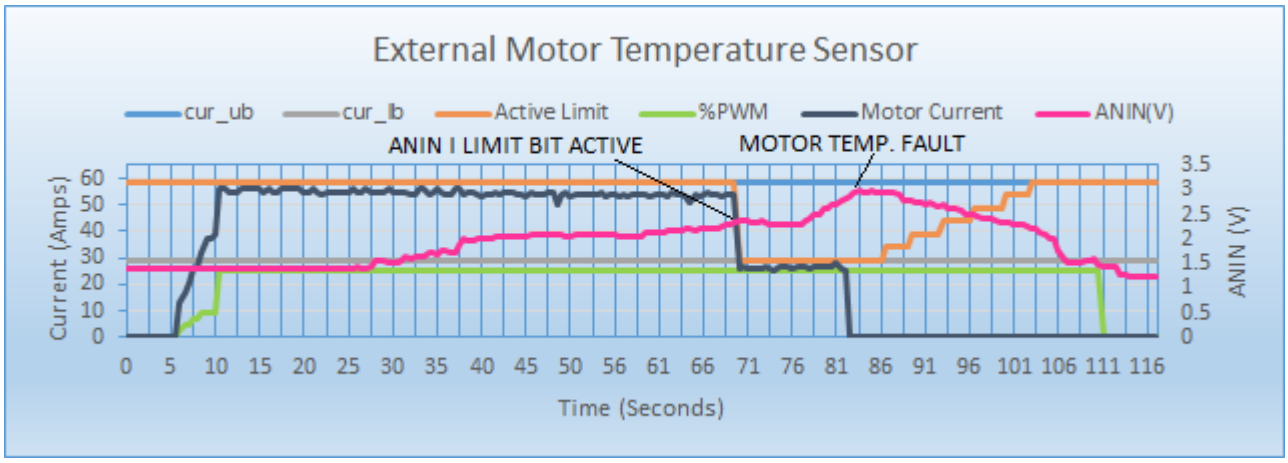
Step Mode 2

This mode will switch to LB when the current is > LB/2 for cur_time just like Step Mode 1. However the recovery is a fixed time equal to 2 * CT. Notice how the current recovers in 20 seconds. The CT is 10 seconds so the recovery is 20 seconds.



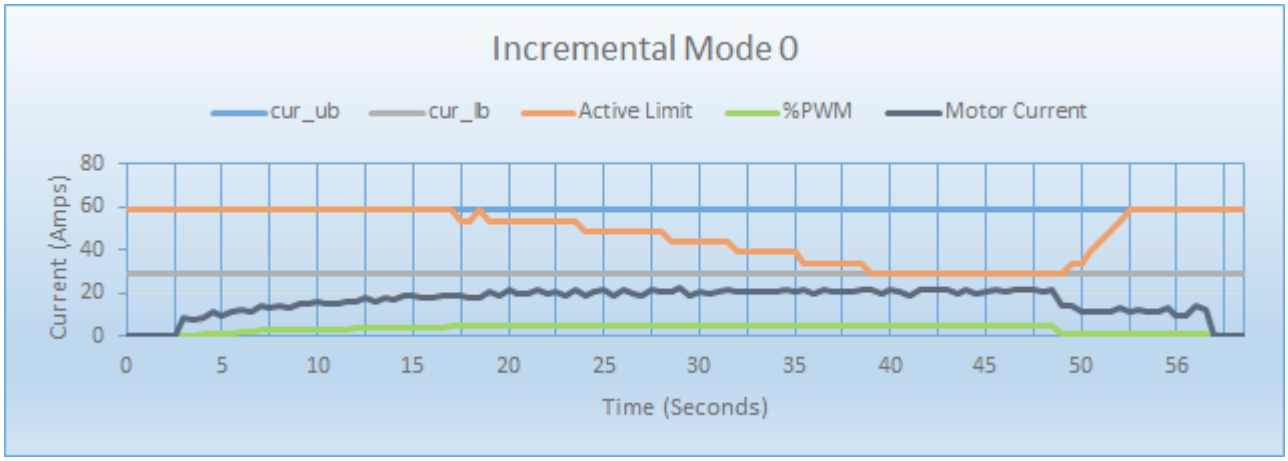
External Motor Temperature

This mode reads the ANALOG IN voltage as a temperature sensor. See Motor Temperature Limit for more detail. You can configure the controller to handle a temperature signal with either a positive or negative response direction. The voltage ranges are also adjustable. This example was set up as a positive sensor using a potentiometer to provide 0-5V to the ANALOG IN input. The the current is limited when the ANALOG IN voltage is above 2.05V. When the temperature is above 2.80V the unit throws a motor temperature fault and stops the motor.



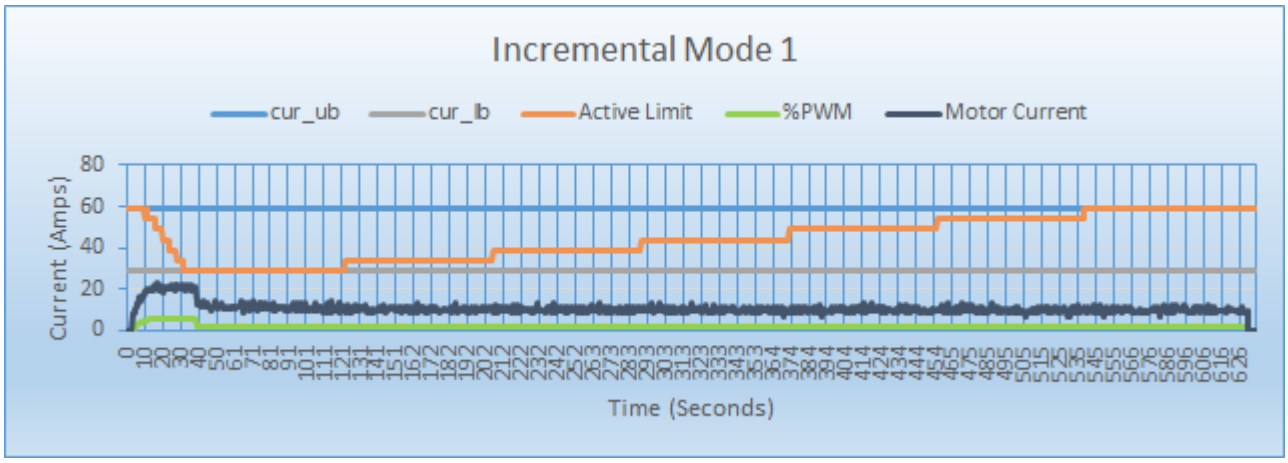
Incremental Mode 0

This mode provides a decrease in current over a time period equal to cur_time with a rapid recovery. The cur_time was set to 20 seconds for this example. Notice the current falls to cur_lb after dropping for about 20 seconds. The recovery is one step every .64 seconds or 6 * .64 or 3.84 seconds.



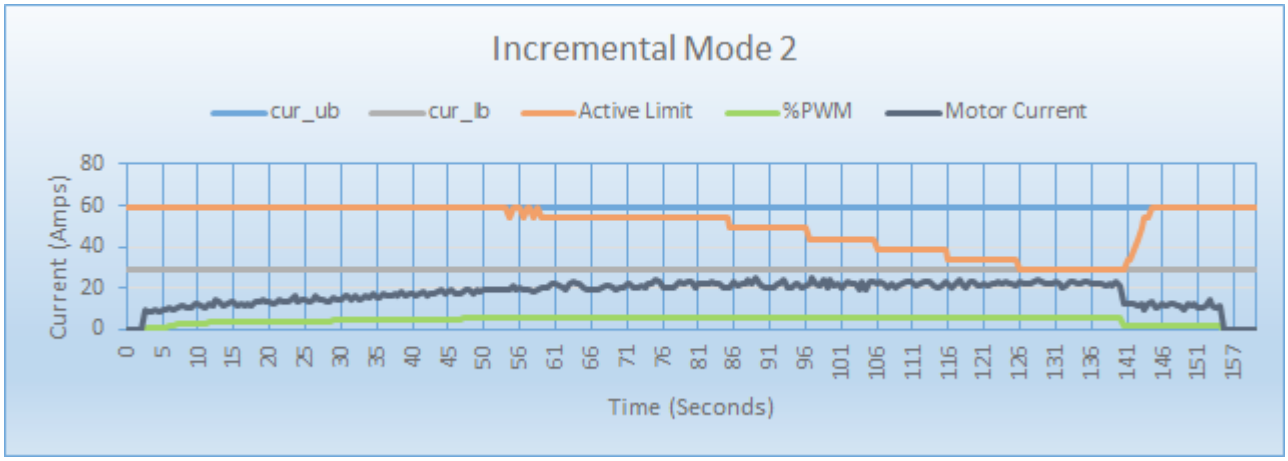
Incremental Mode 1

This mode provides a decrease in current over a time period equal to CT with a slow recovery. The CT was set to 20 seconds for this example. Notice the current falls to LB after dropping for about 20 seconds. The recovery is one step every 82 seconds.



