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CURTIS

# Manual

# Model **1212BL**

## Brushless Permanent Magnet Controller for Lightweight Class III Walkies

**» Software Device Profile: 2.0.0.0 «**

**Curtis Instruments, Inc.**
200 Kisco Avenue
Mt. Kisco, NY 10549
www.curtisinstruments.com

Read Instructions Carefully!

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# 1 — OVERVIEW

The Curtis Model 1212BL motor speed controllers provide efficient, optimal control of brushless DC motors for battery powered vehicles. The 1212BL is optimized for use on light duty Class III pallet trucks and sweeper scrubber floor care machines. Highly flexible programmability allows 1212BL controllers to be used in low power BLDC motor applications.

**Figure 1-1**
*Curtis 1212BL Controller*

# KEY FEATURES

The following sections describe the 1212BL controller's features.

## Fit for Purpose

- Compact, rugged housing with a small footprint for its power rating.
- Heavy-duty M4 busbars for motor and battery connectors.
- Impervious to most oils, solvents, degreasers and other chemicals often encountered by industrial vehicles.
- Tyco Mini-Universal Mate-N-Lok connectors, with ability to add a sealed mating connector.
- Internal main relay embedded into the 1212BL.
- Supports various industry standard motor temperature sensors.

## Smooth and Secure Control

- Advanced speed regulation maintains precise speed over varied terrain, obstacles, curbs and ramps.
- Boost Current feature enhances performance with transient loads, such as starting on a hill and climbing obstacles.
- Linear cutback of current ensures smooth control with no sudden loss of power during undervoltage or overtemperature.
- Emergency reverse inputs.
- Dynamic throttle fault detection (open/short wiring fault detection).
- Adjustable EM-brake holding voltage reduces heating of the brake coil.
- Hydraulic lift lockout functionality to protect the vehicle's batteries from damaging level of discharge.
- Charger inhibit input.
- Inputs are protected against shorts to B+ and B-.
- Short-circuit protected outputs.

## Flexible I/O

I/O can be configured to provide up to:

- Four digital inputs.
- Two analog inputs
- One potentiometer input
- Supports 120° Hall position sensors
- Two 1.5A coil drivers for pump contactor and lower valve
- One 3.0A coil driver for electromagnetic brake
- One motor temperature sensor input
- +5V and +12V external power supplies

### Comprehensive CANopen Capabilities

- Plug and Play support for Curtis CAN displays and a variety of CAN tiller heads.
- Dedicated CAN mailbox for third-party battery monitoring system (BMS) for lithium-ion battery systems.
- Fully compliant with CANopen protocol CiA 301.

### Powerful, High Performance Dual Microprocessors

- Dual-micro architecture achieves up to PL=d, category 2 functional safety under EN ISO 13849-1 and EN 1175:2020.
- Ultra-fast processor speeds allow highly accurate control and regulation of voltage and current.

### CAN Programming

- Model 1212BL is programmable over the CANbus. This allows vehicle level communication with many of the CAN-based service tools used by the major industrial truck manufacturers worldwide.
- Allows use of the Curtis Integrated Toolkit™ (CIT) development suite.

### Superior Diagnostics

- Integrated, high visibility status LED with simplified flash code sequence for at-a-glance system troubleshooting.
- Thermal cutback, warning, and automatic shutdown provide protection to the motor and controller.
- Error logging, fault history tables and CAN emergency messages.

### Complies with Relevant US and International Regulations

For details on regulatory compliance, see the Specifications.

**Note**: Regulatory compliance of the complete vehicle system with the controller installed is the responsibility of the vehicle OEM.

## TECHNICAL SUPPORT

For technical support, contact the Curtis distributor where you obtained your controller or the Curtis sales-support office in your region.

# CONVENTIONS

The following topics describe conventions used in this manual.

## Numeral System Notation

The following table describes how this manual denotes decimal, binary, and hexadecimal numbers.

**Note**: The letter *n* in the format column represents a digit.

| Numeral System | Format | Example |
|---|---|---|
| Decimal | Either of the following:<br>• *nnn*<br>• *nnn*d | • 127<br>• 127d |
| Hexadecimal | Either of the following:<br>• *nnn*h<br>• *0xnnn* | • 62Ah<br>• 0x62A |
| Binary | *nnn*b | 1011b |

In addition, some CANopen examples have hexadecimal values without notation. Those examples are formatted with a monospace font and with the bytes delimited by spaces, as shown in the following example:

```
21 FF 01 11 22 01 00 00
```

## Miscellaneous Conventions

- *RO* means read-only.
- *RW* means read-write.
- *N/A* means not applicable.

# 2 — INSTALLATION, WIRING, AND CONFIGURATION

This chapter explains how to mount and wire the controller. The chapter also describes features and basic configuration for the inputs, outputs, and drivers.

## MOUNTING THE CONTROLLER

To prevent external corrosion and leakage paths, mount the controller in a location that will keep the controller clean and dry. For ease of service, make sure the status LED is visible.

The controller's electronics are sealed to IP65. The environmental protection for the connectors depends upon whether sealed (IP54) or unsealed (IP40) TE Connectivity parts are used.

The following diagram shows the outline and mounting hole dimensions. To mount the controller, use the two mounting holes at the opposing corners of the heatsink.

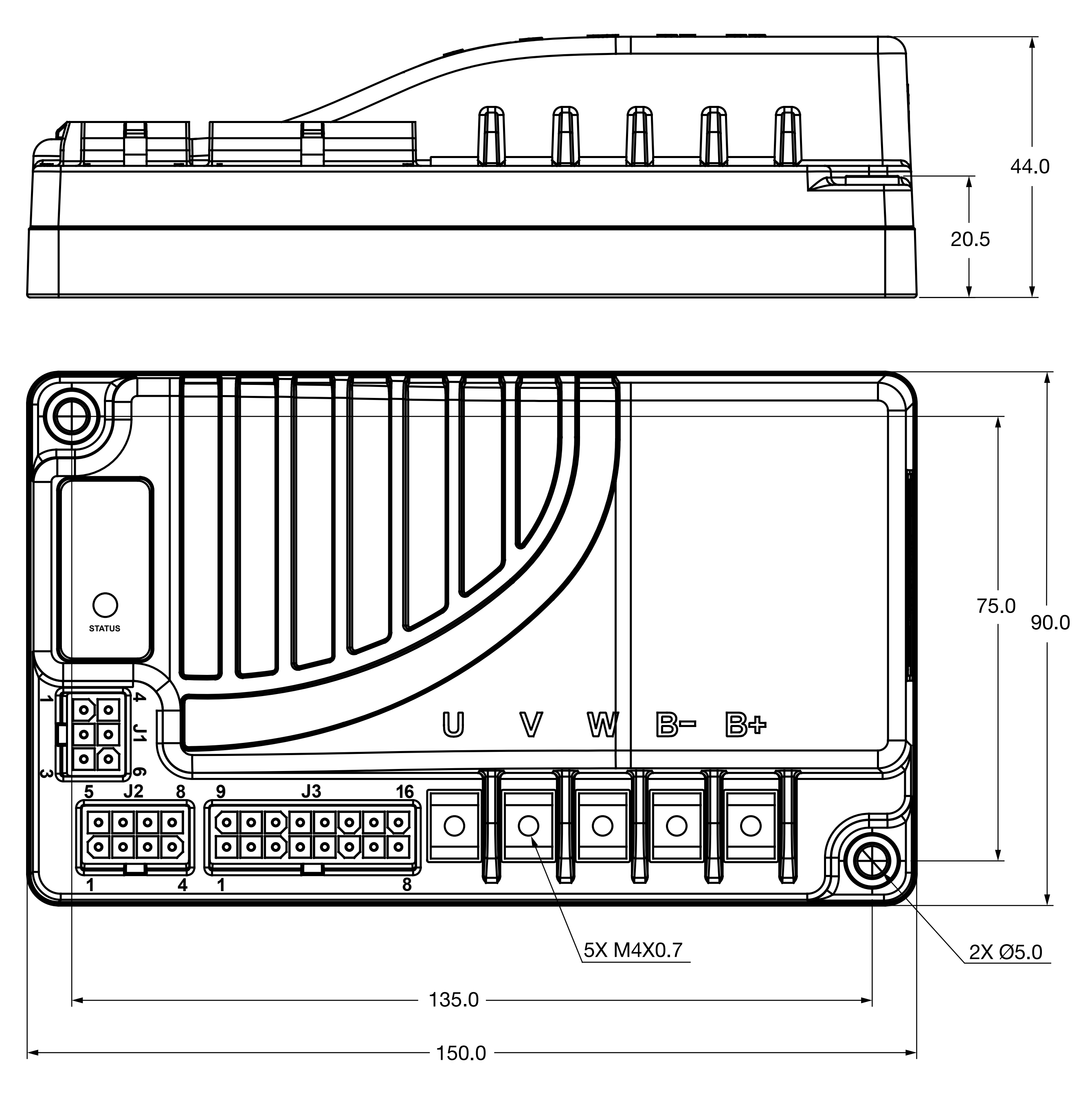



**Figure 2-1**
*Mounting Dimensions*

## WARNINGS

You must heed the following warnings:

**⚠ CAUTION**

**Working on electrical systems is potentially dangerous. Protect yourself against uncontrolled operation, high current arcs, and outgassing from lead-acid batteries:**

**UNCONTROLLED OPERATION —** Some conditions could cause the motor to run out of control. Disconnect the motor or jack up the vehicle and get the drive wheels off the ground before attempting any work on the motor control circuitry.

**HIGH CURRENT ARCS —** Batteries can supply very high power, and arcing can occur if they are short circuited. Always open the battery circuit before working on the motor control circuit. Wear safety glasses and use properly insulated tools to prevent shorts.

**LEAD-ACID BATTERIES —** Charging or discharging generates hydrogen gas, which can build up in and around the batteries. Follow the battery manufacturer's safety recommendations. Wear safety glasses.

You will need to take steps during the design and development of your end product to ensure that its EMC performance complies with applicable regulations. For guidelines, see Appendix A.

The controller contains ESD-sensitive components. Use appropriate precautions in connecting, disconnecting, and handling the controller.

## HIGH CURRENT CONNECTIONS

The controller provides five M4X0.7 terminals for high current connections:

| Terminal | Description |
|---|---|
| B+ | Positive battery input |
| B– | Negative battery input |
| U | Motor phase U |
| V | Motor phase V |
| W | Motor phase W |

For guidelines on connecting the motor's high current wires to the UVW bus bar, see Characterize the Hall Sensors and UVW Output.

## LOW CURRENT CONNECTIONS

The low current connections are provided by three connectors, which are described in the following topics.

### 6-Pin I/O Connector (J1)

The following table describes the pins on the 6-pin connector (J1):

| Pin | Function |
|---|---|
| J1-1 | External +5V power supply |
| J1-2 | Hall A |
| J1-3 | Hall B |
| J1-4 | Hall C |
| J1-5 | I/O ground |
| J1-6 | Motor temperature sensor input |

The connector makes it easy to service vehicles. If the motor needs to be replaced, the technician can just unplug the connector, and does not need an intermediate harness connector or to disturb the other connectors.

The connector can be sealed to IP54 or IP40, depending upon which TE Connectivity parts are used. The following table describes the part numbers:

**Table 2-1 Mating Connector Parts — 6 Pin Connector**

| Part | IP54 Part Number | IP40 Part Number |
|---|---|---|
| Connector | 794895-1, Plug | 172168-1, Plug |
| Contact | 770904-1 | 770904-1 |
| Interface seals | 794772-6 | *N/A* |
| Wire seals | 794758-1 | *N/A* |
| Cavity plug | 794995-1<br>**Note**: Cavity plugs are required for unused pins. | *N/A* |

## 8-Pin I/O Connector (J2)

The following table describes the pins on the 8-pin connector (J2):

| Pin | Function |
|---|---|
| J2-1 | CAN low |
| J2-2 | CAN high |
| J2-3 | Charger inhibit |
| J2-4 | Switch 1/Analog input 1 |
| J2-5 | External +12V power supply |
| J2-6 | I/O ground |
| J2-7 | Horn Driver |
| J2-8 | Switch 2/Analog input 2 |

The connector can be sealed to IP54 or IP40, depending upon which TE Connectivity parts are used. The following table describes the part numbers:

### Table 2-2 Mating Connector Parts — 8-Pin Connector

| Part | IP54 Part Number | IP40 Part Number |
|---|---|---|
| Connector | 794821-1, Plug | 770579-1, Plug |
| Contact | 770904-1 | 770904-1 |
| Interface seals | 794772-8 | *N/A* |
| Wire seals | 794758-1 | *N/A* |
| Cavity plug | 794995-1<br>**Note**: Cavity plugs are required for unused pins. | *N/A* |

## 16-Pin I/O Connector (J3)

The following table describes the pins on the 16-pin connector (J3):

| Pin | Function |
|---|---|
| J3-1 | Emergency reverse normally open (NO) input |
| J3-2 | Switch 3 |
| J3-3 | Pot High |
| J3-4 | Lift inhibit |
| J3-5 | Speed mode |
| J3-6 | Pot wiper |
| J3-7 | Switch 4 |
| J3-8 | B+ |
| J3-9 | Lower driver |
| J3-10 | Lift driver |
| J3-11 | EM Brake– |
| J3-12 | Keyswitch |
| J3-13 | EM Brake+ |
| J3-14 | Forward |
| J3-15 | Interlock |
| J3-16 | Reverse |

The connector can be sealed to IP54 or IP40, depending upon which TE Connectivity parts are used. The following table describes the part numbers:

**Table 2-3 Mating Connector Parts — 16-Pin Connector**

| Part | IP54 Part Number | IP40 Part Number |
|---|---|---|
| Connector | 794824-1, Plug | 770583-1, Plug |
| Contact | 770904-1 | 770904-1 |
| Interface seals | 1-1586362-6 | *N/A* |
| Wire seals | 794758-1 | *N/A* |
| Cavity plug | 794995-1<br>**Note**: Cavity plugs are required for unused pins. | *N/A* |

## WIRING DIAGRAM: STANDARD CONFIGURATION

Figure 2-2 is a representative wiring diagram for Curtis 1212BL models. The diagram is for a Class III Walkie that has operator controls directly wired to the controller.

**Note:** The diagram is designed for typical Class III Walkies and may differ from your application's requirements. However, the controller provides the I/Os and programmable parameters needed to meet the requirements. To discuss how to implement your application, contact your Curtis distributor or support engineer.

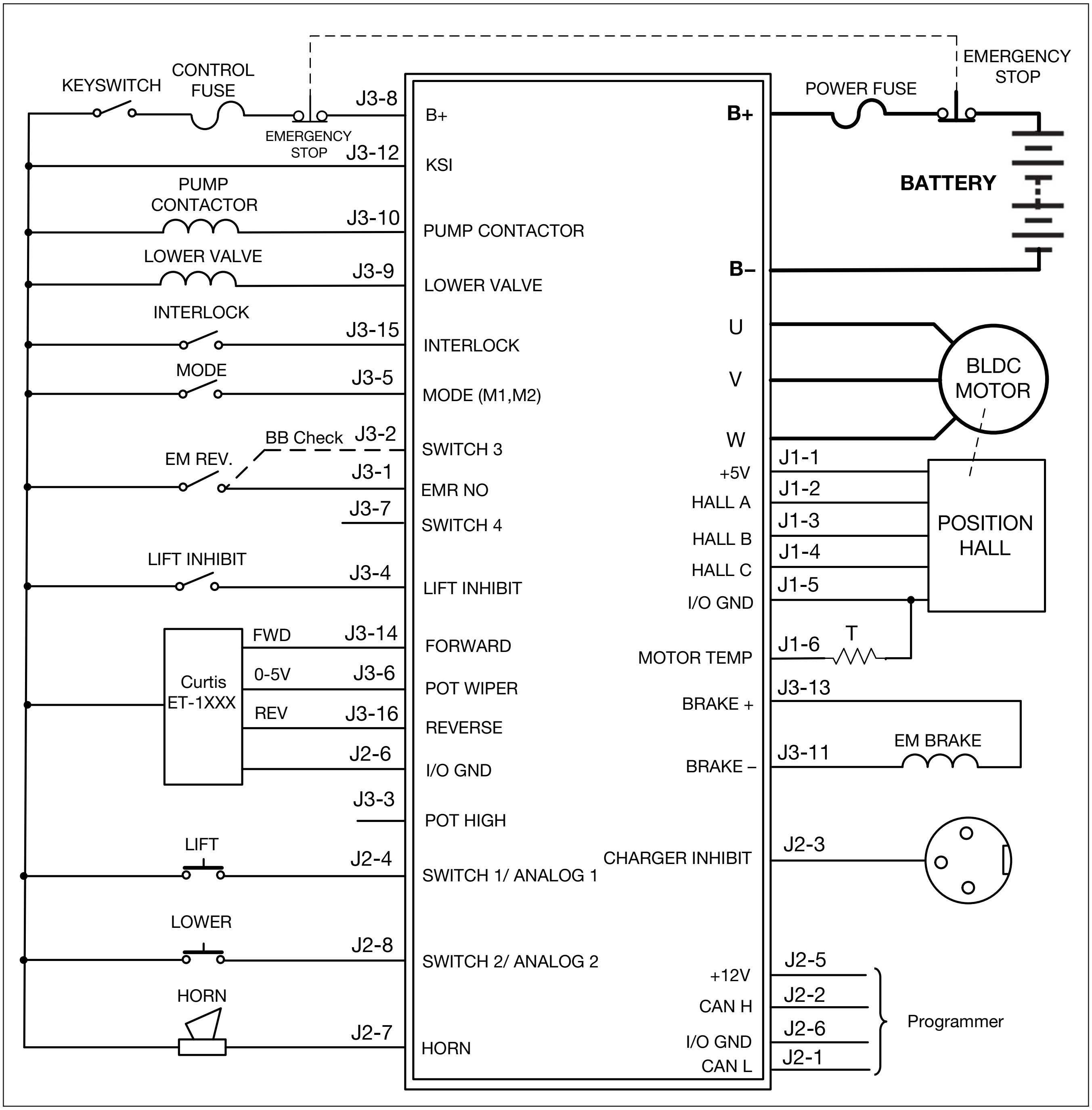



**Figure 2-2**

*Wiring Diagram, Curtis 1212BL Controller*

# INPUTS AND OUTPUTS (I/Os)

The following sections describe specifications and instructions for connecting and configuring I/Os.

Almost all I/Os are protected against shorts to B+ and B–. If an I/O lacks short protection, the I/O's section in this chapter will note it.

**Note:** After you have wired the controller and set the parameters that apply to the vehicle system, perform the steps described in the Commissioning chapter.

## Digital Switch Inputs

The following table describes specifications for the digital inputs:

| Specification | Value |
|---|---|
| Low to High Threshold | Depends upon the input:<br>• Pin J3-1: 15.5V ±5%<br>• All other inputs: 4.0–6.0V |
| High to Low Threshold | Depends upon the input:<br>• Pin J3-1: 15.5V ± 5%<br>• All other inputs: 4.0–6.0V |
| Open Pin Response | High active |
| Maximum Voltage | 72V |
| Maximum Reverse Voltage | –1V |

## Flexible Switch Inputs

The following inputs are *flexible switch inputs*, which can be used for various functions:

| Input | Pin |
|---|---|
| Switch 1/Analog 1 | J2-4 |
| Switch 2/Analog 2 | J2-8 |
| Switch 3 | J3-2 |
| Switch 4 | J3-7 |

All four of the flexible switch inputs can be used for the following functions:

- Lift switch
- Lower valve switch
- Creep switch
- Push switch
- Lift lockout switch
- Horn switch
- Emergency Reverse normally closed (NC) switch
- Steering switch
- Inhibit switch

Each flexible switch input also has an additional function, as described in the following table:

| Input | Function |
|---|---|
| Switch 1 | Analog Input 1 |
| Switch 2 | Analog Input 2 |
| Switch 3 | Belly Button switch |
| Switch 4 | Flex Node ID<br>For more information, see Node IDs. |

Each flexible switch input has a corresponding Switch *n* Function parameter on the Inputs menu, where *n* represents the flexible switch input number. The Switch *n* Function parameters assign functions to the flexible switch inputs.

Take the following steps to configure a flexible switch input:

1. Connect a switch or analog input to a flexible switch input.
2. Select Programming » Inputs, then perform the following steps:

   2.1. Set the Switch *n* Function parameter to the function for which the flexible switch input will be used.

   For example, if you are using flexible switch input 2 as the lower valve switch, set the Switch 2 Function parameter to Lower Switch.

   **Note:** A function can only be assigned to one input. If a function is assigned to multiple inputs, a Parameter Fault (type 4) occurs.

   2.2. Set the parameter that corresponds to the function. The following table describes the functions, parameters, and values:

| Function | Parameter | Value |
|---|---|---|
| Analog 1 | Analog 1 High Threshold | The voltage that indicates the input's high level. |
| Analog 2 | Analog 2 High Threshold | The voltage that indicates the input's high level. |
| Belly button | Switch 3 Function | BB Check Switch |

| Function | Parameter | Value |
|---|---|---|
| Creep | Creep Input Source | Creep Switch |
| EMR NC | Any of the Switch *n* Function parameters. | EMR NC Switch |
| Flex Node ID | Switch 4 Function | Flex Node ID |
| Horn | Horn Input Source | Horn Switch |
| Inhibit | Inhibit Input Source | Inhibit Switch |
| Lift | Lift Input Source | Lift Switch |
| Lift Lockout | Lift Lockout Input Source | Lift Lockout Switch |
| Lower | Lower Input Source | Lower Switch |
| Push | Push Input Source | Push Switch |
| Steering | Steering Input Type<br>This parameter is on the Steering Speed Limit menu. | Whichever of the following corresponds to the switch connected to the input:<br>• NO Switch Input<br>• NC Switch Input |

2.3. Cycle the keyswitch.

## Analog Inputs

Pins J2-4 and J2-8 are flexible switch inputs that can be used as analog inputs. The following table describes specifications for the analog inputs.

| Specification | Value |
|---|---|
| Measurement Range | 0–10V (2% accuracy) |
| Input Resistance (to B– ground) | > 50kΩ |
| Time Constant | < 1ms |

## Throttle Input

The controller supports the following types of throttles:

- 3-wire pot
- 3-wire wigwag pot
- Voltage source (0–5V)
- Wigwag voltage source (0–5V)
- CAN throttle
- CAN wigwag throttle

The Throttle Type parameter specifies the application's throttle.

The pot wiper and pot high inputs (pins J3-6 and J3-3) are for a potentiometer circuit that provides full pot fault protection against open or shorted wires anywhere in the throttle pot assembly.

**⚠ CAUTION** **The controller provides fault protection against open or shorted wires only for pot throttles. For other throttle types, it is the responsibility of the OEM to provide any fault protection that the vehicle system requires.**

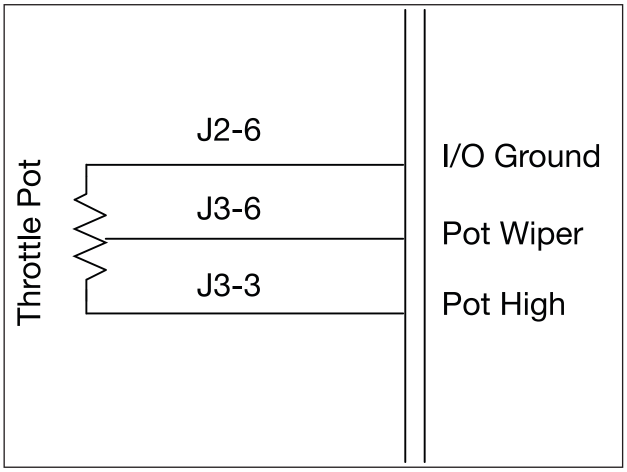
The following table describes the specifications for the pot wiper and pot high inputs:

| Specification | Value |
|---|---|
| Input Range | 0.0–10.0V |
| Input Impedance | > 100KΩ |
| Maximum Voltage | 72V |
| Maximum Reverse Voltage | –1V |

The following topics describe how to connect the various types of throttles.

### 3-Wire Pot Throttles

Connect 3-wire throttles to the pot wiper input, pot high input, and I/O ground as shown in the following diagram:




### Voltage Source Throttles

For 0–5V voltage throttles, connect the output signal to the pot wiper input. The negative side of the voltage source should reference I/O ground.

The Pot High and Pot Low parameters specify the input's voltage range. If the voltage is outside of the range, a Throttle Fault (Type 1) occurs.

### Forward and Reverse Inputs

The driving direction of single ended throttles is specified with the forward and reverse inputs. If the vehicle is equipped with a single-ended throttle, connect the forward switch to pin J3-14 and the reverse switch to pin J3-16. To change the driving direction specified by the inputs without rewiring them, use the Swap Throttle Direction parameter.

**Note:** For wigwag throttles, the direction is forward when the throttle input is above 50%, reverse otherwise.

If the vehicle uses an CAN throttle, the throttle transmits direction to RPDO1.

## Keyswitch

The vehicle should have a keyswitch connected to pins J3-12 and J3-8 (B+) as shown in Figure 2-2. The keyswitch provides power for all low power circuits, including drivers and the precharge function.

The keyswitch can be used as the interlock input by specifying 1 for the Interlock Type parameter.

The following table describes the specifications for the keyswitch input:

| Specification | Value |
|---|---|
| Maximum Input Current | 8A (maximum pin rating) |
| Quiescent Current | 100mA maximum<br>This is at full range battery voltage and does not include current draw from coil loads and external power supplies. |
| Maximum Voltage | 72V |
| Maximum Reverse Voltage | –72V |

## Emergency Stop Switch

To ensure operator safety, it is recommended that the vehicle include an emergency stop switch. The switch, with an auxiliary contact, must be connected to the battery and keyswitch as shown in Figure 2-2.

## Interlock Input

The interlock input signals whether the operator intends to drive the vehicle. The controller allows driving only when the interlock is on.

The interlock input can be either a switch, the keyswitch, or an RPDO1 bit. The Interlock Type parameter specifies which is used.

If the vehicle uses an interlock switch, connect the switch to pin J3-15.

The following considerations apply to the interlock:

- For parameters that configure the interlock input, see Interlock Menu.
- The interlock braking function provides a regenerative motor torque that slows the vehicle when the tiller head is released and the interlock is off.
- If the HPD Enable parameter is set to On, an HPD Sequencing fault occurs if more than 10% throttle is applied before the interlock is on.
- If all of the following conditions occur, an Interlock SRO Fault occurs:
  - The keyswitch is not used as the interlock input.
  - The Interlock SRO Enable parameter is set to On.
  - The interlock signal is On before the keyswitch is turned on.

### Emergency Reverse Inputs

When emergency reverse is activated while the vehicle is driving forward, the controller produces a rapid braking force to stop the vehicle, then slowly drives the vehicle in the opposite direction.

Emergency reverse can be activated by the following inputs:

- A Normally Open (NO) switch connected to pin J3-1.
- A Normally Closed (NC) switch connected to one of the flexible switch inputs.
- Both NO and NC switches used as complementary switches.
  Curtis recommends using complementary switches. When complementary switches are used, the controller continually checks both switches for conditions such as shorts and broken connections.
- CAN messages transmitted by the tiller head and received by the belly button bit of RPDO1. See CAN Tiller Head (RPDO1, TPDO1, TPDO2).

If the vehicle uses an NC switch, the Switch *n* Function parameter that corresponds to the flexible switch input must be set to EMR NC Switch, otherwise a Parameter Fault (type 6) will occur.

The EMR Input Type parameter specifies the emergency reverse input(s), and other Emergency Reverse parameters configure features such as acceleration and deceleration rates and the duration of emergency reverse events. See Emergency Reverse Menu.

### Belly Button Check

The controller provides a belly button check function. The belly button check generates the following fault faults if a broken wire is detected:

- Hardware Fault (type 3)
- Supervision (type 58)

Curtis recommends that the vehicle implement the belly button check. If the vehicle is equipped with an emergency reverse switch, implement the belly button check by taking the following steps:

1. Connect a wire to the Emergency Reverse NO (J3-1) and Switch 3 (J3-2) inputs as shown in Figure 2-2.
2. Set the Switch 3 Function parameter to BB Check Switch.

If the vehicle uses CAN messages for emergency reverse, the belly button check is received by RPDO1.

## EM Brake

If the vehicle uses an electromagnetic (EM) brake, pin J3-11 (Brake–) provides the electromagnetic brake driver. The EM brake should also be connected to pin J3-13 (Brake+) as shown in Figure 2-2.

The following table describes the driver's specifications:

| Specification | Value |
|---|---|
| Active level | Low = On |
| Max Current | 3.0A |
| Frequency | 20 kHz |
| Pulse Width Resolution | 0.5% |
| Maximum Voltage | 72V |
| Maximum Reverse Voltage | –0.5V |
| Open Pin Response | Low/Off (pulled to B–) |
| Logic High Threshold | 7.0V |
| Logic Low Threshold | 4.5V |
| Input Impedance | > 50Ω |

Use the EM Brake Type parameter to specify the vehicle's EM brake type, if any. For information on the EM Brake parameters, see EM Brake Menu.

**Note:** The controller's anti-roll-forward and anti-rollback functions provide safe control when the vehicle starts or stops on hills and ramps. The anti-roll functions are enabled if the EM Brake Type parameter specifies Interlock & Neutral Type.

The driver provides fault diagnostics for shorts and open coils. To configure the controller to generate a Driver Fault (Type 1) for the following conditions, set the Fault Enable parameter to On:

- Missing brake coil
- Shorted brake coil
- Coil driver damage

## Mode Input

Vehicles can include a mode switch that allows operators to choose from the controller's speed modes. One mode can be configured for faster outdoor driving and the other for slower indoor driving.

If the vehicle is equipped with a mode switch, connect the switch to pin J3-5 and set the Mode Input Source parameter to either NO switch or NC Switch.

However, if the vehicle uses CAN to command the speed mode, set Mode Input Source to CAN Switch. (RPDO1 is preconfigured to receive messages that command the speed mode.)

The following list describes the conditions that determine the active speed mode.

- If a mode switch is not connected, mode 1 is active.
- If the mode switch is in the on position, mode 2 is active.
- If the mode switch is in the off position, mode 1 is active.

For information on speed mode parameters, see Speed Menu.

## Charger Inhibit

While the battery is charging, the charger inhibit function engages the electromagnetic brake and disables the lift driver, lower driver and motor. Charger inhibit is activated when pin J2-3 detects that the charger's inhibit pin is low level or when the BMS RPDO receives a message indicating that the battery is charging.

To use charger inhibit with a charger connected to the controller, the charger must have a dedicated inhibit pin (in addition to positive and negative pins). Connect the charger's inhibit pin to pin J2-3 as shown in Figure 2-2.

**Note:** The charger inhibit function automatically powers up the controller without the keyswitch on so that the BDI is tracked during charging. When the BDI reaches 100%, the controller powers down to avoid draining the battery.

## External Power Supply Outputs

The controller provides two output pins for external power supply, as described in the following table:

| External Power Supply Voltage | Pin |
|---|---|
| +5V | J1-1 |
| +12V | J2-5 |

The following table describes the specifications for the external power supply outputs:

| Specification | +5V Supply | +12 Supply |
|---|---|---|
| Nominal Output | 5.5V | 14.5V |
| Output Range | 4.5V~6.0V | 9V~15V |
| Maximum Current | 50mA | 60mA |
| Maximum Voltage | 72V | 72V |
| Maximum Reverse Voltage | –1V | –1V |

## I/O Ground

The following table describes the I/O ground specifications:

| Specification | Value |
| --- | --- |
| Maximum Current | 8A (maximum pin rating) |
| Maximum Voltage | *N/A* |
| Maximum Reverse Voltage | 0V |

The I/O ground pins are not protected against shorts to B+.

## Circuitry Protection Fuses

To protect against accidental shorts, a low current fuse, appropriately sized for the maximum current draw, should be connected in series with the B+ logic supply (pin J3-8). A fuse is also recommended in the high power circuit from the battery to the controller's B+ terminal. This fuse will protect the power system from external shorts and should be sized appropriately for the maximum rated current of the controller.

## Hall Position Sensors

The controller relies upon 120° Hall position sensors to provide the motor rotor position. Connect Hall A, B, and C to pins J1-2, J1-3, and J1-4, respectively.

The sensors are powered by the +5V external power supply.

The following table lists specifications for the Hall sensor inputs.

| Specification | Value |
| --- | --- |
| Input range | 0–15V |
| Max Input Frequency | 20 kHz |
| Low to High Threshold | 2.75V |
| High to Low Threshold | 0.7V |
| Maximum Voltage | 72V |
| Maximum reverse voltage | –1V |

To configure the vehicle system so that the Hall sensors accurately signal the motor rotor position, see Characterize the Hall Sensors and UVW Output.

## Motor Temperature Sensor

Pin J1-6 is for a motor temperature sensor. The controller measures the sensor's resistance, then uses the measured resistance to calculate the motor temperature.

If overheating is detected, the controller applies a limited operating strategy (LOS) to prevent damage caused by overheating. When the motor reaches the threshold specified with the Temperature Hot parameter, the controller linearly cuts back the current from 100% to 0%. Current is cut off (0%) when the motor temperature reaches the Temperature Max threshold.

For information on the parameters that configure the motor temperature sensor function, see Motor Temperature Menu.