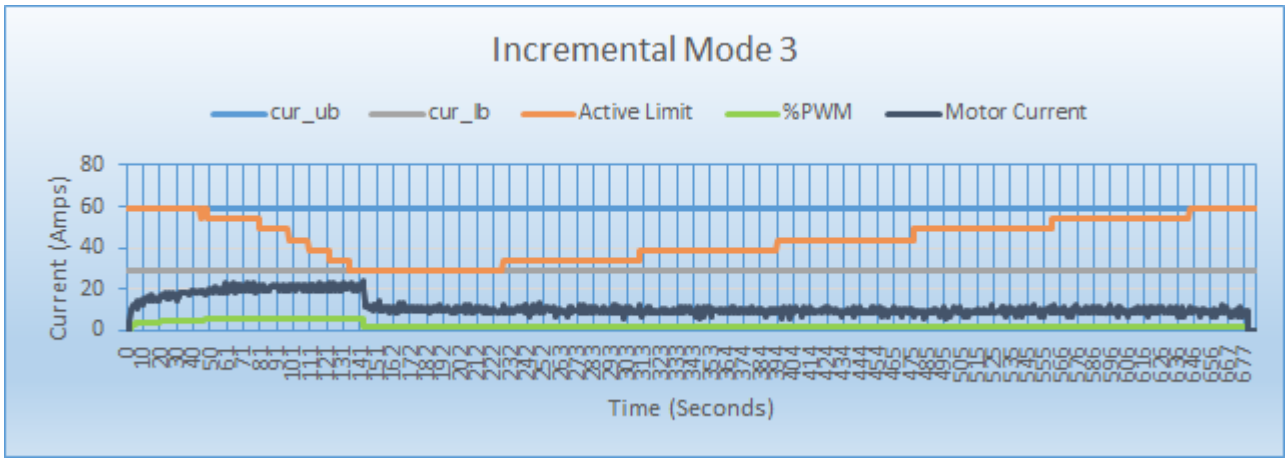
Incremental Mode 2

This mode decreases current one step per each CT period with a fast recovery. The current is decreased by one step every CT interval that the current is > LB/2. The CT was set to 10 seconds for this example. The recovery is one step every .64 seconds or 6 * .64 or 3.84 seconds.



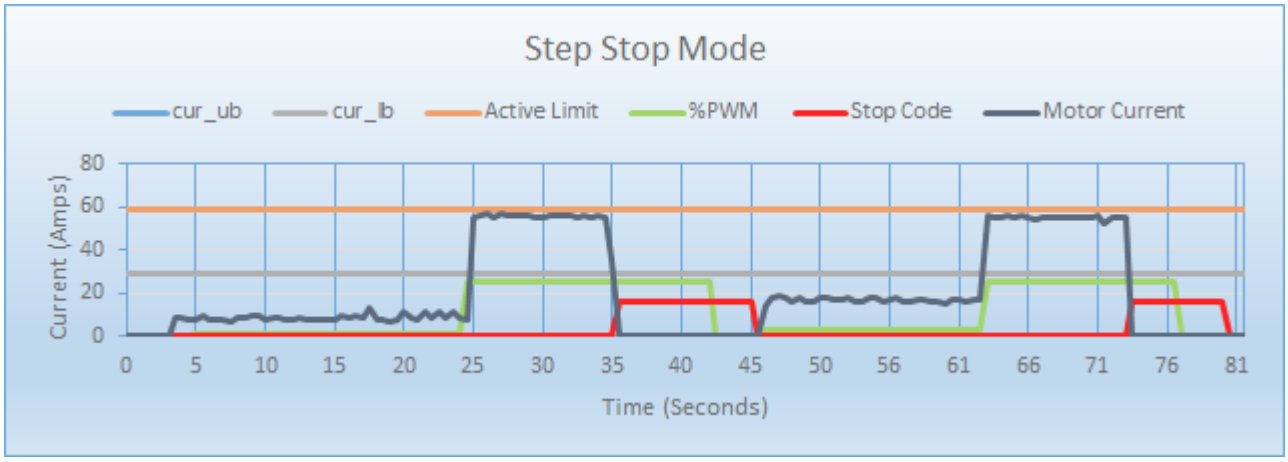
Incremental Mode 3

This mode decreases current one step per each CT period with a slow recovery. The current is decreased by one step every CT interval that the current is > LB/2. The CT was set to 10 seconds for this example. The recovery is one step every 82 seconds.



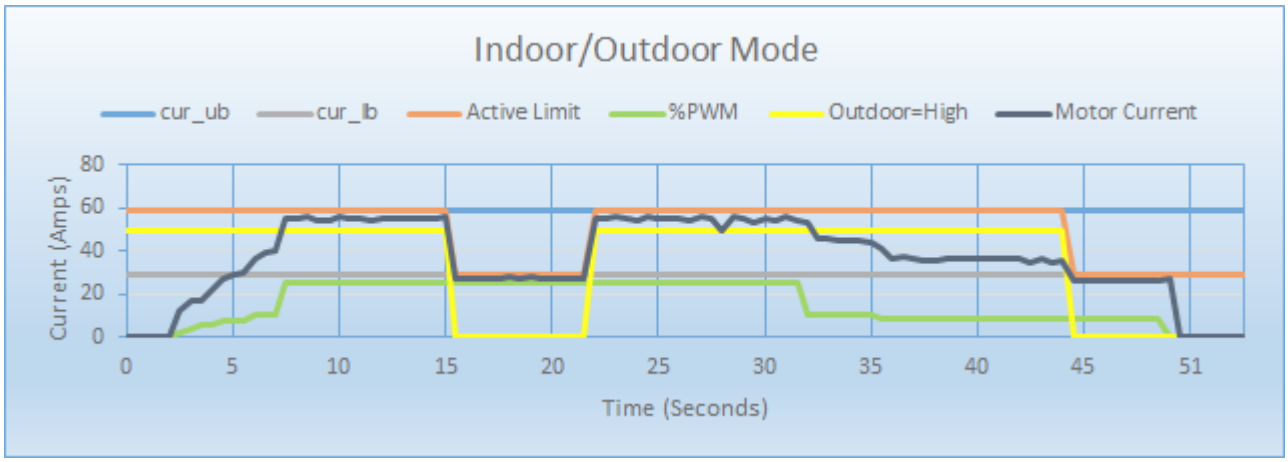
Step Stop Mode

This mode stops the motor after the current has been above LB for CT. A stop code of 0x10 is visible in status message FF03 byte 7. Once the throttle is idle the stop code clears and the motor can be operated again.



Indoor Outdoor Mode

This mode simply uses UB as a limit when the outdoor mode is active and LB when indoor mode is active.



6.9.7 Speed

When the controller is able to measure motor RPM (eg brushless motors) it can implement an RPM limit. On brushed motors there is a PWM
limit that is available. Both brushless and brushed motors are configured with Register 038C. Speed limit re-scaling is achieved by modifying the Max Speed.

6.10 Configuration Registers

Each configurable feature of the controller is defined by one or a combination of configuration register values. This table summarizes the available configuration registers.

These registers are available directly using the CAN Bus interface, and the ranges are those used natively by the controller. User Interface software may present the features or ranges differently (for example, representing a value as a percentage rather than 0-255). When using external software to configure the controller, refer to the external software's documentation for the correct values and ranges.

The operational configuration of the controller is stored permanently in the controller. At powerup, this configuration is copied to a 'shadow' version which is used thereafter. The CAN Bus interface is able to access both the permanent configuration and the shadow configuration. Changes made to the shadow configuration take effect immediately, but are not retained through a power cycle. Changes made to the permanent configuration do not take effect immediately, but are retained permanently. It is up to the system designer to determine whether to make a change permanent.

Danger

Adjusting or changing the controller's configuration can cause unexpected movement of the motor and/or vehicle/system. Always secure the machine before making adjustments to the configuration.

6.10.1 Configuration Registers

These registers are accessed using

- Bank 2, for shadow settings. The Modbus command address is 02xx. xx=register address
- Bank 3, for permanent settings. The Modbus command address is 03xx. xx=register address

See System Commands for details on writing motor registers.

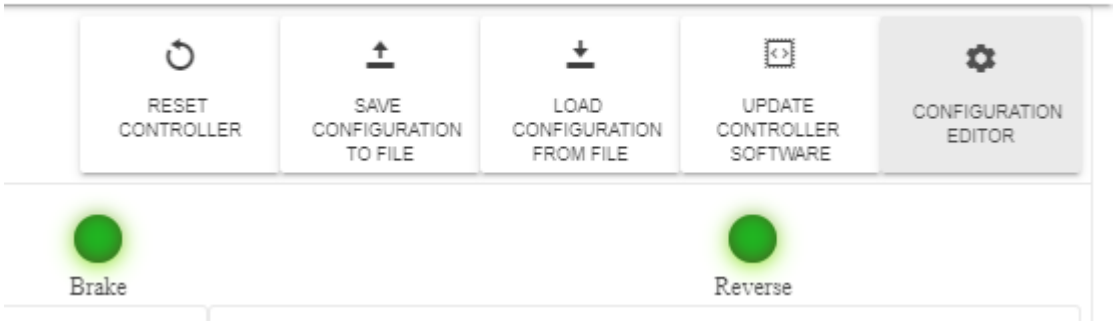
All values are shown in hexadecimal format, unless otherwise noted. For example, Address 0319 refers to register 0x0319. Where a specific bit within a register is addressed, it is shown as rrrr:xx, where rrrr indicates the register in hexadecimal format, and xx indicates the bit number. Example, Address 0317:05 indicates bit 5 of register 0x17.

Note

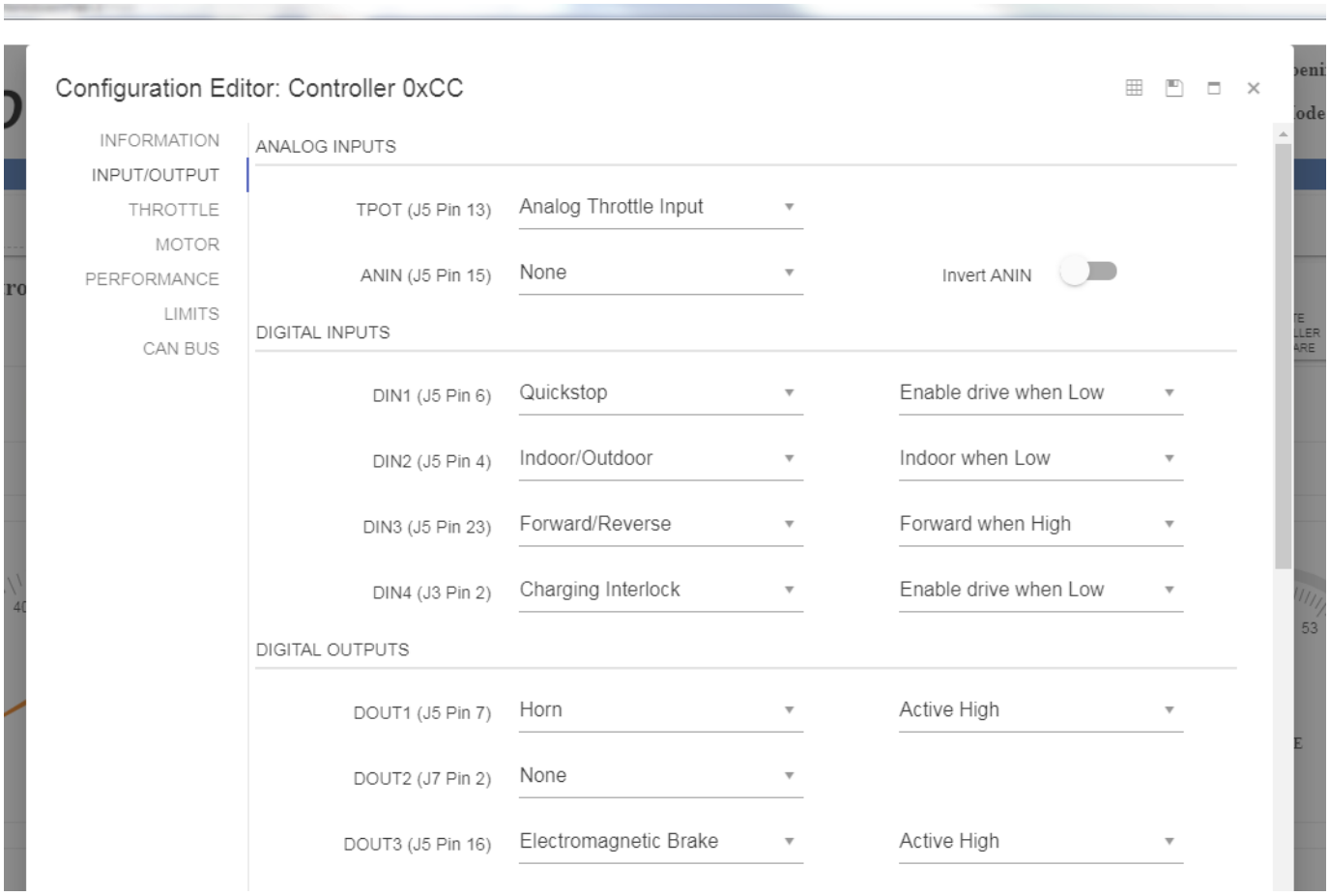
Bits that are not defined or used should be left in their current state. Always read the register and then set or clear the bits you need to change and then write the new value back to the register.

Configuration Editor

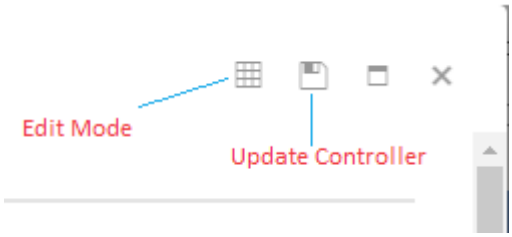
Using the Phoenix Diagnostics app is the easiest way to edit register settings. Simply click "CONFIGURATION EDITOR".



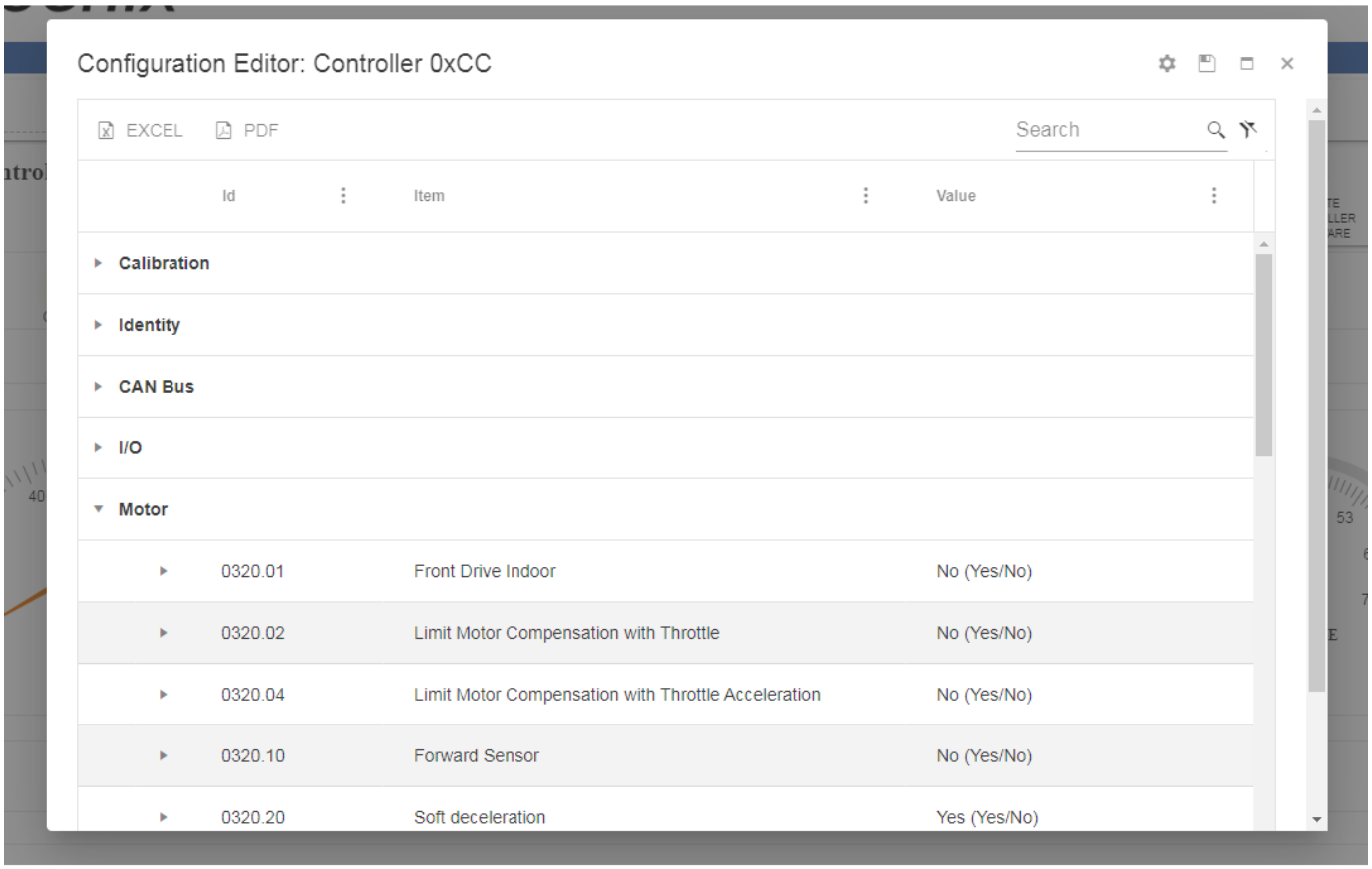
There are two modes for editing, "Normal" and "Advanced" . The mode that comes up is the "Normal" mode. This mode shows settings by category and has tools to aid in selection.