The controller supports the following types of motor temperature sensors:

- KTY83-122
- Two KTY83-122 sensors, in series
- KTY84-130 or KTY84-150
- Two KTY84-130 or KTY84-150 sensors, in series
- PT1000
- PT100

The KTY temperature sensors are silicon temperature sensors with a polarity band, which must be connected to I/O Ground.

**Note:** If the predefined sensor types are unsuitable for your application's requirements, a custom sensor type can be used. To discuss, contact your Curtis distributor or the Curtis sales and support office in your region.

The following table describes the motor temperature sensor's specifications.

| Specification | Value |
|---|---|
| Temperature Range | –40°C to +200°C |
| Resistance Measurement Range | 250Ω–5kΩ |
| Analog Filter | 10 kHz |
| Maximum Sensor Current | < 2.5mA |

## Hydraulic Functions

The controller provides lift and lower valve inputs and drivers. The following table describes the drivers' specifications:

| Specification | Value |
|---|---|
| Active level | Low = On |
| Max Current | 1.5A |
| Frequency | 20 kHz |
| Pulse Width Resolution | 0.5% minimum |
| Maximum Voltage | 72V |
| Maximum Reverse Voltage | –0.5V |
| Open Pin Response | Low/Off (pulled to B–) |
| Logic High Threshold | 7.0V |
| Logic Low Threshold | 4.5V |
| Input Impedance | > 100KΩ |

The Pump SRO Enable parameter enables or disables the pump SRO function. If the function is enabled, the controller generates a Pump SRO Fault if the conditions described in the following table occur:

| Condition | Pump SRO Fault Type | Lift PWM Action | Lower PWM Action |
|---|---|---|---|
| The lift switch is active when the controller is powered on. | 1 | Shut down | No action |
| The lower switch is active when the controller is powered on. | 2 | Shut down | Shut down |
| The lift and lower signals are received by CAN, however RPDO1 did not receive a message within five seconds after the controller was powered on. | 3 | Shut down | Shut down |
| The Lift On Interlock parameter specifies On and the lift input is active before the interlock state is On. | 4 | Shut down | No action |
| The Lower On Interlock parameter specifies On and the lower input is active before the interlock state is On. | 5 | Shut down | Shut down |

In addition to the Pump SRO fault conditions, the following table describes other conditions that forbid hydraulic operations:

| Condition | Lift PWM Action | Lower PWM Action |
|---|---|---|
| The lift and lower inputs are both on. | Shut down | Shut down |
| The battery is charging. | Shut down | Shut down |
| The Lift Lockout Input State is On. | Shut down | No action |
| Traction is on and the First On Mode parameter specifies On. | Shut down | Shut down |
| The Lift Inhibit Input State is On. | Shut down | No action |
| The Inhibit Input State is On. | Shut down | Shut down |

The following sections describe the inputs and drivers for the lift and lower functions.

### Lift Driver and Input

Pin J3-10 is for a lift driver. The lift input can be either a switch connected to a flexible switch input or an RPDO1 bit.

The driver provides an option to generate a fault if a shorted or open coil is detected. To enable this option, set the Lift Driver Fault Enable parameter to On.

### Lift Inhibit Input

You can connect a lift inhibit switch to pin J3-4. When the pin is active, the controller disables the lift driver. The Lift Inhibit Input Source parameter specifies whether the switch is normally open (NO) or normally closed (NC).

### Lift Lockout Input

The lift lockout function disables the lift driver when the lift lockout state is On. If lift lockout is activated during a lift operation, the lockout remains active until the lift operation is finished, after which lift operations will be disabled. This protects the battery when its state of charge is low.

You can use the following for the lift lockout input:

- A switch connected to a flexible switch input.
- An RPDO1 bit.
- BDI percentage: The controller activates the lift lockout function when the battery's state of charge drops to a specified BDI level.

**Note:** The input is active at high level.

To have the controller activate lift lockout when the battery's state of charge reaches a specified level, set the following parameters:

- Lift Lockout Input Source = BDI Lockout.
- Lift Lockout Threshold = the BDI percentage that will activate lift lockout.

### Lower Driver and Input

Pin J3-9 is for a lower valve driver. The lower input can be either a switch connected to a flexible switch input or an RPDO1 bit.

The driver provides an option to generate a fault if a shorted or open coil is detected. To enable this option, set the Lower Driver Fault Enable parameter to On.

## Inhibit Input

The inhibit function disables the lift driver, the lower driver, and driving the motor when the inhibit input is active.

The inhibit input can be either a switch connected to a flexible switch input or an RPDO1 bit.

## Steering Speed Limit Input

The steering speed limit function limits the motor speed based on the steering angle. This provides a smoother drive when the vehicle is steering at various angles.

Use the parameters on the Steering Speed Limit menu to configure the speed limits. You can specify speed limits for two steering angles, as shown in Figure 2-3. For example, speed can be limited to 50% of the maximum speed at a 30° steering angle and to 20% at a 60° angle.

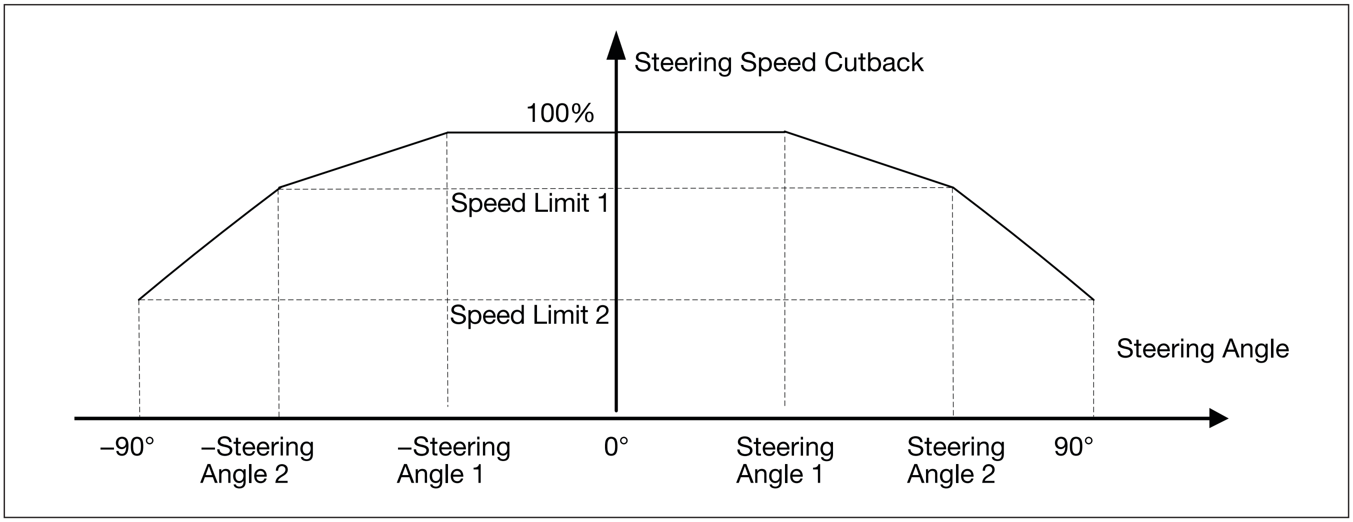



**Figure 2-3**
*Steering Speed Limits*

You can use any of the following for the steering speed limit input:

- A switch connected to a flexible switch input.
- Analog data from a throttle pot wiper.
- An RPDO1 bit.

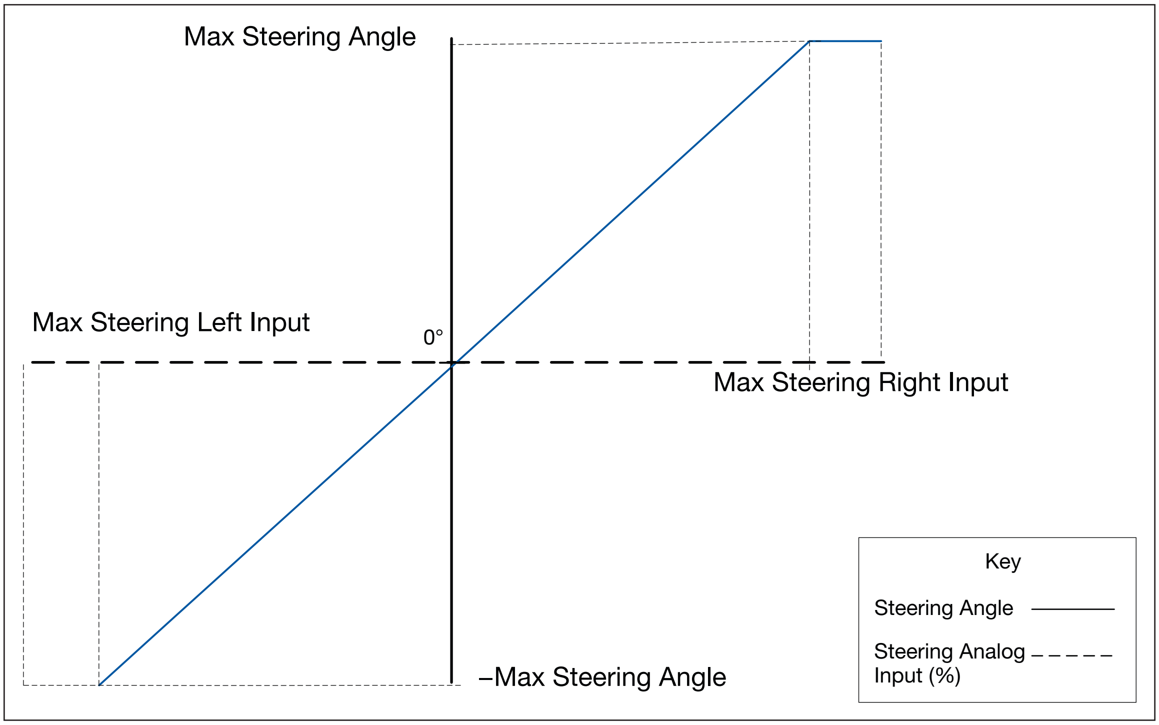
The following topics describe considerations for using a steering switch or analog data.

### Steering Switch

If a switch is used, when the switch state is On the vehicle speed is limited to that specified by the Speed Limit 1 parameter. Connect an NO or NC switch to a flexible switch input.

### Analog Steering Data

When you use analog data, the controller calculates the steering angle using data obtained from the throttle pot wiper. The Max Steering Left Input and Max Steering Right Input parameters define the data's effective range, and the Max Steering Angle parameter defines the maximum steering angle. The Steering Analog Input parameter shows the analog data. The following diagram shows the relationship between these parameters:




**Note:** The Steering Angle parameter indicates the angle calculated by the controller.

The controller will generate a fault if it detects that the steering angle sensor has a broken wire or is shorted.

If the steering speed limit input is an analog input, the throttle must be a CAN or CAN Wigwag throttle. If a different throttle type is specified, a Parameter Fault (type 4) occurs.

To use analog data as the steering speed limit input, take the following steps:

1. Set the Steering Input Type parameter to one of the following values:
   - Resistive throttle = Analog R Input.
   - Voltage throttle = Analog V Input.
2. Cycle the keyswitch.

3. Set the Max Steering Left Input parameter as follows:
    3.1. Turn the steering device to its maximum left angle.
    3.2. Get the Steering Analog Input parameter's value.
    3.3. Set Max Steering Left Input to the Steering Analog Input value.
4. Set the Max Steering Right Input parameter as follows:
    4.1. Turn the steering device to its maximum right angle.
    4.2. Get the Steering Analog Input parameter's value.
    4.3. Set Max Steering Right Input to the Steering Analog Input value.
5. Set the Max Steering Angle parameter to the steering device's maximum steering angle.

## Horn Driver and Input

Pin J2-7 is a horn driver with the following specifications:

| Specification | Value |
|---|---|
| Active Level | Low = On |
| Maximum Current | 30mA |
| Maximum Voltage | 72V |
| Maximum Reverse Voltage | –0.5V |

The horn input can be either a switch connected to a flexible switch input or an RPDO1 bit.

## Creep Mode Input

Creep mode is for situations where the vehicle is operating in a narrow space, such as a container, in which it is difficult to steer the tiller head.

In creep mode, the vehicle is reduced to the speed specified with the Max Creep Speed parameter and interlock braking is activated by the emergency reverse input. Activating creep mode changes the interlock state to On.

The vehicle must be in the following state to activate creep mode:

- The interlock state must be off.
- The emergency reverse state is off.
- The vehicle is still.

The creep input can be either a switch connected to one of the flexible switch inputs or an RPDO1 bit.

The controller generates a Creep SRO Fault if any of the following conditions occur:

| Condition | Fault Type |
|---|---|
| The creep input is on when the controller is powered on. | 1 |
| The creep input is on when the interlock state changes from On to Off. | 2 |
| The interlock input is turned on for more than 40ms while creep mode is active. | 3 |
| After the Interlock Brake Timeout expires, the controller cannot abort the creep mode braking state. | 4 |

## Push Mode Input

When the Push State is On, the controller engages the main relay, releases the EM brake, and allows the motor to be moved freely so that the operator can push the vehicle.

The push input can be either a switch connected to one of the flexible switch inputs or an RPDO1 bit.

To enter push mode, the vehicle must be stationary and the operator must take the following steps in order to protect the push input from being unintentionally toggled:

1. Turn on the push input.
2. Turn off the push input within two seconds.
3. Turn on the push input again within two seconds.

The following considerations apply to push mode:

- If the push input is on before the keyswitch is turned on, the Push State will be Off.
- When the Push State is On, the status LED remains on without flashing.
- After the push input is turned off, the controller aborts push mode when the motor speed is less than the speed specified by the Set Speed Threshold parameter.
- The Push Speed Limit parameter specifies a speed limit for push mode.

### CAN Connections

The controller implements the CANopen protocol. CAN connections use the following pins:

- CAN Low: J2-1
- CAN High: J2-2

CANbus nodes typically are wired using a daisy chain topology with 120Ω terminating resistors at each end. Use twisted-pair wiring to minimize the likelihood of picking up a voltage bias on only one signal. If the controller is the last node in the chain, include an external 120Ω terminating resistor in the wiring harness.

Use the CAN Interface menu to specify properties such as the baud rate, node ID, emergency message rate, and heartbeat rate.

The following table describes the specifications for the CAN pins.

| Specification | Value |
|---|---|
| Baud Rate | Following are the minimum and maximum rates:<br>• Minimum: 100 kb/s<br>• Maximum: 1 MB/s |
| Input Impedance | > 1kΩ and < 1000pF |
| Protected Voltage | –5V ~ +56V |

For information on the controller's CANopen features, see CANopen Communications.

# 3 — APPLICATION-SPECIFIC FEATURES

Some controller features do not have corresponding I/Os. To assist the vehicle designer in the design and development process, this chapter provides information on these features.

## LIMITED SPEED MODE AND SPEED LIMITATION

The *limited speed mode* is the speed mode which has lower values for both the Max Speed and Rev Max Speed parameters. These parameters are on the Mode 1 and Mode 2 menus. For example, if the Max Speed and Rev Max Speed values on the Mode 2 menu are lower than those on the Mode 1 menu, the limited speed mode is mode 2.

**Note:** If the Max Speed and Rev Max Speed parameters have the same values on both menus, the application will not have a limited speed mode. If one mode has a higher Max Speed but a lower Rev Max Speed than the other mode, a Parameter Fault (type 5) occurs.

The following topics describe functions related to limited speed mode.

### Speed Limit HPD

To require the controller to enter the neutral state before aborting the limited speed mode, set the Speed Limit HPD parameter to On. When the speed limit HPD function is enabled and the controller is running in limited speed mode, the following inputs are affected:

| Input | Description |
|---|---|
| Mode | The controller must be in the neutral state before the speed mode can be changed. |
| Inhibit | If the Inhibit input is on when speed limit HPD is enabled, the controller disables traction and hydraulic operations and enters the limited speed mode. The controller aborts limited speed mode when the Inhibit input is turned off and the controller enters the neutral state. |
| Charger Inhibit | If the Charger Inhibit input is on when speed limit HPD is enabled, the controller disables traction and hydraulic operations and enters the limited speed mode. The controller aborts limited speed mode when the Charger Inhibit input is turned off and the controller enters the neutral state. |

### Speed Limit Supervision for Emergency Reverse and Interlock Braking

When the speed limit supervision function is enabled, the speed limit is a specified percentage above the speed at which the vehicle is traveling when emergency reverse or interlock braking is requested.

Speed limit supervision is configured with the parameters on the Speed Limit Supervision menu. The Speed Tolerance parameter specifies the percentage that defines the speed limit. For example, if Speed Tolerance is 20%, speed is limited to 20% above the speed at which the vehicle is traveling when emergency reverse or interlock braking is requested.

# BATTERY PROTECTION AND BDI

The controller provides the following methods for a battery discharge indicator (BDI):

- The controller's internal BDI. See Internal BDI.
- A battery management system (BMS) on the CANbus. See BMS RPDO.
- A device (other than a BMS) on the CANbus. See BDI Percentage Object.