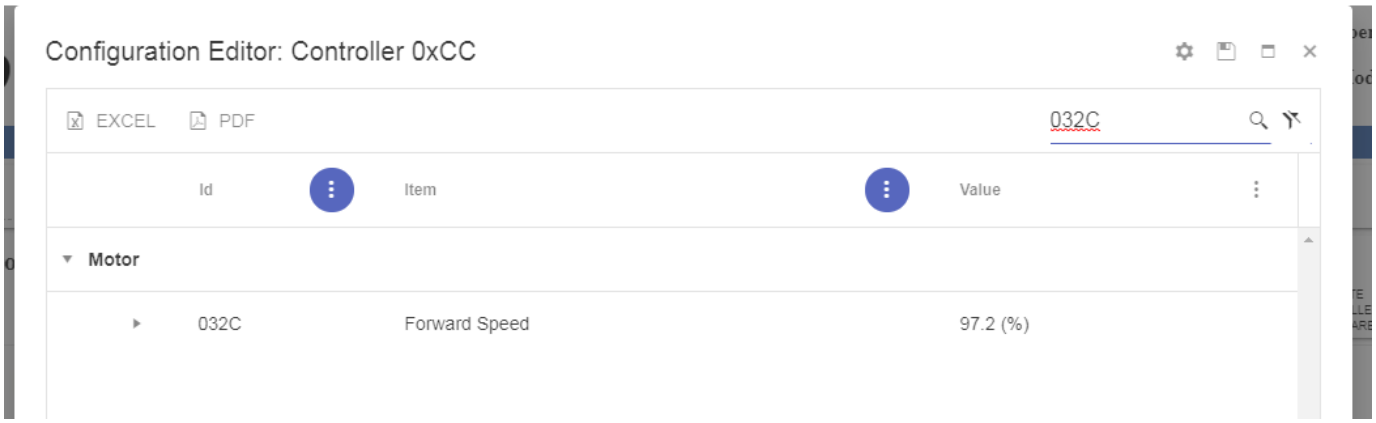
To edit a specific register in the "Advanced" mode click the table icon in the upper right corner.



In the "Advanced" mode you can pick a category and see all of the registers and their bit fields or values.



You can also search for a register such as "032C" to edit forward speed. Any values that are grayed out are restricted from editing.



Motor EEPROM (03) Registers

Here is a detailed list of common registers used to configure the controller.

Addr. (Hex)	Parameter	Format / Range	Description
0300	Max Speed	Byte 0-255	Maximum speed used by some throttle modes.
0315	Hi Motor Temp Cutoff	Byte 0-255	Determines the voltage threshold of the ANALOG IN input. See Motor Temperature
0316	Hi Temp Cutoff	Degrees C + 0x6C 0-255	Determines the temperature at which the output power decreases to zero. See Controller Temperature
0317	Config Options 3	Bitmap 0-1	Bit 5: Unidirectional Throttle Off/On. When 1, throttle causes motion in one direction only.
0318	Config Options	Bitmap 0-1	Bit 0: 1=Beep when in reverse Bit 1: 1=Slow Quick Stop Bit 2: 1=Momentary contact on brake release Bit 3: 1=Key switch must turn off-on-off to power down Bit 4: 1=Lock enable, 0 digital throttle required before first movement Bit 5: Reserved Bit 6: Reserved Bit 7: 1=QSTOP high (Invert QSTOP signal)
0319	Throttle Deadband	5V/256 ~=19.5mV 0-255	Sets the throttle pot range that the controller determines as neutral. 0=No deadband
031B	Throttle Failband	5V/256 ~=19.5mV 0-255	This is an area beyond the full speed throttle voltage that disables the motor. Throttle Failband provides a safety feature to protect against throttle shorts to ground or 5V, which could lead to dangerous runaways. 255=No failband.
031D	Throttle Scale	 0-255	Sets the throttle scale which determines the throttle pot voltage needed for full speed, and sets the amount of throttle movement necessary to obtain full throttle.
031F	Throttle Flags	Bitmap 0-1	Bit 0: Invert Throttle. 1=Inverted throttle polarity Bit 1: Reserved Bit 2: Set to use ANALOG IN input as max speed Bit 3: Reserved Bit 4: Set to use max_spd setting in Register 0x00 Bit 5: Reserved Bit 6: Use Digital Throttle as Max Pot Bit 7: Reserved
0320	Motor Flags	Bitmap 0-1	Bit 0-6: Reserved Bit 7: Set to disable the EM Brake feature
0321	Current Lower Boundary	Current 0-255	Defines the current lower limit for various current limiting features like motor temperature. The value is in 2.5A steps if using standard Phoenix controllers. For dual motor controllers it is 5A.
0322	Current Upper Boundary	Current 0-255	Defines the current upper limit for various current limiting features like motor temperature. The value is in 2.5A steps if using standard Phoenix controllers. For dual motor controllers it is 5A.
0323	Config Options 4	8 Bit 0-1	Bit 0: Indoor High 1=Indoor when high. 0=Indoor when low Bit 1: Zero throttle 0=2.5V Bidirectional 1=0V Unidirectional Bit 2: Reverse Pin 1=Active high 0=Active low

Addr. (Hex)	Parameter	Format / Range	Description
			Bit 5: In/Out current Bit 7: Motor Therm 1=Use ANALOG IN as motor temp sensor
0327	Top State Of Charge	Voltage 0-255	Defines the voltage at which state of charge is 100%. The value is in .35866V steps
0328	Undervoltage	0.35866 V 0-255	Defines the voltage at which a low voltage warning will occur.
032C	Forward PWM Scaling Outdoor	%PWM 0-255	Forward PWM scaling value (outdoor forward speed)
032D	Reverse PWM Scaling Outdoor	%PWM 0-255	Reverse PWM scaling value (outdoor reverse speed)
032E	Forward PWM Scaling Indoor	%PWM 0-255	Forward PWM scaling value (indoor forward speed)
032F	Reverse PWM Scaling Indoor	%PWM 0-255	Reverse PWM scaling value (indoor reverse speed)
0335	EM Brake Time	Time Constant 0-255	Brake delay
0336	Forward Acceleration (Outdoor)	Time Constant 0-255	Forward acceleration constant. The higher the number the longer the time. The formula to convert to seconds is 40.8/(255-x), so a value of 0xD8 results in a PWM ramp of about 1 second.
0337	Forward Deceleration (Outdoor)	Time Constant 0-255	Forward deceleration constant. The higher the number the longer the time.
0338	Forward Deceleration (Outdoor)	Time Constant 0-255	Forward deceleration constant. The higher the number the longer the time.
0339	Reverse Acceleration (Outdoor)	Time Constant 0-255	Reverse acceleration constant. The higher the number the longer the time.
033A	Reverse Deceleration (Outdoor)	Time Constant 0-255	Reverse deceleration constant. The higher the number the longer the time.
033B	Reverse Deceleration (Outdoor)	Time Constant 0-255	Reverse deceleration constant. The higher the number the longer the time.
033C	Forward Acceleration (Indoor)	Time Constant 0-255	Forward acceleration constant. The higher the number the longer the time.
033D	Forward Deceleration (Indoor)	Time Constant 0-255	Forward deceleration constant. The higher the number the longer the time.
033E			

Addr. (Hex)	Parameter	Format / Range	Description
	Forward Deceleration (Indoor)	Time Constant 0-255	Forward deceleration constant. The higher the number the longer the time.
033F	Reverse Acceleration (Indoor)	Time Constant 0-255	Reverse acceleration constant. The higher the number the longer the time.
0340	Reverse Deceleration (Indoor)	Time Constant 0-255	Reverse deceleration constant. The higher the number the longer the time.
0341	Reverse Deceleration (Indoor)	Time Constant 0-255	Reverse deceleration constant. The higher the number the longer the time. >
034D	Configuration Flags	Bitmap	Bit 3: Clear to disable power-on diagnostics.
034E	Over Current Timeout	Current 0-255	Defines the time before action is taken if an amperage boundary is exceeded. The value is in 5A steps if using standard Phoenix controllers. For dual motor controllers it is 2.5A.
0353	Digital Control	Bitmap 0-1	Bit 0: Reserved (set to 0) Bit 2: Trigger a fault if throttle is not in neutral position at startup Bit 3: Trigger a fault on Quickstop (require keyswitch to clear) Bit 4-7: Reserved (set to 0)
0357	Options 6	Bitmap 0-1	Bit 0: Enable digital control (buttons) Bit 1: Disable THROTTLE POT CENTER (analog) throttle Bit 2: Enable Digital Throttle Bit 3: Invert digital throttle (when set, 0xFF throttle means slow, 0 throttle = fast) Bits 4-7: Reserved
035B	Severe Undervoltage	0.35866V 0-255	Defines the low voltage threshold. If the input voltage remains below this value for a period of time, the controller will power off. Note that the controller will not power on unless the input voltage is at least as high as indicated by this setting.
035C	IN1 Type	Bitmap Enum	Switch 1 usage, set upper nibble to '1' to enable ANALOG IN as a temperature 'stop' signal for external motor temperature sensing
035D	IN23 Type	Bitmap	set upper nibble to 'A' to enable 'in2' as a seat stop input. Otherwise, set to 0
035E	Config Options 9	Bitmap 0-1	Bit 2: in2_invert 0 = seat occupied when DIGITAL INPUT 2 = 1, 1 = occupied when DIGITAL INPUT 2 = 0.
035F	Throttle Offset	5V/256 ~=19.5mV -128 - 127	Sets the throttle offset for bidirectional throttles so that the center voltage is offset higher or lower than 2.5V.
0386	Config Options 8	Bitmap 0-1	Bit 5: Aggressive temperature cutback. When set, the controller will begin cutting back power at 32 degrees below the temperature limit, rather than 8 degrees C.
0387	High Voltage Limit	Voltage 0-255	Limit where battery voltage is too high to operate. The value is in . 35866V steps

Addr. (Hex)	Parameter	Format / Range	Description
0388	Motor Type	Bitmap	Bit 0-2: Number of motor pole-pairs Bit 4-5: Sensor geometry: 0: Type 1 1: Type 1A 2: Type 2 3: Type 2A Bit 6: If true, swaps sensors A and C Bit 7: sent if sensors are normally low
038A 0x038B	Max RPM 16-bit Little Endian	0- 32767	**BLDC Prior to V1.7.1** Bit 15: Enable Speed Limit. Bits 0-14: Speed limit in RPM. If enabled, this feature cuts back motor power to keep BLDC motor RPM below the indicated value. Zero=No speed limit. **BLDC As of V1.7.1** This value is the target RPM only. Use RPM Config Register to define the operation.
038C	RPM Config	Bitmap	**BLDC as of V1.7.1** **Brushed as of 1.7.8** BITS 3:0 0: No Speed Loop or Speed Limit 1: Speed loop (speed loop enabled if target RPM != 0) 2: Speed Limit - single limit (specified in Addr 0x8B-8A) 3: Speed Limit - auto-capture (will transition back to 2 after capture) 4: Throttle re-scaling during speed limit. 0: disabled 1: enabled (uses max_spd) BITS 5:7 Reserved
038F	Current Limit Config	Bitmap	Bit 7: Enable current limiting Bit 6: Current time Units (0 = seconds, 1 = minutes) Bit 5: Adjust Current Limit Threshold for FET temperature (0 = disabled, 1 = enabled) Bit 4: Adjust Current Measurement for FET temperature (0 = disabled, 1 = enabled) Bit 0-3: Mode (See Motor Current Limiting) 0 = Step Mode 0 1 = Step Mode 1 2 = StepMode 2 3 = External Motor Temperature 4 = Incremental Mode 0 5 = Incremental Mode 1 6 = Incremental Mode 2 7 = Incremental Mode 3 8-13 = Reserved 14 = Step Stop Mode 15 = In/Out Mode
0392	GPIO Config 2	Bitmap	Normally 0, set upper nibble to '1' to enable ANALOG IN input as a temperature 'stop' signal
039B	ANALOG IN Temperature Offset	Byte 0-255	This value represents the ANALOG IN voltage if the temperature were 0 degrees C. The Range of offset is (0.625 - 1.92V)
039C	ANALOG IN Temperature Gain	Byte 0-255	ANALOG IN scaling factor(bits6:0). Bit 7: 0=positive volt/temp, 1=negative volt/temp

6.10.2 CAN Bus EEPROM (04) Registers

Here is a detailed list of registers used to configure the CAN bus operation.

Address (Hex)	Parameter	Range	Description
0400	CAN Bus ID Low	0-255	Lowest allowed ID. If ID is set lower than this value the ID will be coerced to this value.
0401	CAN Bus ID High	0-255	Highest allowed ID. If ID is set higher than this value the ID will be coerced to this value.
0402	CAN ID	0-255	CAN Bus ID
0403-040A	Reserved	0-255	Do not modify.
040B	CAN Baud	0-3	CAN Bus Baud Rate 0=125K 1=250K 2=500K 3=1Meg
040C	CAN Bus Priority	0-7	CAN Bus Message Priority
040D-040E	Reserved	0-255	Do not modify.
040F	Digital Control Low Byte Motor #1	0-255	Digital Control Options (LSB) Bit 0-3: Reserved Bit 4: 0=Disable digital control 1=Enable digital control Bit 5: 1=Digital Stop (Quick Stop) on comm loss Bit 6: 1=Set digital throttle to 0 on comm loss. Bit 7: 1=Turn off digital brake on comm loss.
0410	Digital Control High Byte Motor #1	0-255	Digital Control Options (MSB) Bit 0: 1=If digital (0x50) commands are sent and register 0x0357 is not set for digital control that feature is temporarily enabled as long as 0x50 commands are being received. This is for use if both analog and digital (CAN Bus) throttle are used. NOTE: Digital throttle will override the analog throttle but as soon as commands stop the analog throttle resumes control Bit 1: 1=Turn off digital horn on comm loss. Bit 4: 1=Echo digital throttle (0x50) commands back to host.
0411	Status Message Enable	0-255	Each bit that is set enables the corresponding status message. Example: bit 2 enables the FF02 status message.
0412-0425	Timers 0-19	.05-2.55 seconds	Sets various timers in units of 10 milliseconds. NOTE: setting a timer to 0xFF causes it to reset to the factory default after the next power cycle. See Timer Configuration for more info. Timer 0: FF00 Status Rate Timer 1: FF01 Status Rate Timer 2: FF02 Status Rate Timer 3: FF03 Status Rate Timer 4: FF04 Status Rate Timer 5: FF05 Status Rate Timer 6: FF06 Status Rate Timer 7: FF07 Status Rate Timers 8-13: Reserved Timer 14: Motor 1 digital throttle timeout Timer 15: CAN Bus Alarm timeout Timer 16: Reserved Timer 17: Motor 2 digital throttle timeout Timers 18-19: Reserved

Address (Hex)	Parameter	Range	Description
0426-0428	Reserved	0-255	Do not modify.
0429	Digital Control Low Byte Motor #2	0-255	Digital Control Options (LSB) Bit 0-3: Reserved Bit 4: 0=Disable digital control 1=Enable digital control Bit 5: 1=Digital Stop (Quick Stop) on comm loss Bit 6: 1=Set digital throttle to 0 on comm loss. Bit 7: 1=Turn off digital brake on comm loss.
042A	Digital Control High Byte Motor #2	0-255	Digital Control Options (MSB) Bit 0: 1=If digital (0x50) commands are sent and register 0x0357 is not set for digital control that feature is temporarily enabled as long as 0x50 commands are being received. This is for use if both analog and digital (CAN Bus) throttle are used. NOTE: Digital throttle will override the analog throttle but as soon as commands stop the analog throttle resumes control Bit 1: 1=Turn off digital horn on comm loss. Bit 4: 1=Echo digital throttle (0x50) commands back to host.
042B-044A	Reserved	0-255	Custom Status (Version 4.5.0 and above). See Custom Status Configuration for more info.
044B	Reserved	0-255	Bootloader Version MAJOR Version 4.5.0 and above
044C	Reserved	0-255	Bootloader Version MINOR Version 4.5.0 and above
044D	Reserved	0-255	Bootloader Version PATCH Version 4.5.0 and above
044E	Reserved	0-255	CAN Bus Processor Version MAJOR Version 4.5.0 and above
044F	Reserved	0-255	CAN Bus Processor Version MINOR Version 4.5.0 and above
0450	Reserved	0-255	CAN Bus Processor Version PATCH Version 4.5.0 and above

6.11 CAN Bus Configuration

Settings for CAN Bus apply only to Controllers with a CAN Bus interface installed. Further, the CAN Bus Configuration may only be set using the CAN Bus interface.

After changing settings, the Controller must be reset (via power cycle or RESET command) before the new settings will take effect.

Note: the examples in this section assume the Controller's CAN Bus address is 0x80 while the Host device is 0x90. Different values must be substituted if your CAN Bus network is designed differently.

Configuration parameters are accessed using the System Commands message.

> **Note**
>
> The examples on this page use a Host Device ID of 0x90, and a Controller address of 0x80. These values will vary according to the design of the CAN Bus network.**

6.11.1 Available Info and Settings

Software Version

For non-DSP controllers there is a version for the motor processor and a version for the CAN Bus processor.

For DSP controllers there is a single version for motor and CAN Bus app.

Example

Read the Motor software version for a non-DSP controller. The version is stored at address low RAM 0x000A.

```
                    FC  MT  ADD LEN
Command:    10EF8090 45  00  0A  03
Response:   1CEF9080 45  01  07  0B
FC=Function Code  MT=Memory Type  ADD=Address  LEN=Length
The response is version 1.7.11
```

Example

Read the CAN Bus processor software version for version 4.5.0 or greater CAN Bus processor or a DSP controller. The version is stored at address 0x044E.

```
                    FC  MT  ADD LEN
Command:    10EF8090 45  04  4E  03
Response:   1CEF9080 45  04  05  00

FC=Function Code  MT=Memory Type  ADD=Address  LEN=Length
The response is version 4.5.0
```

The 0x49 command is a deprecated feature, but it may be the only way to read the CAN Bus processor version prior to version 4.5.0.

```
Parameter: 0x02
```

B0	B1	B2	B3	B4	B5	B6	B7
0x49	{OP}	{Parameter}	0	Minor Version	Major Version	Patch Version	0

Example

Read the version of an older CAN Bus processor

```
Command:    10EF8090 49 43 02
Response:   10EF9080 49 43 02 00 15 03 05 00 (Version = 3.21.5)
```

CAN Bus Baud Rate

The CAN Bus baud rate is stored at 0x040B. The valid values are in the table below.

Rate	Selected Baud Rate
0	125 Kb/s
1	250 Kb/s (default)
2	500 Kb/s
3	1 Mb/s

Write Baud Rate Example

Set baud rate to 500K or (2).