The BDI Source parameter specifies the application's BDI method. For information on the BDI parameters, see BDI Menu.

The following list describes terminology the manual uses when describing the BDI functions:

- **BDI percentage**: Indicates how charged the battery is, based on the range of voltages specified with the Empty Volts Per Cell and Full Volts Per Cell parameters.
- **Cell**: Several of the parameter values are expressed as volts per cell. To calculate a battery's number of cells, divide the battery's nominal voltage by 2. For example, a 36V battery has 18 cells.

The following list describes battery protection functions:

- If the BDI percentage is lower than the Low BDI Threshold parameter, the controller will generate a Low BDI fault and reduce the maximum speed to the speed specified by the Low BDI Max Speed parameter. This protects the battery against severe discharging issues.
- *First on work mode* protects the battery by inhibiting the traction and lift from being active at the same time. The First On Mode parameter enables first-on work mode.
- Lift lockout inhibits lift operations when the Lift Lockout Input State is On. If the Lift Lockout Input Source parameter specifies BDI as the lift lock input, lift operations will be inhibited if the BDI percentage is below the percentage specified with the Lift Lockout Threshold parameter.

## Internal BDI

The internal BDI defines full and empty battery with the Full Volts Per Cell and Empty Volts Per Cell parameters. The BDI percentage is decremented when the battery voltage is below the *moving threshold* for the period of time specified with the Battery Discharge Time parameter. The moving threshold is calculated as follows:

```
BDI percentage * (Full Volts Per Cell – Empty Volts Per Cell)
```

When a charger is connected, the BDI percentage is increased when the battery voltage is above the Start Charge Voltage parameter. The Battery Charge Time parameter specifies the charge period. If the controller is being charged, the sleep function is disabled until the BDI percentage reaches 100%.

The BDI percentage is reset to 100% if both of the following conditions are true within two seconds after the controller was powered on:

- The battery voltage is greater than the Reset Volts Per Cell parameter.
- The BDI percentage is less than the BDI Reset Percent parameter.

## Calibrate the Internal BDI

Take the following steps to calibrate the internal BDI:

Step 1. Set BDI Parameters to Initial Values

Step 2. Set Full Charge Voltage

Step 3. Set Reset Volts Per Cell

Step 4. Set Full Volts Per Cell

Step 5. Set Empty Volts Per Cell

Step 6. Set Battery Discharge Time

Step 7. Set Battery Charge Time and Start Charge Voltage

Step 8. Test and Tune

### Step 1 Set BDI Parameters to Initial Values

Take the following steps to set the BDI parameters to initial values:

1. Select Programming » Battery » BDI.
2. Set the following parameters to the following values:

| Parameter | Value |
|---|---|
| Full Charge Voltage | 2.35V |
| Start Charge Voltage | 2.10V |
| Reset Volts Per Cell | 2.09V |
| Full Volts Per Cell | 2.04V |
| Empty Volts Per Cell | 1.73V |
| Battery Charge Time | 300 minutes |
| Battery Discharge Time | 600 minutes |

### Step 2 Set Full Charge Voltage

Set the Full Charge Voltage parameter by taking the following steps:

1. Plug in the charger.
2. Fully charge the batteries.
3. With the charger still attached and running, measure the battery voltage with a voltmeter.
4. Set Full Charge Voltage to 0.02V lower than the measured voltage divided by the battery's number of cells.

### Step 3 Set Reset Volts Per Cell

Set the Reset Volts Per Cell parameter by taking the following steps:

1. Turn off or disconnect the charger.
2. Let the batteries sit for 1 hour.
3. Measure the battery voltage with a voltmeter.
4. Set Reset Volts Per Cell to 0.02V lower than the measured voltage divided by the battery's number of cells.

### Step 4 Set Full Volts Per Cell

Set the Full Volts Per Cell parameter by taking the following steps.

1. Drive the vehicle at medium speed on a level surface for 10–15 minutes.
2. Select Monitor » Voltage.
3. Note the voltage indicated by the Keyswitch Voltage parameter.
4. Set the Full Volts Per Cell parameter to the observed voltage divided by the battery's number of cells.

### Step 5 Set Empty Volts Per Cell

The 1.73V value to which you previously set the Empty Volts Per Cell parameter should work for most batteries. However, you may need increase the Empty Volts Per Cell value for some sealed batteries. If you are not sure, consult the battery manufacturer.

### Step 6 Set Battery Discharge Time

Set the Battery Discharge Time parameter by taking the following steps:

1. Drive the vehicle with a heavy load.
2. Pay attention to the battery voltage, BDI percentage, and time.
3. Stop driving when the vehicle becomes sluggish and the battery voltage drops significantly. When that happens, you have reached the fully discharged point of the battery.
4. If the BDI percentage did not reach 0% before you stopped driving, decrease the Battery Discharge Time parameter. Use the following formula to calculate the new Battery Discharge Time value:

```
New Battery Discharge Time = Present Battery
       Discharge Time * (100% - BDI%)
```

### Step 7 Set Battery Charge Time and Start Charge Voltage

How you set the Battery Charge Time and Start Charge Voltage parameters depends upon whether the vehicle is required to support partial charging.

The typical method is to require a full recharge, which means the BDI percentage is reset only after the battery is fully charged. However, the controller can be configured to allow the operator to stop charging in mid-cycle and view a partial charge reading.

To configure these parameters, perform one of the following procedures:

- To require full charging:
  1. Set Battery Charge Time to 600 minutes.
  2. Set Start Charge Voltage to the Full Charge Voltage parameter's value.
- To allow partial charging:
  1. Set Battery Charge Time to the product of the following equation, which uses the battery's amp hour rating and the charger's average amp output:

     ```
     1.5 * (Battery amp hours / Charger amps)
     ```

  2. Starting with the dead battery that resulted when you set the Battery Discharge Time parameter, plug in the charger.
  3. Charge for 10 minutes.
  4. Measure the battery voltage with a voltmeter.
  5. Set the Start Charge Voltage parameter to the measured voltage divided by the number of battery cells.

### Step 8 Test and Tune

Once you have calibrated the controller's internal BDI, you'll have a good initial BDI configuration. However, for optimal BDI accuracy, test the BDI configuration for the vehicle's expected usage. Factors such as battery age, hilliness, driving surface, and user weight all impact the BDI percentage's accuracy. If testing indicates you need to fine-tune the BDI accuracy, repeat the steps in the Calibrate the Internal BDI section.

## OVERVOLTAGE AND UNDERVOLTAGE PROTECTION

The controller's overvoltage and undervoltage protection consists of hardware limits that can be customized by parameters. The Battery menu contains most of the parameters that configure overvoltage and undervoltage protection.

The following table describes the hardware voltage limits:

| Nominal Battery Voltage | Brownout | Severe Undervoltage | Undervoltage | Overvoltage | Severe Overvoltage |
|---|---|---|---|---|---|
| 36V | 12V | 14.4V | 25V | 45V | 54V |
| 48V | 16V | 20V | 34V | 60V | 72V |

### Overvoltage Protection

Overvoltage protection works as follows:

- The *allowed maximum voltage* is the lesser of the Severe Overvoltage limit and the voltage specified with the User Overvoltage parameter.
- If the battery voltage exceeds the allowed maximum voltage when either the vehicle is in the regenerative state or the speed is greater than 100 RPM, the Overvoltage Cutback fault occurs and the controller cuts back current.

  The overvoltage cutback is handled by a PID controller. The Overvoltage Cutback parameter indicates how much cutback, if any, is being applied.
- If the battery voltage is 10V higher than the allowed maximum voltage, a Severe Overvoltage fault (type 1) occurs and the controller shuts down driving.
- If the keyswitch voltage is 4V higher than the allowed maximum voltage, a Severe Overvoltage fault (type 2) occurs and the controller shuts down driving.

### Undervoltage Protection

When the battery voltage goes below the undervoltage threshold, the controller activates a closed loop proportional/integral undervoltage controller. The undervoltage controller attempts to keep the battery voltage from drooping by cutting back the drive current, thus reducing the load on the battery.

The Kp UV and Ki UV parameters specify the undervoltage controller's proportional and integral gain.

Undervoltage protection works as follows:

- The *allowed minimum voltage* is the greater of the Severe Undervoltage limit and the voltage specified with the User Undervoltage parameter.
- If the battery voltage is less than the allowed minimum voltage, the Undervoltage Cutback fault occurs and the controller cuts back current. If the cutback reaches 100%, a Severe Undervoltage fault (type 1) occurs.

  The undervoltage cutback is handled by a PID controller. You can configure the proportional and integral terms of the undervoltage controller with the Kp UV and Ki UV parameters. The Undervoltage Cutback parameter indicates how much cutback, if any, is being applied.
- If the keyswitch voltage is less than the Severe Undervoltage limit for 5ms when the controller starts up, a Severe Undervoltage fault (type 2) occurs and the controller shuts down driving.

## PASSWORD PROTECTION

The password protection feature allows only authorized users to change parameter values. Password protection is available in your application if the Password Enable parameter indicates On.

The Password Enable parameter is read-only; the value is set during the manufacturing process. If your application requires the Password Enable parameter value to be changed, contact the Curtis distributor where you obtained your controller or the Curtis sales-support office in your region.

If password protection is enabled, the Password and Change Password menus are visible. Use these parameters to log on and to change the password.

**⚠ CAUTION** **The default password is 0. Curtis recommends that you immediately change the default password.**

The Password Status parameter on the Password menu indicates whether parameter values can be changed. Parameters can be changed only when Password Status indicates Passed.

The following topics describe how to log on and how to change the password.

### Log On to Change Parameters

If the Password Status parameter indicates a value other than Passed, you must log on in order to change parameter values. To log on, take the following steps:

1. Select Programming » Password to access the Password menu.
2. Set the Password Input parameter to the password.
3. Set Password Enter to On. If the password is valid, the Password Status parameter will indicate Passed.

Once you have logged on, parameter values can be changed until the keyswitch is cycled. In other words, disconnecting a Curtis programming device will not log out.

### Change the Password

Take the following steps to change the password:

1. If the Password Status parameter indicates a value other than Passed, log on as described in the previous topic.
2. Select Programming » Password » Change Password to access the Change Password menu.
3. Set the New Password parameter to the new password.
4. Set New Password Enter to On.

If the Password Status is Passed, the password has been successfully changed, otherwise repeat these steps.

# 4 — PROGRAMMING MENU PARAMETERS

**SPEED MENU.................................... p. 39**

- Controller Mode
- High Speed
- Low Speed
- **MODE 1/MODE 2 MENUS...... p. 42**
  - Max Speed
  - Min Speed
  - Rev Max Speed
  - Rev Min Speed
  - Full Accel Rate HS
  - Full Accel Rate LS
  - Low Accel Rate
  - Neutral Decel Rate HS
  - Neutral Decel Rate LS
  - Full Brake Rate HS
  - Full Brake Rate LS
  - Low Brake Rate
  - Partial Decel Rate
- **SPEED SETTINGS MENU........ p. 43**
  - Swap Speed Direction
  - Kp
  - Ki
  - Keyoff Decel Rate
  - Push Speed Limit
  - Push Gain
  - Speed Limit HPD
  - **SPEED LIMIT SUPERVISION MENU...................... p. 44**
    - Enable
    - Speed Tolerance
    - Speed Ramp Delay
    - Speed Ramp Rate
  - **STEERING SPEED LIMIT MENU..................... p. 45**
    - Steering Analog Input
    - Steering Input Type
    - Max Steering Left Input
    - Max Steering Right Input
    - Max Steering Angle
    - Steering Angle 1
    - Steering Angle 2
    - Speed Limit 1
    - Speed Limit 2
- **COMMISSIONING MENU....... p. 46**
  - Commissioning Enable
  - Speed Command Limit
  - Current Limit

**THROTTLE MENU............................. p. 47**

- Throttle Type
- Pot R
- Forward Deadband
- Forward Max
- Forward Map
- Reverse Deadband
- Reverse Max
- Reverse Map
- Pot High
- Pot Low
- CAN Throttle Min
- CAN Throttle Max
- Swap Throttle Direction
- HPD Enable
- Sequencing Delay
- Throttle Pot Calibration Enable

**INTERLOCK MENU........................... p. 50**

- Interlock Type
- Interlock SRO Enable
- Max Creep Speed
- Interlock Brake Enable
- Interlock Brake Decel Rate
- Interlock Brake Timeout

**CURRENT MENU.............................. p. 51**

- Drive Current Limit
- Regen Current Limit
- Interlock Brake Current Limit
- Boost Enable
- Boost Current Limit
- Boost Time

**MAIN RELAY MENU.......................... p. 52**

- Pull In Voltage
- Holding Voltage
- Open Delay
- DNC Voltage Threshold
- Main Welded PWM

**EM BRAKE MENU............................. p. 53**

- EM Brake Type
- Pull In Voltage
- Holding Voltage
- Set Speed Threshold
- Fault Motor Revs
- Release Delay
- EM Brake Delay
- Fault Enable

**BATTERY MENU................................ p. 55**

- Nominal Voltage
- User Overvoltage
- User Undervoltage
- Kp UV
- Ki UV
- **BDI MENU............................ p. 56**
  - BDI Source
  - Full Charge Voltage
  - Start Charge Voltage
  - Reset Volts Per Cell
  - Full Volts Per Cell
  - Empty Volts Per Cell
  - BDI Reset Percent
  - Battery Charge Time
  - Battery Discharge Time
  - Low BDI Threshold
  - Low BDI Max Speed
  - Lift Lockout Threshold

The controller provides numerous parameters that you can program with a Curtis programming device. Use these parameters to customize a vehicle's performance and functionality.

The parameters are grouped hierarchically into menus and are described in the following topics. Each parameter is identified with a parameter name and CAN index.

The following list describes the columns in the parameter description tables:

- **Parameter** and **CAN Index**: The parameter name and the CAN index and sub-index. If the keyswitch needs to be cycled after a parameter's value is changed, the column will include the notation "[PCF]".

  **Note:** When a parameter marked as [PCF] is changed, a Parameter Fault occurs. The fault is cleared by cycling the keyswitch.
- **Values** and **Raw Values**: The allowed values as shown in Curtis programming devices and in raw units suitable for CAN.
- **Data Size** and **Read/Write**: The parameter's data size and whether the parameter is writable.
- **Access Level**: The Curtis programming device access level at or below which the parameter is available.

## SPEED MENU

The controller provides two speed modes, which are useful for driving in different conditions. For example, one speed mode can be used for outdoor driving and the other for slower indoor driving.

The parameters on the Speed menu configure speed-related functions such as minimum and maximum speeds and acceleration and deceleration rates.

In addition to its parameters, the Speed menu contains the Mode 1 and Mode 2 menus. These menus include several acceleration rate and deceleration rate parameters whose names end with "HS" or "LS". The controller applies the "HS" rates when the speed reaches that specified by the High Speed parameter, and applies the "LS" rates when the speed reaches that specified by the Low Speed parameter. See Low and High Speed Acceleration Rates and Low and High Speed Deceleration Rates.

The Speed menu contains the following menus:

- Mode 1
- Mode 2
- Speed Settings
- Commissioning

The following table describes the parameters on the Speed menu.