Example

Write 0x02 to 0x040B.

```
                    FC  MT  ADD DATA...
Command:    10EF8090 46  04  0B  02
Response:   1CEF9080 46  00  (00=Success)
```

TX Message Priority

The CAN Bus priority is stored at 0x040C. The Priority determines the J1939 priority used by the Controller when sending messages. Messages with higher priority are less likely to be delayed. Adjusting this value allows the system designer to indicate which messages are most important within a given system.

Priority may be set to a value between 0 and 7 inclusive. Zero indicates the highest priority.

Example

Write priority 6 to 0x040C.

```
                    FC  MT  ADD DATA...
Command:    10EF8090 46  04  0C  06
Response:   1CEF9080 46  00  (00=Success)
```

Digital Control Options

Flags is a bitmapped 16 bit value. It is used to configure the behavior of the digital throttle control over CAN Bus. The default value is 0x0000.

NOTE: For dual motor controllers there are two Flag values. Motor #1 is stored at 0x040F-0x0410 and Motor #2 is stored at 0x0429-0x042A. The bit assignments are shown in the table below.

Byte	Bit	If set to '1'
040F	Bits 0:3	Reserved (set to 0)
-	Bit 4	Enable Digital Control functions
-	Bit 5	Enable Digital Stop (if no Digital Control messages are received, motion is inhibited)
-	Bit 6	Zero digital throttle when flow of digital throttle commands stops.
-	Bit 7	Turn off digital brake when flow of digital throttle commands stops.
0410	Bit 0	Set to 1 to automatically switch between digital and analog control depending on presence or absence of digital control messages.
-	Bit 1	Turn off digital horn when flow of digital throttle commands stops.
-	Bits 2:3	Reserved (set to 0)
-	Bit 4	Echo digital throttle (0x50) commands back to host.
-	Bits 5:7	Reserved (set to 0)

Examples

Set digital throttle to 0 when CAN Bus throttle commands cease. Force controller to enable Digital Throttle when throttle commands start being received.

Example

Write 0x0150 to 0x040F-0x0410 (LSB First).

For versions prior to 4.2.0

```
                    FC  MT  ADD DATA...
Command:    10EF8090 46  04  0F  50
Response:   1CEF9080 46  00  (00=Success)
Command:    10EF8090 46  04  10  01
Response:   1CEF9080 46  00  (00=Success)
```

For versions 4.2.0 and above

```
                    FC  MT  ADD DATA...
Command:    10EF8090 46  04  0F  50  01
Response:   1CEF9080 46  00  (00=Success)
```

Status Message Configuration

MSG Enable Flags is a bitmapped value. The value is stored at 0x0411. All messages are enabled by default.

Bit Mask	If set to '1'
0x01	Message FF00 Enabled
0x02	Message FF01 Enabled
0x04	Message FF02 Enabled
0x08	Message FF03 Enabled
0x10	Message FF04 Enabled
0x20	Message FF05 Enabled
0x40	Message FF06 Enabled
0x80	Message FF07 Enabled Not available prior to version 4.5.0

Example

Enable Messages FF00 and FF05 only

```
                    FC  MT  ADD DATA...
Command:    10EF8090 46  04  11  21
Response:   1CEF9080 46  00  (00=Success)
```

Timer Configuration

These timers are 10 millisecond software timers that control status message timing as well as CAN Bus message timeouts. If the "Value" is set to 255 (0xFF), the timeout will be 2.55 seconds until the next power cycle then the value reverts back to the factory default value.

Timer : There are 20 timers

Value : Is the time in 10 milliseconds units. The range is 5-255 or .05 to 2.55 seconds.

Address	Timer	Description	Default Value
0x0412	0	FF00 Status Repeat Rate	10
0x0413	1	FF01 Status Repeat Rate	100
0x0414	2	FF02 Status Repeat Rate	50
0x0415	3	FF03 Status Repeat Rate	100
0x0416	4	FF04 Status Repeat Rate	10
0x0417	5	FF05 Status Repeat Rate	25
0x0418	6	FF06 Status Repeat Rate	25
0x0419	7	Reserved	100
0x041A	8	Reserved	100
0x041B	9	Reserved	100
0x041C	10	Reserved	100
0x041D	11	Restricted	N/A
0x041E	12	Restricted	N/A
0x041F	13	Restricted	N/A
0x0420	14	Digital Throttle Silence Timeout Motor #1	50
0x0421	15	CAN Bus Message Silence timeout	100
0x0422	16	Reserved	100
0x0423	17	Digital Throttle Silence Timeout Motor #2	100
0x0424	18	Reserved	100
0x0425	19	Reserved	100

Example

Change Status Message FF03 repeat rate to 400 milliseconds

```
                    FC  MT  ADD DATA...
Command:    10EF8090 46  04  15  28  (0x28=40 decimal)
Response:   1CEF9080 46  00  (00=Success)
```

Change Digital Throttle Silence Timeout Motor #1 to 250 milliseconds

```
                    FC  MT  ADD DATA...
Command:    10EF8090 46  04  20  19  (0x19=25 decimal)
Response:   1CEF9080 46  00  (00=Success)
```

Reset Status Message FF00 to the factory default value

```
Write 0xFF to timer 0
Command:      10EF8090 46  04  12  FF
Response:     1CEF9080 46  00  (00=Success)
```

```
FF00 status is sent every 2.55 seconds.
Read Timer 0:
Command:      10EF8090 45  04  12  1
Response:     1CEF9080 45  FF
Cycle the power
Read Timer 0:
Command:      10EF8090 45  04  12  1
Response:     1CEF9080 45  0A  (0x0A=10 decimal)
FF00 status is sent every .1 seconds.
```

Custom Status Configuration

This applies to version 4.5.0 or later or DSP controllers.

All of the FF02 and FF07 status message bytes can be configured to read any memory location. The read can be done continuously or once after power up. If you want to read a software version the one time read is recommended. For live status you should use continuous reads. However for every continuous read added the time required to update all of the status data will increase by 10 milliseconds. This could create enough of a delay to make real time control harder.

Each custom status byte is comprised of the memory type or 'Command' 0-5 and the address 0x00-0xFF. To make a read one time only set Bit 3 of the command byte.

Status Byte	Command Storage	Address Storage
FF02: Byte 0	0x042B	0x042C
FF02: Byte 1	0x042D	0x042E
FF02: Byte 2	0x042F	0x0430
FF02: Byte 3	0x0431	0x0432
FF02: Byte 4	0x0433	0x0434
FF02: Byte 5	0x0435	0x0436
FF02: Byte 6	0x0437	0x0438
FF02: Byte 7	0x0439	0x043A
FF07: Byte 0	0x043B	0x043C
FF07: Byte 1	0x043D	0x043E
FF07: Byte 2	0x043F	0x0440
FF07: Byte 3	0x0441	0x0442
FF07: Byte 4	0x0443	0x0444
FF07: Byte 5	0x0445	0x0446
FF07: Byte 6	0x0447	0x0448
FF07: Byte 7	0x0449	0x044A

Example #1

Make first 3 bytes of the FF02 status message show the motor code version from Low RAM addresses 0x0A-0x0C with a one time read.

```
                    FC  MT  ADD DATA...
Command:    10EF8090 46  04  2B  08  (Command: Read Low RAM one time)
Response:   1CEF9080 46  00  (00=Success)
Command:    10EF8090 46  04  2C  0A  (Address: Read address 0x0A "Major Version")
Response:   1CEF9080 46  00  (00=Success)
Command:    10EF8090 46  04  2D  08  (Command: Read Low RAM one time)
Response:   1CEF9080 46  00  (00=Success)
Command:    10EF8090 46  04  2E  0B  (Address: Read address 0x0B "Minor Version")
Response:   1CEF9080 46  00  (00=Success)
Command:    10EF8090 46  04  2F  08  (Command: Read Low RAM one time)
Response:   1CEF9080 46  00  (00=Success)
Command:    10EF8090 46  04  30  0C  (Address: Read address 0x0C "Patch Version")
Response:   1CEF9080 46  00  (00=Success)
```

After a power cycle the FF02 status for version 1.7.8 would look like

10FF0280 01 07 08 00 00 00 00 00

Example #2

Make last 2 bytes of the FF07 status message show the digital pot and digital buttons values from the motor Low RAM 0x7A-0x7B with a continuous read. This can be used to verify that a '0x50' command is being sent properly (See Digital Throttle).

```
                    FC  MT  ADD DATA...
Command:    10EF8090 46  04  47  00  (Command: Continous read of Low RAM)
Response:   1CEF9080 46  00  (00=Success)
Command:    10EF8090 46  04  48  7A  (Address: Read address 0x7A Digital Pot)
Response:   1CEF9080 46  00  (00=Success)
Command:    10EF8090 46  04  49  00  (Command: Continous read of Low RAM)
Response:   1CEF9080 46  00  (00=Success)
Command:    10EF8090 46  04  4A  7B  (Address: Read address 0x7B Buttons)
Response:   1CEF9080 46  00  (00=Success)
```

Immediately the FF07 status might look like

10FF0780 00 00 00 00 00 00 40 DF Assuming that Digital Pot = 0x40 = 64 = 25% PWM Digital Buttons = 0xDF (Reverse bit (5) is active low)

7. Troubleshooting

7.1 Overview

In this section, common operating problems are listed, with troubleshooting steps. Still having trouble? Contact Us

7.1.1 Motor Won't Move

- Verify correct wiring
- Verify that throttle input is at an appropriate level
- Check for fault codes (depending on model, may be indicated by a flashing LED or reported by diagnostic software).
- Check for Stop Diagnostics reported by CAN Bus 10FF03 status message. Also see System Status Message and Special Diagnostic Commands.