SPEED MENU

| PARAMETER<br>CAN INDEX | VALUES<br>RAW VALUES | DATA SIZE<br>READ/WRITE | ACCESS LEVEL | DESCRIPTION |
|---|---|---|---|---|
| **Controller Mode**<br>`0x380E:00` | Enumerated<br>*0–2* | 8-bit<br>RW | OEM Dealer | Specifies the motor control method:<br>0 = Throttle Control Mode: The throttle input corresponds to the motor torque output.<br>1 = Speed Control Mode: The throttle input corresponds to the motor speed output.<br>**Note:** For more information on the throttle and speed control modes, see Specify the Controller Mode.<br>2 = Commissioning Mode: Used in the commissioning process; see Characterize the Hall Sensors and UVW Output. If Commissioning Mode is specified, the Commissioning menu is visible. |
| **High Speed**<br>`0x3824:00` | 0–100%<br>*0–32767* | 16-bit<br>RW | OEM Dealer | Specifies the percentage of the motor's maximum speed above which the high speed ("HS") parameters are used.<br>The motor's maximum speed is specified with the Max Speed parameter. |
| **Low Speed**<br>`0x3825:00` | 0–100%<br>*0–32767* | 16-bit<br>RW | OEM Dealer | Specifies the percentage of the motor's maximum speed below which the low speed ("LS") parameters are used. |

### Low and High Speed Acceleration Rates

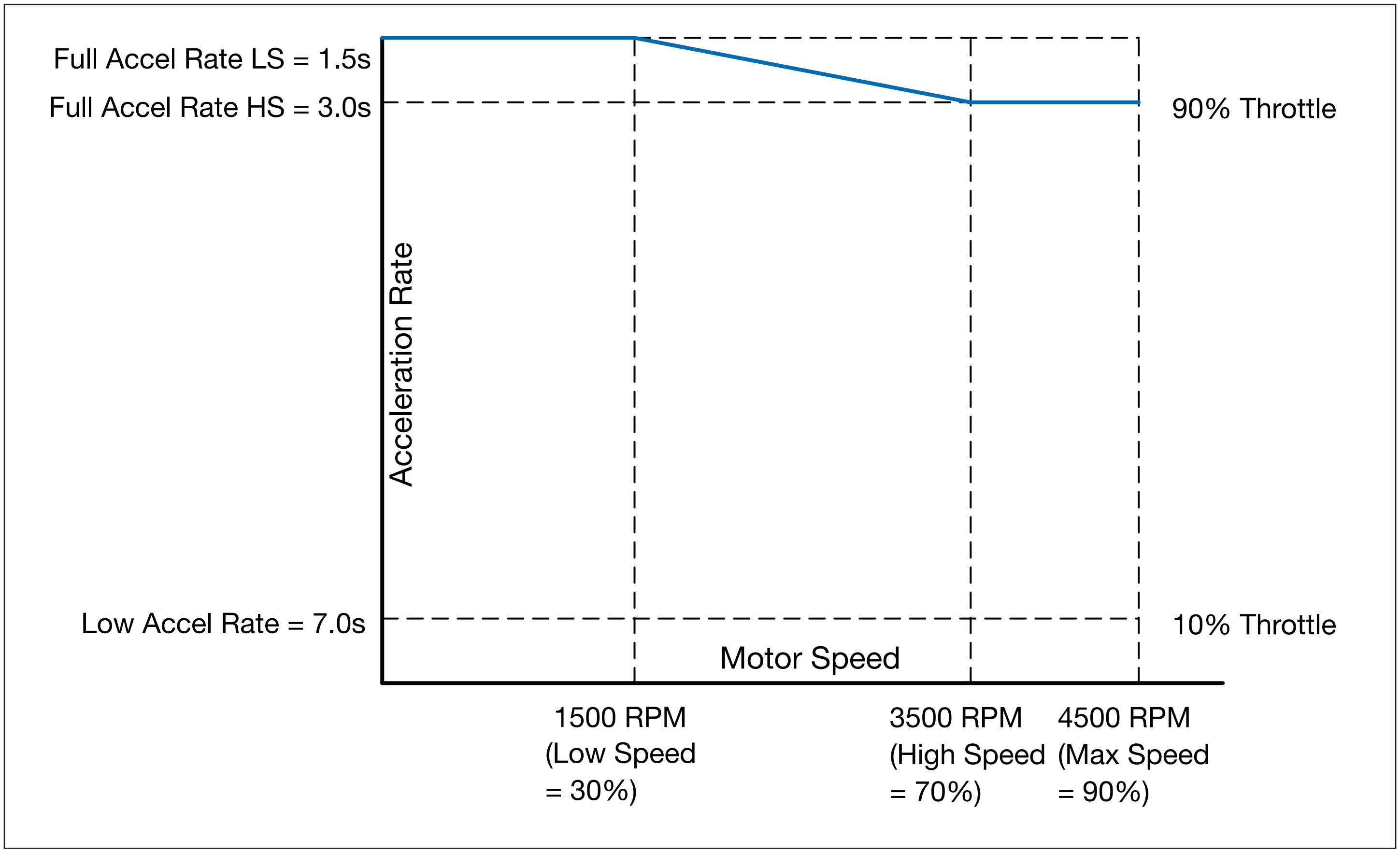
The Full Accel Rate HS and Full Accel Rate LS parameters on the Mode 1 and Mode 2 menus configure acceleration rates for low and high speeds. When throttle is applied while the vehicle is traveling between the specified low and high speeds, the acceleration rate is linearly scaled between the low and high acceleration rates. These acceleration rates apply to both forward and reverse.

#### Example

Suppose you set the following parameter values:

| Parameter | Value |
|---|---|
| Low Speed | 30% |
| High Speed | 70% |
| Full Accel Rate LS | 1.5s |
| Full Accel Rate HS | 3.0s |
| Low Accel Rate | 7.0s |

The following diagram shows the acceleration rate when 90% throttle is applied to a motor with a 5000 RPM maximum speed.




For steps on configuring acceleration and deceleration rates, see Set the Acceleration and Deceleration Rates.

## Low and High Speed Deceleration Rates

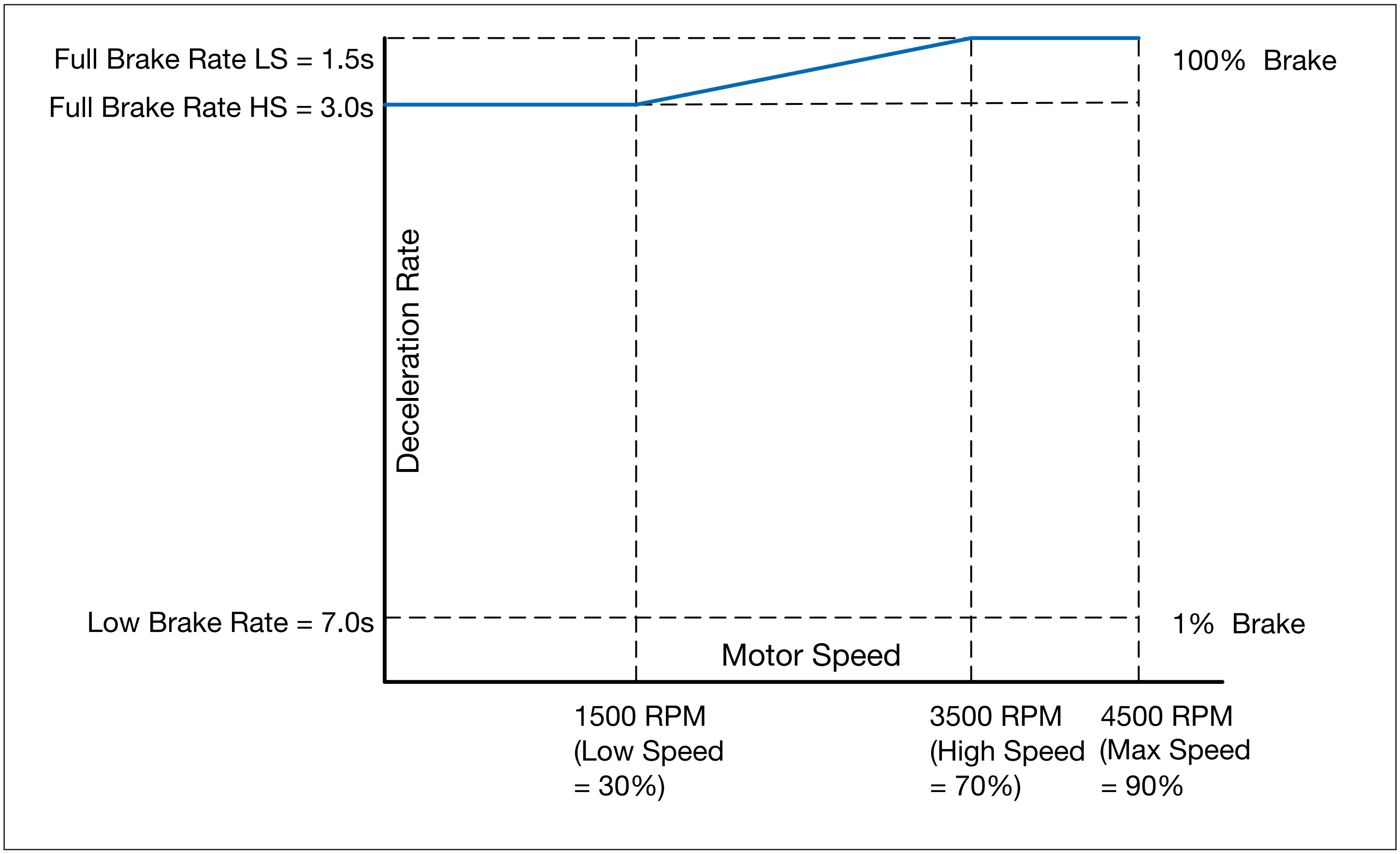
The Full Brake Rate HS and Full Brake Rate LS parameters on the Mode 1 and Mode 2 menus configure deceleration rates for low and high speeds. When the vehicle is traveling between the specified low and high speeds and full throttle is applied in the opposite direction, the deceleration rate is linearly scaled between the low and high speed rates. The deceleration rates apply to forward and reverse.

### Example

Suppose you set the following parameter values:

| Parameter | Value |
|---|---|
| LS (Low Speed) | 30% |
| HS (High Speed) | 70% |
| Full Brake Rate LS | 3.0s |
| Full Brake Rate HS | 1.5s |
| Low Brake Rate | 7.0s |

The following diagram shows the deceleration rates when full throttle is applied in the opposite direction to a motor with a 5000 RPM maximum speed.



## Mode 1 and Mode 2 Menus

Use the Mode 1 and Mode 2 menus to configure speed modes 1 and 2. Both menus contain parameters with the same names, so the following table describes both menus' parameters. The first column contains the CAN indexes for both modes.

**Note:** The percentage-based parameters are percentages of the motor's maximum speed.

SPEED MODE — MODE 1 AND MODE 2 MENUS

| PARAMETER<br>CAN INDEX | VALUES<br>RAW VALUES | DATA SIZE<br>READ/WRITE | ACCESS<br>LEVEL | DESCRIPTION |
|---|---|---|---|---|
| **Max Speed**<br>`0x3800:00`<br>`0x3807:00` | 0–100%<br>*0–32767* | 16-bit<br>RW | OEM Dealer | Specifies the maximum forward speed. |
| **Min Speed**<br>`0x3801:00`<br>`0x3808:00` | 0–100%<br>*0–32767* | 16-bit<br>RW | OEM Dealer | Specifies the minimum forward speed. |
| **Rev Max Speed**<br>`0x3802:00`<br>`0x3809:00` | 0–100%<br>*0–32767* | 16-bit<br>RW | OEM Dealer | Specifies the maximum reverse speed. |
| **Rev Min Speed**<br>`0x3803:00`<br>`0x380A:00` | 0–100%<br>*0–32767* | 16-bit<br>RW | OEM Dealer | Specifies the minimum reverse speed. |
| **Full Accel Rate HS**<br>`0x3812:00`<br>`0x381B:00` | 0.1s–12.0s<br>*50–6000* | 16-bit<br>RW | OEM Dealer | Specifies the rate at which the vehicle accelerates when full throttle is applied at high vehicle speeds. Larger values represent slower response.<br>See Low and High Speed Acceleration Rates. |
| **Full Accel Rate LS**<br>`0x3813:00`<br>`0x381C:00` | 0.1s–12.0s<br>*50–6000* | 16-bit<br>RW | OEM Dealer | Specifies the rate at which the vehicle accelerates when full throttle is applied at low vehicle speeds. Larger values represent slower response. |
| **Low Accel Rate**<br>`0x3819:00`<br>`0x3822:00` | 0.1s–12.0s<br>*50–6000* | 16-bit<br>RW | OEM Dealer | Specifies the rate at which the vehicle accelerates when a small amount of throttle is applied.<br>Adjust this parameter if you need to tune the vehicle for low speed maneuverability. |
| **Neutral Decel Rate HS**<br>`0x3814:00`<br>`0x381D:00` | 0.1s–12.0s<br>*50–6000* | 16-bit<br>RW | OEM Dealer | Specifies the rate at which the vehicle decelerates when the throttle is released to neutral at high speed. |
| **Neutral Decel Rate LS**<br>`0x3815:00`<br>`0x381E:00` | 0.1s–12.0s<br>*50–6000* | 16-bit<br>RW | OEM Dealer | Specifies the rate at which the vehicle decelerates when the throttle is released to neutral at low speed. |
| **Full Brake Rate HS**<br>`0x3816:00`<br>`0x381F:00` | 0.1s–12.0s<br>*50–6000* | 16-bit<br>RW | OEM Dealer | Specifies the rate at which the vehicle decelerates from high speeds when full throttle is applied in the opposite direction. |
| **Full Brake Rate LS**<br>`0x3817:00`<br>`0x3820:00` | 0.1s–12.0s<br>*50–6000* | 16-bit<br>RW | OEM Dealer | Specifies the rate at which the vehicle decelerates from low speeds when full throttle is applied in the opposite direction. |
| **Low Brake Rate**<br>`0x381A:00`<br>`0x3823:00` | 0.1s–12.0s<br>*50–6000* | 16-bit<br>RW | OEM Dealer | Specifies the rate at which the vehicle decelerates when a small amount of throttle is applied in the opposite direction. |
| **Partial Decel Rate**<br>`0x3818:00`<br>`0x3821:00` | 0.1s–12.0s<br>*50–6000* | 16-bit<br>RW | OEM Dealer | Specifies the rate at which the vehicle decelerates when the throttle is reduced without being released to neutral.<br>Larger values provide a slower response. |

## Speed Settings Menu

The following table describes the Speed Settings parameters.

**Note:** The Speed Settings menu contains the Speed Limit Supervision and Steering Speed Limit menus.

### SPEED MODE — SPEED SETTINGS MENU

| PARAMETER CAN INDEX | VALUES RAW VALUES | DATA SIZE READ/WRITE | ACCESS LEVEL | DESCRIPTION |
|---|---|---|---|---|
| **Swap Speed Direction [PCF]** `0x353C:00` | Off/On *0–1* | 8-bit RW | OEM Dealer | Changes the motor speed direction. Specify On to change the direction.<br>The motor speed direction is indicated by the Motor RPM parameter. Motor RPM should be positive when the vehicle is moving forward and negative in reverse. If the opposite is occurring, toggle Swap Speed Direction.<br>If Swap Speed Direction is specified incorrectly, emergency reverse will not work and a Parameter Fault (type 3) will occur. |
| **Kp** `0x3810:00` | 0–100% *0–32767* | 16-bit RW | OEM Dealer | Specifies the proportional term of the speed PI controller. Larger values provide tighter control. |
| **Ki** `0x3811:00` | 0–100% *0–32767* | 16-bit RW | OEM Dealer | Specifies the integral term of the speed PI controller. Larger values provide tighter control. |
| **Keyoff Decel Rate** `0x382A:00` | 0.2–0.8s *100–400* | 16-bit RW | OEM Dealer | Specifies the rate at which the vehicle decelerates at key-off or in the event of a major fault. |
| **Push Speed Limit** `0x3865:00` | 0–100% *0–32767* | 16-bit RW | OEM Dealer | Specifies the speed limit for push mode. If the speed limit is exceeded, the controller will generate a braking force.<br>The value is a percentage of the Max Speed parameter (Motor menu). To disable the speed limit, specify 0. |
| **Push Gain** `0x3867:00` | 0–100% *0–32767* | 16-bit RW | OEM Dealer | Specifies the gain for the push speed limit. Larger values provide tighter control. |
| **Speed Limit HPD** `0x3909:00` | Off/On *0–1* | 8-bit RW | OEM Dealer | Specifies whether the controller must enter the neutral state before limited speed mode can be aborted. See Speed Limit HPD. |

## Speed Limit Supervision Menu

The Speed Limit Supervision parameters configure whether and how speed is limited for emergency reverse and interlock braking operations. For more information, see Speed Limit Supervision for Emergency Reverse and Interlock Braking.

### SPEED MODE — SPEED LIMIT SUPERVISION MENU

| PARAMETER<br>CAN INDEX | VALUES<br>RAW VALUES | DATA SIZE<br>READ/WRITE | ACCESS<br>LEVEL | DESCRIPTION |
|---|---|---|---|---|
| **Enable**<br>`0x3910:00` | Off/On<br>*0–1* | 8-bit<br>RW | OEM Dealer | Specifies whether speed limit supervision is enabled. |
| **Speed Tolerance**<br>`0x3911:00` | 0–100%<br>*0–32767* | 16-bit<br>RW | OEM Dealer | Specifies the speed limit. The value is a percentage of the speed at which the vehicle is traveling when emergency reverse or interlock braking is requested. |
| **Speed Ramp Delay**<br>`0x3912:00` | 100–2000ms<br>*100–2000* | 16-bit<br>RW | OEM Dealer | Specifies the interval between when the speed limit is exceeded and when speed must begin decreasing. |
| **Speed Ramp Rate**<br>`0x3913:00` | 100–500%<br>*1024–5120* | 16-bit<br>RW | OEM Dealer | Specifies the slowest allowable ramp transition from the maximum speed to zero. |

## Steering Speed Limit Menu

The Steering Speed Limit parameters configure the steering speed limit function; see Steering Speed Limit Input. The following table describes the parameters.

### SPEED MODE — STEERING SPEED LIMIT MENU

| PARAMETER<br>CAN INDEX | VALUES<br>RAW VALUES | DATA SIZE<br>READ/WRITE | ACCESS<br>LEVEL | DESCRIPTION |
|---|---|---|---|---|
| **Steering Analog Input**<br>`0x384C:00` | 0–100%<br>*0–1000* | 16-bit<br>RO | OEM Dealer | Indicates the analog steering input data if the Steering Input Type parameter specifies an analog input. |
| **Steering Input Type**<br>`0x3841:00` | Enumerated<br>*0–5* | 8-bit<br>RW | OEM Dealer | Specifies the steering speed limit input:<br>0 = None<br>1 = NO Switch Input<br>2 = NC Switch Input<br>3 = Analog R Input<br>4 = Analog V Input<br>5 = CAN Input |
| **Max Steering Left Input**<br>`0x3842:00` | 0–100%<br>*0–1000* | 16-bit<br>RW | OEM Dealer | Specifies the analog data that indicates the tiller head is at its maximum left angle.<br>This parameter applies only to analog inputs. |
| **Max Steering Right Input**<br>`0x3843:00` | 0–100%<br>*0–1000* | 16-bit<br>RW | OEM Dealer | Specifies the analog data that indicates the tiller head is at its maximum right angle.<br>This parameter applies only to analog inputs. |
| **Max Steering Angle**<br>`0x384B:00` | 0–90º<br>*0–16383* | 16-bit<br>RW | OEM Dealer | Specifies the maximum steering angle for the left and right sides. |
| **Steering Angle 1**<br>`0x3844:00` | 0–90º<br>*0–16383* | 16-bit<br>RW | OEM Dealer | Specifies the steering angle at which the Speed Limit 1 parameter's speed is applied. |
| **Steering Angle 2**<br>`0x3845:00` | 0–90º<br>*0–16383* | 16-bit<br>RW | OEM Dealer | Specifies the steering angle at which the Speed Limit 2 parameter's speed is applied. |
| **Speed Limit 1**<br>`0x3846:00` | 0–100%<br>*0–32767* | 16-bit<br>RW | OEM Dealer | Depends upon whether the steering input is an NO or NC switch:<br>• NO or NC switch: Specifies the speed limit when the switch is on.<br>• Other input types: Specifies the speed limit when the steering angle is at Steering Angle 1. |
| **Speed Limit 2**<br>`0x3847:00` | 0–100%<br>*0–32767* | 16-bit<br>RW | OEM Dealer | Specifies the speed limit when the steering angle is at Steering Angle 2.<br>This parameter is not used if the steering input is an NO or NC switch. |

### Commissioning Menu

The Commissioning menu is visible when the Controller Mode parameter is set to Commissioning Mode. The Commissioning parameters are used to automatically characterize the Hall sensor phases; see Characterize the Hall Sensors and UVW Output. The following table describes the Commissioning parameters.

**SPEED MODE — COMMISSIONING MENU**

| PARAMETER<br>CAN INDEX | VALUES<br>RAW VALUES | DATA SIZE<br>READ/WRITE | ACCESS<br>LEVEL | DESCRIPTION |
|---|---|---|---|---|
| **Commissioning Enable**<br>`0x5020:00` | Off/On<br>*0–1* | 8-bit<br>RW | OEM Dealer | Enables the automatic commissioning process. |
| **Speed Command Limit**<br>`0x5021:00` | 8–50%<br>*2621–16383* | 16-bit<br>RW | OEM Dealer | Specifies the maximum allowed speed during commissioning. |
| **Current Limit**<br>`0x3444:00` | 5–40A<br>*20–160* | 16-bit<br>RW | OEM Dealer | Specifies the maximum current that the controller supplies to the motor during commissioning. |

## THROTTLE MENU

Use the Throttle menu to specify the type of throttle used by the vehicle and to configure the throttle. The following table describes the Throttle parameters.

**Note:** The Forward and Reverse Deadband, Max, and Map parameter values are percentages of the throttle's maximum wiper voltage.

THROTTLE MENU

| PARAMETER<br>CAN INDEX | VALUES<br>RAW VALUES | DATA SIZE<br>READ/WRITE | ACCESS<br>LEVEL | DESCRIPTION |
|---|---|---|---|---|
| **Throttle Type [PCF]**<br>`0x3340:00` | Enumerated<br>*0–5* | 16-bit<br>RW | OEM Dealer | Specifies the throttle type:<br>0 = 3-wire pot<br>1 = 3-wire wigwag pot<br>2 = 0–5V voltage<br>3 = 0–5V wigwag voltage<br>4 = CAN<br>5 = CAN wigwag |
| **Pot R**<br>`0x334A:00` | 800Ω–15000Ω<br>*800–15000* | 16-bit<br>RW | OEM Dealer | Specifies the throttle pot's resistance. |
| **Forward Deadband**<br>`0x3341:00` | 0–100%<br>*0–1000* | 16-bit<br>RW | OEM Dealer | Specifies the wiper voltage at the deadband threshold while the vehicle is moving forward. |
| **Forward Max**<br>`0x3342:00` | 0–100%<br>*0–1000* | 16-bit<br>RW | OEM Dealer | Specifies the wiper voltage that generates 100% controller output while the vehicle is moving forward. |
| **Forward Map**<br>`0x3343:00` | 0–100%<br>*0–32767* | 16-bit<br>RW | OEM Dealer | Specifies the controller output that is generated when the throttle input is at 50% while the vehicle is moving forward.<br>Following are guidelines for setting Forward Map:<br>• 50% provides a linear output response to the throttle input.<br>• Values below 50% reduce the controller output at low throttle positions, providing enhanced slow speed maneuverability.<br>• Values above 50% give the vehicle a faster, more responsive feel at low throttle positions.<br>For more information, see Throttle Response Parameters. |
| **Reverse Deadband**<br>`0x3344:00` | 0–100%<br>*0–1000* | 16-bit<br>RW | OEM Dealer | These parameters work just like the corresponding Forward parameters, except that they apply while the vehicle is moving in reverse. |
| **Reverse Max**<br>`0x3345:00` | 0–100%<br>*0–1000* | 16-bit<br>RW | OEM Dealer | |
| **Reverse Map**<br>`0x3346:00` | 0–100%<br>*0–32767* | 16-bit<br>RW | OEM Dealer | |
| **Pot High**<br>`0x3356:00` | 3.0–15.0V<br>*2457–12288* | 16-bit<br>RW | OEM Dealer | Specifies the maximum voltage for voltage throttles.<br>If the throttle voltage is outside the range defined by Pot Low and Pot High, a Throttle Fault (type 1) occurs. |
| **Pot Low**<br>`0x3357:00` | 0–3.0V<br>*0–2457* | 16-bit<br>RW | OEM Dealer | Specifies the minimum voltage for voltage throttles. |
| **CAN Throttle Min**<br>`0x3347:00` | –32768 to +32767<br>*–32768 to +32767* | 16-bit<br>RW | OEM Dealer | Specifies the minimum throttle request for CAN throttles.<br>If the throttle request is outside the range defined by CAN Throttle Min and CAN Throttle Max, a Throttle Fault (type 1) occurs. |

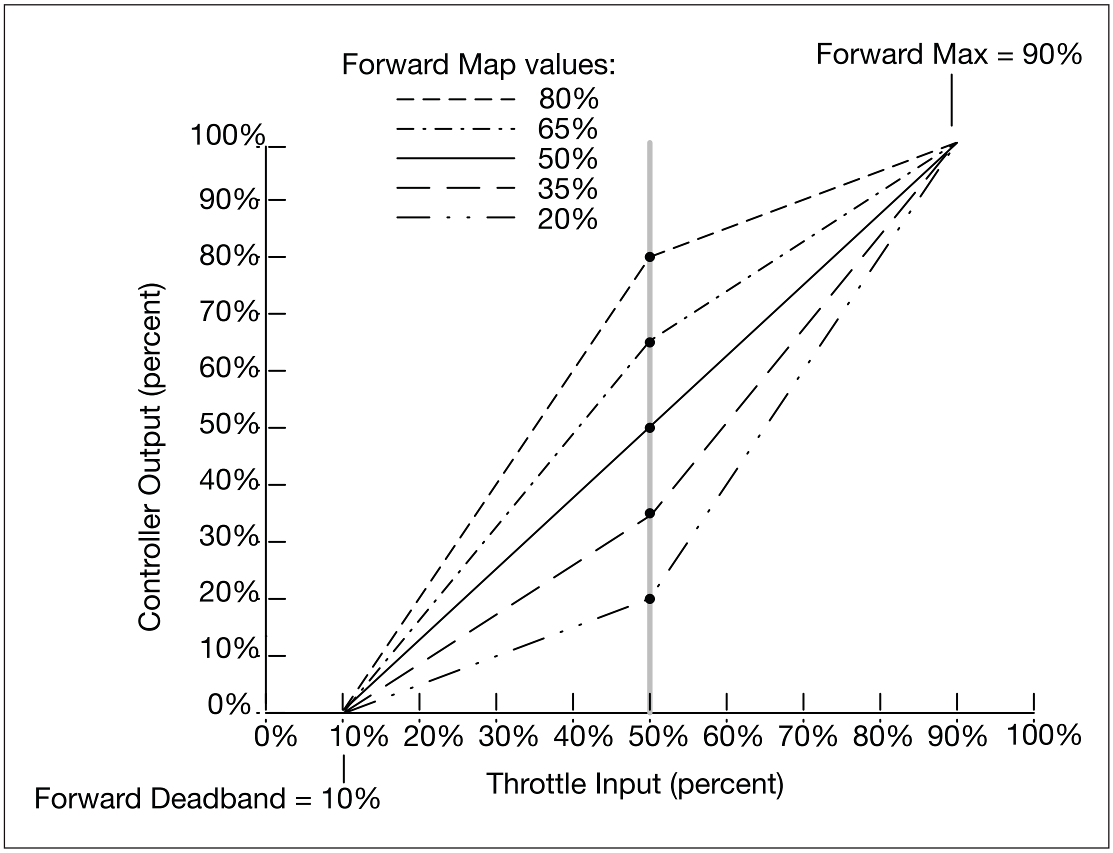
## THROTTLE MENU, cont'd

| PARAMETER<br>CAN INDEX | VALUES<br>RAW VALUES | DATA SIZE<br>READ/WRITE | ACCESS<br>LEVEL | DESCRIPTION |
|---|---|---|---|---|
| **CAN Throttle Max**<br>`0x3348:00` | –32768 to +32767<br>*–32768 to +32767* | 16-bit<br>RW | OEM Dealer | Specifies the maximum throttle request for CAN throttles. |
| **Swap Throttle Direction [PCF]**<br>`0x335B:00` | Off/On<br>*0–1* | 8-bit<br>RW | OEM Dealer | Changes the throttle direction to the opposite direction. For example, if you toggle this value for a single-ended throttle, the forward input would become the reverse input, and vice versa. |
| **HPD Enable [PCF]**<br>`0x334B:00` | Off/On<br>*0–1* | 8-bit<br>RW | OEM Dealer | Indicates whether the HPD feature is enabled.<br>When HPD is enabled, a fault occurs if the Throttle Demand exceeds 10% when the interlock is turned on and the Sequencing Delay expires.<br>The fault depends upon how long this interlock/throttle demand state exists:<br>• 48ms: HPD Sequencing fault<br>• 10s: Throttle Fault (type 2) |
| **Sequencing Delay**<br>`0x334C:00` | 40–2000ms<br>*10–500* | 16-bit<br>RW | OEM Dealer | Specifies the time during which the interlock can cycle before the HPD-related faults occur.<br>A delay is useful for cases where the interlock might be momentarily cycled, such as when an operator briefly bounces off the seat. In such cases, the vehicle typically should continue moving. |
| **Throttle Pot Calibration Enable**<br>`0x4F06:00` | Off/On<br>*0–1* | 16-bit<br>RW | OEM Dealer | Calibrates the throttle. The throttle circuit by default is calibrated for a 5kΩ pot. If a non-5kΩ pot is used, take the following steps to calibrate the throttle circuit:<br>1. Set Pot R to the potentiometer's resistance.<br>2. Connect the throttle's pot high and ground to the controller, with the pot wiper floating.<br>3. Set Throttle Pot Calibration Enable to On. |

## Throttle Response Parameters

The Forward/Reverse Deadband, Forward/Reverse Max, and Forward/Reverse Map parameters specify the throttle demand that is generated by the throttle position. The following diagram shows how these parameters work:

**Figure 4-1**
*Throttle Response Parameters*




When the throttle input reaches 50%, the controller output depends upon the Forward Map parameter. For example, if Forward Map is 80%, the controller output is 80% when the throttle input is 50%.

## INTERLOCK MENU

The following table describes the interlock parameters.

INTERLOCK MENU

| PARAMETER<br>CAN INDEX | VALUES<br>RAW VALUES | DATA SIZE<br>READ/WRITE | ACCESS<br>LEVEL | DESCRIPTION |
|---|---|---|---|---|
| **Interlock Type [PCF]**<br>`0x34B0:00` | Enumerated<br>*0–2* | 8-bit<br>RW | OEM Dealer | Specifies the source of the interlock input:<br>0 = Interlock Switch<br>1 = Keyswitch Interlock<br>2 = CAN Interlock |
| **Interlock SRO Enable**<br>`0x34B3:00` | Off/On<br>*0–1* | 8-bit<br>RW | OEM Dealer | Indicates whether the interlock SRO function is enabled when Interlock Type is not set to Keyswitch.<br>If interlock SRO is enabled, an Interlock SRO Fault occurs if the interlock is on when the keyswitch is turned on. |
| **Max Creep Speed**<br>`0x34B2:00` | 0–100%<br>*0–32767* | 16-bit<br>RW | OEM Dealer | Specifies the maximum speed when the vehicle is in creep mode. The value is a percentage of the speed mode's maximum speed. |
| **Interlock Brake Enable**<br>`0x34B5:00` | Off/On<br>*0–1* | 8-bit<br>RW | OEM Dealer | Specifies whether interlock braking is activated when the interlock signal is turned off:<br>On = The controller uses regen braking to stop the vehicle.<br>Off = The controller turns the motor off and lets the vehicle roll freely. This option is typically used when the vehicle is equipped with a user-controlled mechanical or hydraulic brake. |
| **Interlock Brake Decel Rate**<br>`0x34B6:00` | 0.1–8.0s<br>*50–4000* | 16-bit<br>RW | OEM Dealer | Specifies the rate at which the vehicle brakes to a stop when interlock braking is activated. |
| **Interlock Brake Timeout**<br>`0x34B7:00` | 0.2–8.0s<br>*25–1000* | 16-bit<br>RW | OEM Dealer | Specifies the maximum duration of an interlock braking event. |

## CURRENT MENU

The following table describes the Current menu's parameters.

**Note:** The parameter values are percentages of the controller's fully rated current.

CURRENT MENU

| PARAMETER<br>CAN INDEX | VALUES<br>RAW VALUES | DATA SIZE<br>READ/WRITE | ACCESS<br>LEVEL | DESCRIPTION |
|---|---|---|---|---|
| **Drive Current Limit**<br>`0x3440:00` | 10–60A<br>*40–240* | 16-bit<br>RW | OEM Dealer | Specifies the maximum current the controller supplies to the motor during driving. |
| **Regen Current Limit**<br>`0x3441:00` | 10–60A<br>*40–240* | 16-bit<br>RW | OEM Dealer | Specifies the maximum current the controller supplies to the motor during regenerative braking. |
| **Interlock Brake Current Limit**<br>`0x3445:00` | 10–60A<br>*40–240* | 16-bit<br>RW | OEM Dealer | Specifies the maximum current the controller supplies to the motor during interlock braking.<br>During interlock braking, the controller's current limit is specified by whichever of the Interlock Brake Current Limit and Regen Current Limit parameters specifies the highest voltage. |
| **Boost Enable**<br>`0x3433:00` | Off/On<br>*0–1* | 8-bit<br>RW | OEM Dealer | Enables or disables the boost current function.<br>Boost current provides a brief increase of current to improve performance with transient loads such as starting on a hill, crossing a threshold, and climbing obstacles. |
| **Boost Current Limit**<br>`0x3442:00` | 10–70A<br>*40–280* | 16-bit<br>RW | OEM Dealer | Specifies the maximum current the controller supplies to the motor during a boost current operation. |
| **Boost Time**<br>`0x3435:00` | 1–10s<br>*63–625* | 16-bit<br>RW | OEM Dealer | Specifies the maximum duration of a boost current operation. |

## MAIN RELAY MENU

The following table describes the parameters on the Main Relay menu.