7.2 Diagnostic Monitoring

The controller performs both start-up and continuous monitoring of various conditions. A condition that is outside a normal range may cause the controller to automatically take mitigating action (e.g. cut back output power) or trigger a fault.

For clarity, the term condition refers to a specific status indication. A low battery voltage is an example of a condition. The term fault refers to a condition that causes the controller to inhibit motion, and requires a keyswitch cycle to clear.

So, for example, a throttle deadband check can result in a condition that inhibits motion, but it is not a fault. When the deadband condition clears (throttle moved back to neutral) the condition clears and motion is allowed.

7.2.1 Conditions

The following conditions are monitored and reported as status. Conditions are not exclusive (more than one abnormal condition can be reported at a time)

Controller Temperature

An onboard sensor measures the temperature of the controller near the drive electronics. As the temperature rises near the limit, the controller will indicate a high temperature condition and automatically reduce power. When the temperature decreases, output power will be restored and the high temperature indication will clear. See Controller Temperature Limit for more information.

Motor Temperature

> **Applies to**
>
> Version 1.7.2 and higher

When wired to a temperature sensor in the motor, the controller's ANALOG IN input monitors the sensor. There are two temperature thresholds. The first one causes the motor current to be reduced when the threshold is exceeded. The second (higher) limit will cause the motor to stop, report a fault, and require a key switch cycle before the motor will run again. See Motor Temperature Limiting for more information.

Under Voltage

The controller monitors the input voltage and compares it to two values: a threshold for displaying a low battery indication (Undervoltage), and a second threshold (Severe Undervoltage) that reduces the output power in order to extend battery life and potentially allow the vehicle to return to a charging point before stopping completely. When the voltage drops below the severe undervoltage threshold by a few volts, the controller switches off. Cycling keyswitch will turn the unit back on if the system voltage has increased above the severe undervoltage limit.

To troubleshoot an under-voltage condition, check for

- Depleted batteries
- Correct wiring between the battery and motor controller
- Correct configuration of the low-voltage limit.

Over Voltage

The system High Voltage Limit is configurable. If the system voltage increases toward this limit, the controller will report an overvoltage condition and will begin to limit the output power. When the over-voltage condition clears, power will be restored. A common situation that can lead to an overvoltage condition is heavy regenerative braking with a fully charged battery.

If the voltage continues to rise above the high-voltage limit, the controller will stop to protect the hardware from damage. The controller will resume operation when the over-voltage condition clears and (if Deadband Check is enabled) the throttle returns to a neutral position.

Current Limiting

If the output current to the motor exceeds the preset limit, the controller limits its output to prevent damage to the system.

Throttle Deadband Check

If configured to do so, the controller will not allow movement after power on, until the throttle has been detected to be in the neutral position. This is intended to prevent unexpected movement when the controller is switched on, and the throttle is not in neutral. Moving the throttle to the neutral position will clear the condition.

Other things to check:
- Correct configuration of the Throttle Deadband
- Correct configuration of the Throttle Neutral
- Correct configuration of the No Deadband Start setting.

Quickstop Active

The Quickstop input allows the external system to inhibit motion. The Quickstop signal is configurable; for example, whether it is active high or low, how quickly the motor decelerates when the condition occurs, and whether the keyswitch must be cycled in order to restore motion. See Register 0x0318 and Register 0x0353 for more configuration information.

Typically this condition means that a safety sensing device such as a seat switch, proximity sensor, emergency stop button has been activated. Check for
- A device connected to the Quickstop input indicating a stop condition
- Loose or broken connection to the Quickstop input
- Incorrect configuration of the Quickstop input

Motor Stall

A stall condition was detected using the motor position sensors. Check for

- Obstacles preventing movement
- Correct wiring to the motor and motor sensors.
- Correct configuration of the motor sensor(s)

The controller will continue to provide power to the motor during a stall condition.

CAN Bus Communication

If CAN Bus equipped, and CAN Bus is being used to provide control inputs, a loss of CAN Bus communication (too many missed messages or bus off condition) will cause the controller to inhibit motion. Re-establishing the CAN Bus connection will restore operation. Note: if the Deadband Check feature is enabled, the throttle must first be moved to the neutral position before motion is allowed.

7.2.2 Motor State

The controller provides a motor state output byte that is useful for monitoring the drive state of the controller. Its value is one of the following. See System Status Message for more information.

State	Condition	Description
0	Powering Up/Down	A temporary state while the controller completes its power-up or power-down processing
1	Idle	The controller is ready but is not driving the motor
2	Idle Hold	The controller is ready but is not driving the motor, and is in a regenerative braking mode that resists motion.
3	Push Mode	The controller is running in push mode. The motor was turned by external forces which generated voltage enough to power on the module.
8	Overvoltage Protect	The controller is limiting output power due to a high input voltage condition
9	Diagnostic Fault	Motion is inhibited due to a fault condition
10	Operating Fault Decel	The motor is stopping due to an abnormal condition
11	Operating Fault Zero PWM	The motor is stopped due to an abnormal condition
16	Reverse Idle	The controller is ready to drive in reverse. The throttle is in a neutral position
17	Forward Idle	The controller is ready to drive forward. The throttle is in a neutral position
20	Reverse Limited	The controller is driving reverse, but a power-limiting condition is active. Refer to PWM Diagnostics for details.
21	Forward Limited	The controller is driving forward, but a power-limiting condition is active. Refer to PWM Diagnostics for details.
24	Reverse	The controller is driving in Reverse
25	Forward	The controller is driving in Forward

7.2.3 System State

The controller provides a status output that signals conditions in an abnormal range. It is possible for multiple conditions to be reported as out-of-range at the same time. See System Status Message for more information.

Bit Mask	Condition	Description
0x01	Overtemperature	The on-board sensor is indicating a temperature approaching the limit
0x02	Stall	The controller has detected that the motor is not moving (stalled). This condition applies to BLDC motor types.
0x04	Undervoltage	The controller has detected that the input voltage is near or below the undervoltage threshold.
0x08	Overvoltage	The controller has detected that the input voltage is near or above the high voltage threshold.
0x10	Sensor_Fault	Set when invalid motor sensor pattern detected
0x20	Over Volt Protect	Set when High Volt Protect active
0x40	Holdoff 1.8.2+/ Throttle Fail	Holdoff (motor control is held idle. Could be a failure condition or charger detected but not active). Throttle Fail is set when throttle has entered fail band. This feature was removed in 1.8.2.
0x80	Quickstop Active	Set when quick stop active

7.2.4 PWM Diagnostics

The controller provides a status message that contains information about what could be causing no PWM or limited PWM to occur. Multiple bits can be set. See System Status Message for more information.

Bit Mask	Condition	Description
0x01	Accel Drive	PWM is set to zero due to acceleration drive
0x02	Hard Stop / Current Limited	Prior to 1.7.8 PWM is set to zero due to hard stop 1.7.8 and above this means current limit is not cur_ub
0x04	Limited	PWM is being limited by unspecified source
0x08	Max PWM	PWM is being limited by max_pwm setting
0x10	Low Battery	PWM limiting w/in range of Low Battery Voltage
0x20	High Voltage	PWM limiting w/in range of High Battery Voltage
0x40	High Temperature	PWM limiting w/in range of High FET Temperature
0x80	High Motor Temperature	PWM limiting w/in range of High Motor Temperature

7.2.5 Stop Diagnostics

The controller provides a status message that contains information about what caused the motor to stop. This is an enumerated value. Bits 0-3 contain the value. See System Status Message for more information.

Value	Condition	Description
0	No stop condition	No stop has been activated
1	Drive time exceeded	Drive Timer Exceeded
2	Forward/Reverse inhibits active	Contact detected with object
3	Digital stop active	Stopped receiving CAN Bus Digital Throttle commands
4	Qstop pin active	Emergency stop signal activated
5	Seat stop active	Seat switch shows seat not occupied
6	Charging active	Battery is being charged
7	Deadband start fault	Throttle was not in deadband when powering on
8	Key off active	Key switch is turned off. Unit may shut off
9	Throttle failure active	Throttle exceeded Failband limits
10	Sensor failure active	Hall sensor disconnected/malfunction
11	ANALOG IN stop active	External temperature limit exceeded
12	Waiting for deadband start	Throttle is not in deadband
13	Locked	Special CAN Bus feature that requires 0 throttle before running
14	No Drive / Internal Failure	Diagnostic failure
15	Latched Failure	Fault occurred, key switch is required to clear fault
16	Current Limit Exceeded	Current limit exceeded. See Motor Current Limiting

7.2.6 Miscellaneous Diagnostics

The controller provides a status message that contains miscellaneous information about what could be causing certain faults or conditions. See System Status Message for more information.

Bit Mask	Condition	Description
0x01	Reserved	
0x02	Reserved	
0x04	Reserved	
0x08	Reserved	
0x10	Reserved	
0x20	Sensor Error	Hall Effect Sensor error active
0x40	ANALOG IN Limit	Motor temperature is above software limit. Throttle input range is being affected.
0x80	Seat Stop Active	Seat Stop request active

7.2.7 Special Diagnostic Commands

Special diagnostic information on motor faults can be found by reading special RAM registers.

Register	Function	Description
0106	Diagostic Warnings	0x00 No Warnings 0x81 EEPROM Revision Error 0x82 Calibration Error
0107	FET Test	Test for motor opens and shorts 0x00 No faults 0x18 - 0x1F Faults during "No FET" test 0x38 - 0x3F Faults during "One FET" test 0x48 - 0x4B Faults during "FET Pairs" test 0x4C - 0x4F Open Motor Faults

7.2.8 Charge Mode

The charge mode status byte indicates the status of the connected battery charger (applies to compatible chargers only). If the value is 0, the controller is not in charging mode.

Value	Description
0x01	Pre-Charge
0x02	Bulk Charge
0x04	Balancing
0x08	Float
0x80	Just changed from charge mode to drive mode. Key cycle or power cycle is required to clear this.

7.2.9 Diagnostic Reports

There are several diagnostic records stored inside the controller's EEPROM. Here is a list of information available.

Note: If EEPROM Register 0302 Bit 2 is set, the address of the counters is OR'ed with 0x0080. For example the reset cause will be at 03E9 instead of 0369.

EEPROM Address	Description	Details
0301	Fault Log Pointer	EEPROM address of most recent fault in fault log
0370-037F	Fault Log	Circular buffer of last 16 fault codes
0360 or 03E0	Motor Runtime Counters (LSB)	LSB of total run time in .065536 second units
0361/03E1	Motor Runtime Counters (MSB)	MSB of total run time in .065536 second units
0362/03E2	Motor Runtime Hours (LSB)	LSB of total run time in hours
0363/03E3	Motor Runtime Hours (MSB)	MSB of total run time in hours
0364/03E4	Charge Float Errors	LSB of charge float errors
0365/03E5	Low Battery Runtime	LSB of low battery operation
0367/03E7	Over Temperature Fault Counter	Count of OT fault count (Max = 255)
0368/03E8	Throttle Fault Counter	Count of throttle fault count (Max = 255)
0369/03E9	Reset Cause	Cause of last microprocessor reset Bit 0 = Timed shutdown Bit 1 = Charge Finished Bit 2 = Key Switch

7.2.10 Identification

See Identity.

Item	Description
Serial #	The controller’s factory-assigned serial number.
Motor SW Version	Indicates the version of software (major.minor.patch) contained in the motor control microprocessor
Comm SW Version	Indicates the version of software (major.minor.patch) contained in the CAN Bus microprocessor (for CAN Bus-equipped and non DSP controllers)

7.3 Faults

A fault may occur when an abnormal diagnostic condition is detected. In almost all cases, a fault inhibits motion, and requires a keyswitch off/on cycle to clear.

Depending on the Controller model, fault codes may be reported using

- A flashing LED on the controller (cover must be removed). The controller blinks the first digit of the fault, followed by a short pause, then blinks the second digit.
- Via diagnostic software like the Phoenix App. See Using the App.
- Using an HHP (Hand Held Programmmer CS1171).
- As a CAN Bus fault status message.

Fault codes are 2 digit hexadecimal codes. Note that some fault codes may not be applicable to all models.

A non-volatile fault log is maintained by the controller. This log contains the most recent faults experienced by the controller.

7.3.1 Fault Codes

Code	Meaning	Result	Comments
0x00	No Fault		Controller is operating normally
0x08	Battery Voltage out of range	Motion Inhibited	Battery voltage is too low or too high. Check the battery voltage and connections. After the condition is corrected, cycle the keyswitch to clear the fault.
0x09	Voltage Shutdown	Motion Inhibited	Battery voltage is too low to keep unit powered. Unit will shut off in 60 seconds. Check the battery voltage and connections. After the condition is corrected, cycle the keyswitch to clear the fault.
0x11	Brake Short	Motion Inhibited	Check for - A loose or broken connection between brake and motor controller - Faulty brake. After the condition is corrected, cycle the keyswitch to clear the fault.
0x12	Brake Open	Motion Inhibited	Check for -Brake is missing when one is expected - Brake shorted to case -A loose or broken connection between brake and motor controller After the condition is corrected, cycle the keyswitch to reset the fault.
0x13	Quickstop/Drive Inhibit	Motion Inhibited	A safety sensing device such as a seat switch, proximity sensor, emergency stop button has been activated and Quickstop is configured to generate a fault. Check for - A device connected to the Quickstop input indicating a stop condition - Loose or broken connection to the Quickstop input - Incorrect configuration of the Quickstop input After the condition is corrected, cycle the keyswitch to reset the fault.
0x14	Deadband Inhibit	Motion Inhibited	If configured to do so (Fault Deadband Start), this fault will be declared when the controller is switched on and the throttle is not in the neutral position. To clear the fault, return the throttle to neutral and cycle keyswitch.
0x15	Brake Release Fault	Motion Inhibited	This fault occurs when the brake is being manually released through CAN Bus commands and the throttle is not in deadband.
0x21	Motor Short	Motion Inhibited	Check for -Faulty motor -Loose/broken connection to motor on large motor leads. After the condition is corrected, cycle the keyswitch to clear the fault.
0x22	Motor Open	Motion Inhibited	Check for -Faulty motor -Loose/broken connection to motor on large motor leads. After the condition is corrected, cycle the keyswitch to clear the fault.
0x23	Power Relay Short	Motion Inhibited	Depending on application, the Power Relay may be onboard the Motor Controller, or an exteral contactor controlled by the motor controller. This fault indicates that the power relay is not

Code	Meaning	Result	Comments
			operating properly. Check for -Faulty Power Relay -Faulty connection to external Power Relay. After the condition is corrected, cycle the keyswitch to clear the fault.
0x24	PSL Motor Short	Motion Inhibited	Loose/broken connection to Power Seat Lift motor
0x28	Motor Sensor Fault	Motion Inhibited	An invalid condition was detected for the motor position sensors. Check for - Correct wiring to the motor and motor sensors. - Correct configuration of the motor sensor(s) After the condition is corrected, cycle the keyswitch to clear the fault. Check the motor sensor and the wiring connections - Replace or reconnect the motor temperature sensor After the condition is corrected, cycle the keyswitch to clear the fault.
0x29	External Temperature Sensor	Motion Inhibited	A problem was detected with the external temperature sensor.
0x2A	High Voltage Protect Error	Motion Inhibited	High voltage was detected on the motor outputs. Check for disconnected power cables. - Reconnect cables. After the condition is corrected, returning the throttle to neutral will clear the fault.
0x31	FET Over Temperature	Power cutback or Motion Inhibited	The FET (Field Effect Transistor) temperature sensor on-board has indicated a temperature above the allowable limit. Check for -Operating in extreme environment, -excessive load, -faulty or disconnected brake engaged while driving. Allowing controller to cool will restore full power and/or allow motion. This fault is sticky, meaning that once it occurs, it will persist until the keyswitch is cycled.
0x32	Motor Over Temperature	Power cutback or Motion Inhibited	The temperature sensor on the motor has indicated a temperature above the allowable limit. Check for -Operating in extreme environment, -excessive load, -faulty or disconnected brake engaged while driving. Allowing the motor to cool will restore full power and/or allow motion
0x41	Over Voltage Condition During Charge	Motion Inhibited	The battery voltage is too high during charge charge cycle
0x42	Charge Mode Time Out	Motion Inhibited	The charge cycle did not complete within the expected time.
0x43	Charger Over Temperature Condition	Motion Inhibited	The charger overheated during the charge cycle
0x51	Low FET Error	Motion Inhibited	Power up test on high side FET detected a problem. -Check battery voltage -Check motor wiring

Code	Meaning	Result	Comments
			After the condition is corrected, cycle the keyswitch to clear the fault.
0x52	High FET Error	Motion Inhibited	Power up test on low side FET detected a problem. -Check battery voltage -Check motor wiring After the condition is corrected, cycle the keyswitch to clear the fault.
0x53	Throttle Failband	Motion Inhibited	Check for -shorted or off-center throttle input Correct configuration of Throttle Failband
0x54	Throttle 2 Failband	Motion Inhibited	Check for -shorted or off-center throttle input Correct configuration of Throttle Failband
0x71	Controller Temperature Error	Motion Inhibited	The on-board temperature sensor is indicating an out of range condition. Check for -Operating in extreme environment, -excessive load, -faulty or disconnected brake engaged while driving. Allowing controller to cool will may restore full power and/or allow motion. If the problem persists the controller PCB may be damaged.
Other	Internal Failure	Motion Inhibited	Motor Controller problem detected. Replace controller

8. Contact Us

Customer Service is a top priority at Control Solutions. We are committed to being a leader in our industries, while providing our customers with superior quality, value, and service. We are here to help you find answers to your questions.

For warranty information please refer to the website

If you have any questions, experience technical problems, or need any parts or service, contact Control Solutions LLC Customer Service during normal business hours (Monday-Friday, 8:00 a.m. – 5:00 p.m. Central Time) at (630) 806-7062.