MAIN RELAY MENU

| PARAMETER<br>CAN INDEX | VALUES<br>RAW VALUES | DATA SIZE<br>READ/WRITE | ACCESS<br>LEVEL | DESCRIPTION |
|---|---|---|---|---|
| **Pull In Voltage**<br>`0x34C8:00` | 0–100%<br>*0–4096* | 16-bit<br>RW | OEM Dealer | Specifies the initial voltage of the relay when the driver is first turned on.<br>The controller allows a high initial voltage to ensure the relay closes. The voltage then decreases to the specified Holding Voltage. |
| **Holding Voltage**<br>`0x34C6:00` | 0–100%<br>*0–4096* | 16-bit<br>RW | OEM Dealer | Specifies the voltage the controller applies to the relay coil after the relay closes.<br>Set Holding Voltage high enough so that the relay remains closed under all shock and vibration conditions that the vehicle is expected to encounter. |
| **Open Delay**<br>`0x34CA:00` | 0.0–40.0s<br>*0–10000* | 16-bit<br>RW | OEM Dealer | Specifies how long the relay should remain closed after the interlock has opened.<br>A delay prevents unnecessary cycling of the relay. |
| **DNC Voltage Threshold**<br>`0x34CB:00` | 0.5V–10.0V<br>*50–1000* | 16-bit<br>RW | OEM Dealer | Specifies the allowed voltage difference between the keyswitch and capacitor bank voltages.<br>If this voltage difference is exceeded for 96ms, a Main Relay Did Not Close fault occurs. |
| **Main Welded PWM**<br>`0x3540:00` | 8–20%<br>*2621–6554* | 16-bit<br>RW | OEM Factory | Specifies the PWM the controller applies to the motor to check for the Main Relay Welded fault. |

## EM BRAKE MENU

The following table describes the parameters on the EM Brake menu.

EM BRAKE MENU

| PARAMETER<br>CAN INDEX | VALUES<br>RAW VALUES | DATA SIZE<br>READ/WRITE | ACCESS<br>LEVEL | DESCRIPTION |
|---|---|---|---|---|
| **EM Brake Type [PCF]**<br>`0x3479:00` | Enumerated<br>*0–2* | 8-bit<br>RW | OEM Dealer | Specifies how the electromagnetic brake responds to the interlock input, throttle, and motor speed:<br>0 = EM Brake Disable. This is for vehicles that are not equipped with an EM brake.<br>**Note:** When EM Brake Disable is specified, the EM brake function can be commanded by CAN. See EM Brake Override Object.<br>1 = Interlock Type<br>2 = Interlock & Neutral Type. This value enables the anti-roll functions.<br>For information on the EM brake's engage and release conditions, see Table 4-1. |
| **Pull In Voltage**<br>`0x3473:00` | 20–100%<br>*51–255* | 8-bit<br>RW | OEM Dealer | Specifies the EM braking system's initial voltage when the EM brake is activated.<br>To ensure that the EM brake is released, the controller allows a high initial voltage when the EM brake is activated. This peak voltage then decreases to the specified Holding Voltage. |
| **Holding Voltage**<br>`0x3472:00` | 20–100%<br>*51–255* | 8-bit<br>RW | OEM Dealer | Specifies the reduced voltage the controller applies to the brake coil once the brake has been released.<br>Set the Holding Voltage high enough so that the brake remains released under all shock and vibration conditions that the vehicle is expected to encounter. |
| **Set Speed Threshold**<br>`0x3476:00` | 5–100 RPM<br>*5–100* | 16-bit<br>RW | OEM Dealer | Specifies the motor speed below which the controller engages the EM brake.<br>Setting this speed too high can cause an abrupt stop when the EM brake is engaged. |
| **Fault Motor Revs**<br>`0x3471:00` | 10–200 RPM<br>*10–200* | 16-bit<br>RW | OEM Dealer | Specifies the maximum allowed speed after the EM brake has been engaged.<br>If the motor speed exceeds the specified value for 80ms with the EM brake engaged, an EM Brake Failed To Set fault occurs. |
| **Release Delay**<br>`0x3474:00` | 40–2000ms<br>*5–250* | 16-bit<br>RW | OEM Dealer | Specifies how long it takes for the controller to release the EM brake when the controller output increases above 0%.<br>If the delay is too short, the vehicle might roll back when the EM brake is released. |
| **EM Brake Delay**<br>`0x3475:00` | 0.0–2.0s<br>*0–250* | 16-bit<br>RW | OEM Dealer | Specifies how long it takes for the controller to engage the EM brake when the controller output decreases to 0%.<br>To ensure the vehicle doesn't move before the brake fully engages, the delay should be longer than the actual brake setting time. |
| **Fault Enable**<br>`0x3403:00` | Off/On<br>*0–1* | 8-bit<br>RW | OEM Dealer | Enables or disables whether the controller generates a Driver Fault (type 1) if one of the following conditions occurs:<br>• Missing brake coil<br>• Shorted brake coil<br>• Coil driver damage |

The following table describes the conditions that cause the controller to release and engage the EM brake when EM braking is enabled.

**Table 4-1 EM Brake Response**

<table>
<tr><th>EM Brake Type Parameter</th><th>Release</th><th>Engage</th></tr>
<tr><td>Interlock Type</td><td>Releases when the main relay is engaged, the interlock is on, and the Release Delay has expired.</td><td>Depends upon whether interlock braking is enabled:<ul><li>Enabled: Depends upon the motor speed:<ul><li>If the motor speed is greater than Set Speed Threshold, the controller regen brakes the vehicle to a stop and then engages the EM brake.</li><li>If the motor speed is less than Set Speed Threshold, the EM brake engages after the Sequencing Delay has expired.</li></ul></li><li>Disabled: Engages when the Sequencing Delay has expired.</li></ul></td></tr>
<tr><td>Interlock & Neutral Type</td><td>Releases when the main relay is engaged, the interlock is on, the throttle is out of neutral, and the Release Delay has expired.</td><td>Engages when one of the following conditions occurs:<ul><li>The throttle command is zero and the motor speed is less than Set Speed Threshold.</li><li>The throttle command is zero and the EM Brake Delay has expired, even if the motor speed is greater than Set Speed Threshold.</li></ul></td></tr>
</table>

## BATTERY MENU

The Battery menu parameters specify the nominal voltage and configure overvoltage and undervoltage protection. The menu also contains the BDI menu. The following table describes the parameters on the Battery menu.

BATTERY MENU

| PARAMETER<br>CAN INDEX | VALUES<br>RAW VALUES | DATA SIZE<br>READ/WRITE | ACCESS<br>LEVEL | DESCRIPTION |
|---|---|---|---|---|
| **Nominal Voltage**<br>`0x33A7:00` | 36–48V<br>*3600–4800* | 16-bit<br>RW | OEM Factory | Specifies the battery's nominal voltage. |
| **User Overvoltage**<br>`0x33A2:00` | 105–150%<br>*1075–1536* | 16-bit<br>RW | OEM Factory | Specifies the overvoltage threshold. The value is a percentage of the Nominal Voltage.<br>For more information, see Overvoltage and Undervoltage Protection. |
| **User Undervoltage**<br>`0x33A3:00` | 40–95%<br>*410–973* | 16-bit<br>RW | OEM Factory | Specifies the undervoltage threshold. The value is a percentage of the Nominal Voltage. |
| **Kp UV**<br>`0x338B:00` | 0.0–100.0%<br>*0–1024* | 16-bit<br>RW | OEM Factory | Specifies the undervoltage controller's proportional gain. The value is the desired percentage of cutback per volt. For example, a setting of 25% provides full cutback with 4V of droop.<br>**Note:** Typically, the Kp UV and Ki UV parameters are configured together to provide the best response. To specify a linear response, set Ki UV to 0%. |
| **Ki UV**<br>`0x3389:00` | 0–100%<br>*0–1024* | 16-bit<br>RW | OEM Factory | Specifies the undervoltage controller's integral gain, which accumulates the voltage droop and attempts to bring the battery droop back to 0V. Higher gains will react more strongly and quickly. |

## BDI MENU

The BDI menu contains parameters for configuring the controller's internal BDI. For more information on the controller's BDI functions and on configuring the internal BDI, see Battery Protection and BDI.

### BATTERY MENU — BDI MENU

| PARAMETER<br>CAN INDEX | VALUES<br>RAW VALUES | DATA SIZE<br>READ/WRITE | ACCESS<br>LEVEL | DESCRIPTION |
|---|---|---|---|---|
| **BDI Source**<br>0x33AC:00 | Enumerated<br>*0–2* | 8-bit<br>RW | OEM Dealer | Specifies the BDI data source:<br>0 = Internal BDI<br>1 = CAN BDI<br>2 = BMS BDI |
| **Full Charge Voltage**<br>0x339B:00 | 0.900–3.000V<br>*900–3000* | 16-bit<br>RW | OEM Dealer | Specifies the voltage above which the controller considers the battery as having finished charging. |
| **Start Charge Voltage**<br>0x339C:00 | 0.900–3.000V<br>*900–3000* | 16-bit<br>RW | OEM Dealer | Specifies the voltage above which the controller considers the battery as starting to charge. |
| **Reset Volts Per Cell**<br>0x33A0:00 | 0.900–3.000V<br>*900–3000* | 16-bit<br>RW | OEM Dealer | Specifies the battery voltage above which the controller resets the BDI percentage to 100% if both of the following conditions are true within two seconds after the controller was powered on:<br>• The battery voltage is greater than the Reset Volts Per Cell parameter.<br>• The BDI percentage is less than the BDI Reset Percent parameter.<br>Specify a voltage that is higher than the Full Volts Per Cell voltage. |
| **Full Volts Per Cell**<br>0x339E:00 | 0.900–3.000V<br>*900–3000* | 16-bit<br>RW | OEM Dealer | Specifies the battery cell voltage at which the battery is considered 100% charged. |
| **Empty Volts Per Cell**<br>0x339D:00 | 0.900–3.000V<br>*900–3000* | 16-bit<br>RW | OEM Dealer | Specifies the battery cell voltage at which the battery is considered 0% charged. |
| **BDI Reset Percent**<br>0x33A6:00 | 0–100%<br>*0–100* | 8-bit<br>RW | OEM Dealer | Specifies the percentage of battery voltage below which the controller will reset the BDI percentage to 100% if the conditions described in the Reset Volts Per Cell parameter description are met.<br>When a battery has a high BDI percentage, its float voltage when the keyswitch is powered on could cause false BDI resets. The BDI Reset Percent parameter lets you preempt this problem by specifying a minimum threshold for resetting the BDI percentage. |
| **Battery Charge Time**<br>0x33A1:00 | 1–600 minutes<br>*1–600* | 16-bit<br>RW | OEM Dealer | Specifies how many minutes it takes for the BDI percentage to increase from 0% to 100% while the battery is being charged.<br>Higher battery amp/hour ratings require a larger Battery Charge Time. |
| **Battery Discharge Time**<br>0x339F:00 | 1–600 minutes<br>*1–600* | 16-bit<br>RW | OEM Dealer | Specifies the period of time during which the battery voltage must be below the moving threshold before the controller will decrement the BDI percentage. |
| **Low BDI Threshold**<br>0x33AA:00 | 0–100%<br>*0–100* | 8-bit<br>RW | OEM Dealer | Specifies the BDI percentage at or below which the Low BDI fault occurs. |
| **Low BDI Max Speed**<br>0x33AE:00 | 20–80%<br>*6554–26214* | 16-bit<br>RW | OEM Dealer | Specifies the speed limit the controller will apply if a Low BDI fault occurs. |
| **Lift Lockout Threshold**<br>0x33A9:00 | 0–100%<br>*0–100* | 8-bit<br>RW | OEM Dealer | Specifies the BDI percentage at or below which the controller disables the hydraulic lift to prevent battery damage. |

## MOTOR MENU

The following table describes the Motor menu's parameters.

**Note:** The Motor menu also contains the Motor Driving Phases and Motor Temperature menus.

MOTOR MENU

| PARAMETER<br>CAN INDEX | VALUES<br>RAW VALUES | DATA SIZE<br>READ/WRITE | ACCESS<br>LEVEL | DESCRIPTION |
|---|---|---|---|---|
| **Max Speed**<br>`0x380F:00` | 500–8000 RPM<br>*500–8000* | 16-bit<br>RW | OEM Dealer | Specifies the maximum speed of the motor. To set this parameter, take the following steps:<br>1. Set the Enable parameter on the Speed Limit Supervision menu to Off.<br>2. Apply full PWM to drive the motor without a load.<br>3. Set Max Speed to the value indicated by the Motor RPM parameter. |
| **Pole Pairs [PCF]**<br>`0x353A:00` | 1–36<br>*1–36* | 16-bit<br>RW | OEM Dealer | Specifies the motor's number of pole pairs. |
| **Swap Motor Direction [PCF]**<br>`0x353B:00` | Off/On<br>*0–1* | 8-bit<br>RW | OEM Dealer | Changes the motor's running direction. |
| **Stall Fault Time**<br>`0x3510:00` | 0–32s<br>*0–8000* | 16-bit<br>RW | OEM Dealer | Specifies how long the controller must detect the motor as not moving before a Stall Detected fault can occur.<br>A Stall Detected fault occurs when the motor speed is less than the Stall Fault Speed for the Stall Fault Time and one of the following conditions is true:<br>• Armature PWM is greater than Stall Fault PWM; or<br>• Armature Current is greater than 90% of the Drive Current Limit.<br>To disable stall fault detection, specify 0.<br>The Armature PWM and Armature Current parameters are on the Monitor menu's Motor menu. |
| **Stall Fault PWM**<br>`0x3511:00` | 25–100%<br>*8192–32767* | 16-bit<br>RW | OEM Dealer | Specifies the motor PWM threshold that indicates the motor is not moving. |
| **Stall Fault Speed**<br>`0x3512:00` | 20–200 RPM<br>*20–200* | 8-bit<br>RW | OEM Dealer | Specifies the motor speed threshold that indicates the motor is not moving. |

## Motor Driving Phases Menu

The Motor Driving Phases parameters specify the UVW output steps that correspond to the Hall sensor states. These parameters are set by the function that automatically characterizes the Hall sensors; see Characterize the Hall Sensors and UVW Output.

The following table describes the parameters. Parameter values 1 through 6 represent UVW output steps 1 through 6. Parameter value 0 indicates the parameter is not used. Parameter value 7 is reserved for future use.

**MOTOR MENU — MOTOR DRIVING PHASES MENU**

| PARAMETER<br>CAN INDEX | VALUES<br>RAW VALUES | DATA SIZE<br>READ/WRITE | ACCESS LEVEL | DESCRIPTION |
|---|---|---|---|---|
| **Driving Phase At Hall State 0**<br>`0x3520:00` | 0–7<br>*0–7* | 8-bit<br>RW | OEM Dealer | *Reserved.* |
| **Driving Phase At Hall State 1**<br>`0x3521:00` | 0–7<br>*0–7* | 8-bit<br>RW | OEM Dealer | Specifies the output step for Hall sensor state 1. |
| **Driving Phase At Hall State 2**<br>`0x3522:00` | 0–7<br>*0–7* | 8-bit<br>RW | OEM Dealer | Specifies the output step for Hall sensor state 2. |
| **Driving Phase At Hall State 3**<br>`0x3523:00` | 0–7<br>*0–7* | 8-bit<br>RW | OEM Dealer | Specifies the output step for Hall sensor state 3. |
| **Driving Phase At Hall State 4**<br>`0x3524:00` | 0–7<br>*0–7* | 8-bit<br>RW | OEM Dealer | Specifies the output step for Hall sensor state 4. |
| **Driving Phase At Hall State 5**<br>`0x3525:00` | 0–7<br>*0–7* | 8-bit<br>RW | OEM Dealer | Specifies the output step for Hall sensor state 5. |
| **Driving Phase At Hall State 6**<br>`0x3526:00` | 0–7<br>*0–7* | 8-bit<br>RW | OEM Dealer | Specifies the output step for Hall sensor state 6. |
| **Driving Phase At Hall State 7**<br>`0x3527:00` | 0–7<br>*0–7* | 8-bit<br>RW | OEM Dealer | *Reserved.* |

## Motor Temperature Menu

The following table describes the Motor Temperature parameters:

**MOTOR MENU — MOTOR TEMPERATURE MENU**

| PARAMETER<br>CAN INDEX | VALUES<br>RAW VALUES | DATA SIZE<br>READ/WRITE | ACCESS<br>LEVEL | DESCRIPTION |
|---|---|---|---|---|
| **Sensor Type**<br>`0x3546:00` | Enumerated<br>*0–6* | 8-bit<br>RW | OEM Dealer | Specifies the type of temperature sensor used by the vehicle. The following values represent the controller's predefined sensor types:<br>0 = Null<br>1 = KTY83-122<br>2 = Two KTY83-122 sensors in series<br>3 = KTY84-130 or KTY84-150<br>4 = Two KTY84-130 or KTY84-150 sensors in series<br>5 = PT1000<br>6 = PT100<br>The industry standard KTY temperature sensors are silicon temperature sensors with a polarity band (cathode). The polarity band must be connected to I/O Ground. |
| **Sensor Temp Offset**<br>`0x3545:00` | –20°C to 20°C<br>*–200 to +200* | 16-bit<br>RW | OEM Dealer | Specifies a temperature by which the controller compensates for known offsets in the vehicle system's components. Use this parameter to handle conditions such as the following:<br>• The sensor is placed in the motor at a location with a known offset to the critical temperature.<br>• The sensor itself has a known offset. |
| **Temperature Hot**<br>`0x3541:00` | 0°C–200°C<br>*0–2000* | 16-bit<br>RW | OEM Dealer | Specifies the temperature at which the controller starts cutting back current. |
| **Temperature Max**<br>`0x3543:00` | 0°C–200°C<br>*0–2000* | 16-bit<br>RW | OEM Dealer | Specifies the temperature at which the controller cuts back current to zero. |
| **Motor Temp LOS Max Speed**<br>`0x3542:00` | 0–100%<br>*0–32767* | 16-bit<br>RW | OEM Dealer | Specifies the maximum speed after a Motor Temperature Fault occurs. The value is a percentage of the application's maximum speed.<br>When a Motor Temperature Fault occurs, the controller applies a limited operating strategy (LOS) that reduces the maximum speed by the specified percentage. |
| **Current Rating**<br>`0x3548:00` | 5–60A<br>*20–240* | 16-bit<br>RW | OEM Dealer | Specifies the motor's current rating. Use the rating provided by the motor's manufacturer. |
| **Max Current Time**<br>`0x3549:00` | 0–120s<br>*0–120* | 16-bit<br>RW | OEM Dealer | Specifies how long the motor runs at full current if the motor has overheated. The controller cuts back current after this timeout has expired. |
| **Cutback Gain**<br>`0x354A:00` | 0–100%<br>*0–255* | 16-bit<br>RW | OEM Dealer | Specifies how quickly the controller cuts back current if the motor has overheated and the Max Current Time has expired.<br>Higher values provide a quicker cutback. |

# EMERGENCY REVERSE MENU

The following table describes the Emergency Reverse parameters.

## EMERGENCY REVERSE MENU

| PARAMETER<br>CAN INDEX | VALUES<br>RAW VALUES | DATA SIZE<br>READ/WRITE | ACCESS<br>LEVEL | DESCRIPTION |
|---|---|---|---|---|
| **EMR Input Type [PCF]**<br>0x3498:00 | Enumerated<br>*0–3* | 8-bit<br>RW | OEM Dealer | Specifies the input(s) for emergency reverse:<br>0 = NO switch<br>1 = NC switch<br>2 = Complementary NO and NC switches<br>3 = CAN switch<br>If an NC switch is used, one of the Switch *n* Function parameters must be set to EMR NC Switch, otherwise a Parameter Fault (type 6) will occur. |
| **EMR Current Limit**<br>0x3443:00 | 10–60A<br>*40–240* | 16-bit<br>RW | OEM Dealer | Specifies the maximum current during emergency reverse operations. |
| **EMR Time Limit**<br>0x3497:00 | 0–15s<br>*0–3750* | 16-bit<br>RW | OEM Dealer | Specifies how long emergency reverse is active after the vehicle starts moving in reverse. |
| **EMR Speed**<br>0x3496:00 | 10–100%<br>*3276–32767* | 16-bit<br>RW | OEM Dealer | Specifies the maximum vehicle speed during emergency reverse. The value is a percentage of the maximum speed. |
| **EMR Accel Rate**<br>0x3492:00 | 0.1–1.0s<br>*50–500* | 16-bit<br>RW | OEM Dealer | Specifies the rate at which the vehicle accelerates in the opposite direction after emergency reverse stops the vehicle. |
| **EMR Decel Rate**<br>0x3493:00 | 0.1–1.0s<br>*50–500* | 16-bit<br>RW | OEM Dealer | Specifies the rate at which the vehicle brakes to a stop when emergency reverse is activated. |
| **EMR SRO Enable**<br>0x335A:00 | Off/On<br>*0–1* | 8-bit<br>RW | OEM Dealer | Specifies whether the controller generates an EMR SRO Fault if any of the conditions in the fault's description occur. |
| **EMR Interlock**<br>0x3499:00 | Off/On<br>*0–1* | 8-bit<br>RW | OEM Dealer | Specifies whether the interlock must be cleared before the operator resumes driving after an emergency reverse operation:<br>On = The interlock, direction switches, and throttle must be cleared.<br>Off = Only the direction switches and throttle must be cleared. |

## INPUTS MENU

The Inputs parameters specify the inputs used for various functions. The Switch 1 Function through Switch 4 Function parameters specify the functions used by the flexible switch inputs. The other parameters assign functions to inputs.

For information on assigning functions to flexible switch inputs, see Flexible Switch Inputs.

The Switch 1 Function through Switch 4 Function parameters allow the values listed in the following table.

**Table 4-2 Allowed Values for Switch *n* Function Parameters**

| Enumerated Value | Numeric Value |
|---|---|
| None. (This indicates the corresponding flexible switch input is not used.) | 0 |
| Lift switch | 1 |
| Lower switch | 2 |
| Creep switch | 3 |
| Push switch | 4 |
| Lift Lockout switch | 5 |
| Horn switch | 6 |
| EMR NC (emergency reverse normally closed) switch | 7 |
| Steering switch | 8 |
| Inhibit switch | 9 |
| Analog Input 1 (*Switch 1 Function only*) | 10 |
| Analog Input 2 (*Switch 2 Function only*) | |
| BB Check Switch (*Switch 3 Function only*) | |
| Flex Node ID (*Switch 4 Function only*) | |

The following table describes the Inputs parameters:

INPUTS MENU

| PARAMETER<br>CAN INDEX | VALUES<br>RAW VALUES | DATA SIZE<br>READ/WRITE | ACCESS<br>LEVEL | DESCRIPTION |
|---|---|---|---|---|
| **Switch 1 Function**<br>`0x3330:00` | Enumerated<br>*0–10* | 8-bit<br>RW | OEM Dealer | Specifies the switch 1 input's function. Table 4-2 lists the allowed values. |
| **Switch 2 Function**<br>`0x3331:00` | Enumerated<br>*0–10* | 8-bit<br>RW | OEM Dealer | Specifies the switch 2 input's function. Table 4-2 lists the allowed values. |
| **Switch 3 Function**<br>`0x3332:00` | Enumerated<br>*0–10* | 8-bit<br>RW | OEM Dealer | Specifies the switch 3 input's function. Table 4-2 lists the allowed values. |
| **Switch 4 Function**<br>`0x3333:00` | Enumerated<br>*0–10* | 8-bit<br>RW | OEM Dealer | Specifies the switch 4 input's function. Table 4-2 lists the allowed values. |
| **Analog 1 High Threshold**<br>`0x333C:00` | 0.0–10.0V<br>*0–1000* | 16-bit<br>RW | OEM Dealer | Specifies the voltage that defines the analog 1 input's high level. |
| **Analog 2 High Threshold**<br>`0x333D:00` | 0.0–10.0V<br>*0–1000* | 16-bit<br>RW | OEM Dealer | Specifies the voltage that defines the analog 2 input's high level. |
| **Lift Input Source**<br>`0x3334:00` | Enumerated<br>*0–1* | 8-bit<br>RW | OEM Dealer | Specifies the lift input's source:<br>0 = Lift Switch<br>1 = CAN Lift |
| **Lower Input Source**<br>`0x3335:00` | Enumerated<br>*0–1* | 8-bit<br>RW | OEM Dealer | Specifies the lower input's source:<br>0 = Lower Switch<br>1 = CAN Lower |
| **Creep Input Source**<br>`0x3336:00` | Enumerated<br>*0–1* | 8-bit<br>RW | OEM Dealer | Specifies the creep input's source:<br>0 = Creep Switch<br>1 = CAN Creep |
| **Push Input Source**<br>`0x3337:00` | Enumerated<br>*0–1* | 8-bit<br>RW | OEM Dealer | Specifies the push input's source:<br>0 = Push Switch<br>1 = CAN Push |
| **Mode Input Source**<br>`0x3338:00` | Enumerated<br>*0–2* | 8-bit<br>RW | OEM Dealer | Specifies the mode input's source:<br>0 = NO Switch<br>1 = NC Switch<br>2 = CAN Mode |
| **Lift Lockout Input Source**<br>`0x3339:00` | Enumerated<br>*0–2* | 8-bit<br>RW | OEM Dealer | Specifies the lift lockout input's source:<br>0 = Lift Lockout Switch<br>1 = CAN Lift Lockout<br>2 = BDI Lockout |
| **Inhibit Input Source**<br>`0x333E:00` | Enumerated<br>*0–1* | 8-bit<br>RW | OEM Dealer | Specifies the inhibit input's source:<br>0 = Inhibit Switch<br>1 = CAN Inhibit |
| **Lift Inhibit Input Source**<br>`0x333B:00` | Enumerated<br>*0–1* | 8-bit<br>RW | OEM Dealer | Specifies the lift inhibit input's source:<br>0 = NO Switch<br>1 = NC Switch |
| **Horn Input Source**<br>`0x333A:00` | Enumerated<br>*0–1* | 8-bit<br>RW | OEM Dealer | Specifies the horn input's source:<br>0 = Horn Switch<br>1 = CAN Horn |

## OUTPUTS MENU

The following table describes the parameters on the Outputs menu:

OUTPUTS MENU

| PARAMETER<br>CAN INDEX | VALUES<br>RAW VALUES | DATA SIZE<br>READ/WRITE | ACCESS<br>LEVEL | DESCRIPTION |
|---|---|---|---|---|
| **Lift Driver Fault Enable**<br>`0x3404:00` | Off/On<br>*0–1* | 8-bit<br>RW | OEM Dealer | Indicates whether the lift driver fault check is enabled. If the check is enabled, the controller generates a Driver Fault (type 2) if it detects either of the following conditions:<br>• The driver is off and the coil is open.<br>• The driver is on and the coil is shorted. |
| **Lower Driver Fault Enable**<br>`0x3405:00` | Off/On<br>*0–1* | 8-bit<br>RW | OEM Dealer | Indicates whether the lower driver fault check is enabled. If the check is enabled, the controller generates a Driver Fault (type 3) if it detects either of the following conditions:<br>• The driver is off and the coil is open.<br>• The driver is on and the coil is shorted. |
| **Lift Pull In Voltage**<br>`0x3407:00` | 0–100%<br>*0–255* | 8-bit<br>RW | OEM Dealer | Specifies the lift driver's initial voltage when the driver is turned on.<br>Specify a voltage high enough to ensure that the lift contactor engages. |
| **Lift Holding Voltage**<br>`0x3408:00` | 0–100%<br>*0–255* | 8-bit<br>RW | OEM Dealer | Specifies the average voltage the controller applies to the lift driver. |
| **Lower Pull In Voltage**<br>`0x3409:00` | 0–100%<br>*0–255* | 8-bit<br>RW | OEM Dealer | Specifies the lower driver's initial voltage when the driver is turned on.<br>Specify a voltage high enough to ensure that the lower valve engages. |
| **Lower Holding Voltage**<br>`0x340A:00` | 0–100%<br>*0–255* | 8-bit<br>RW | OEM Dealer | Specifies the average voltage the controller applies to the lower driver. |
| **Lift Time Limit**<br>`0x340D:00` | 0–120s<br>*0–120* | 8-bit<br>RW | OEM Dealer | Specifies the maximum duration of a lift operation while the lift input is active. When the time limit expires, the controller stops supplying power to the lift.<br>To disable the lift time limit, specify 0. |
| **Lift On Interlock**<br>`0x3410:00` | Off/On<br>*0–1* | 8-bit<br>RW | OEM Dealer | Specifies whether lift operations are available only when the interlock is on. |
| **Lower On Interlock**<br>`0x3411:00` | Off/On<br>*0–1* | 8-bit<br>RW | OEM Dealer | Specifies whether lower operations are available only when the interlock is on. |

## CAN INTERFACE MENU

The following table describes the parameters contained by the CAN Interface menu.

**Note:** The CAN Interface menu also contains the PDO Setups menu, which contains the PDO Byte Map menus; see RPDO and TPDO Byte Map Menus.

CAN INTERFACE MENU

| PARAMETER<br>CAN INDEX | VALUES<br>RAW VALUES | DATA SIZE<br>READ/WRITE | ACCESS<br>LEVEL | DESCRIPTION |
|---|---|---|---|---|
| **Baud Rate**<br>`0x2001:01` | Enumerated<br>*–1 to +4* | 16-bit<br>RW | OEM Dealer | Specifies the CAN baud rate:<br>–1 = 100 Kbps<br>0 = 125 Kbps<br>1 = 250 Kbps<br>2 = 500 Kbps<br>3 = 800 Kbps<br>4 = 1 Mbps |
| **Heartbeat Rate**<br>`0x1017:00` | 0–2000ms<br>*0–2000* | 16-bit<br>RW | OEM Dealer | Specifies the cyclic rate of the controller's heartbeat messages. |
| **Emergency Message Rate**<br>`0x1015:00` | 16–400ms<br>*4–100* | 32-bit<br>RW | OEM Dealer | Specifies the minimum time between emergency messages transmitted by the controller.<br>An interval between emergency messages prevents the controller from generating an excessive number of emergency messages that could otherwise flood the CANbus. |
| **CAN NMT State**<br>`0x32A4:00` | Enumerated<br>*0–127* | 16-bit<br>RO | OEM Dealer | Indicates the NMT state:<br>• 0 = Initialization<br>• 4 = Stopped<br>• 5 = Operational<br>• 127 = Pre-operational |
| **CAN Node ID 1**<br>`0x2000:01` | 1h–7Fh<br>*1–127* | 16-bit<br>RW | OEM Dealer | Specifies the controller's first node ID. If the Switch 4 Function parameter does not specify Flex Node ID, CAN Node ID 1 is always used as the controller's node ID.<br>**Note:** Node ID 127 is reserved for Curtis programming devices. |
| **CAN Node ID 2**<br>`0x3200:00` | 1h–7Fh<br>*1–127* | 16-bit<br>RW | OEM Dealer | Specifies the controller's second node ID. If the Switch 4 Function parameter specifies Flex Node ID, whether CAN Node ID 1 or CAN Node ID 2 is used as the node ID depends upon the state of switch input 4.<br>For more information, see Node IDs. |
| **BMS Node ID**<br>`0x33C0:00` | 1h–7Fh<br>*1–127* | 8-bit<br>RW | OEM Dealer | Specifies the node ID of the BMS if the BDI Source parameter is set to BMS BDI. |
| **BMS PDO Timeout**<br>`0x33C4:00` | 0–65535ms<br>*0–65535* | 16-bit<br>RW | OEM Dealer | Specifies the CAN communication timeout for the BMS. If a BMS is used for the BDI, a PDO Timeout fault (type 5) will be generated if the timeout expires before the controller receives a message from the BMS. |
| **Auto Operational**<br>`0x32B0:00` | Off/On<br>*0–1* | 8-bit<br>RW | OEM Factory | Specifies the controller's NMT state when the controller powers up:<br>Off = Pre-operational<br>On = Operational |

## RPDO and TPDO Byte Map Menus

The PDO Setups menu contains the RPDO 1–2 Byte Map and TPDO 1–2 Byte Map menus. These menus let you use Curtis programming devices to configure PDOs.

**Note:** The controller provides preconfigured PDOs for communicating with a CAN tiller head and a BMS. Modify a preconfigured PDO only if the application does not require the PDO's preconfigured function. For more information, see PDOs.

The menus contain parameters with the same names, allowed values, and data sizes. The only differences between parameters of the same name are their CAN indexes. For simplicity's sake, the following table describes the RPDO 1–2 Byte Map and TPDO 1–2 Byte Map menus' parameters and Table 4-3 lists the parameters' CAN indexes.

### CAN INTERFACE — RPDO AND TPDO BYTE MAP MENUS

| PARAMETER | VALUES<br>RAW VALUES | DATA SIZE<br>READ/WRITE | ACCESS<br>LEVEL | DESCRIPTION |
|---|---|---|---|---|
| **RPDO *n* Event Time** | 0–65535ms<br>*0–65535* | 16-bit<br>RW | OEM Factory | Specifies the RPDO's timeout. If the RPDO does not receive data before the timeout elapses, a PDO Timeout fault occurs.<br>To disable the timeout, specify 0. |
| **TPDO *n* Event Time** | 0–65535ms<br>*0–65535* | 16-bit<br>RW | OEM Factory | Specifies the cyclic rate of the TPDO's messages. |
| **RPDO *n* COB ID and TPDO *n* COB ID** | 0–FFFFFFFFh<br>*0–FFFFFFFFh* | 32-bit<br>RW | OEM Dealer | Specifies the PDO's COB-ID. |
| **Length** | 0–8<br>*0–8* | 8-bit<br>RW | OEM Dealer | Specifies the number of objects mapped to the PDO. |
| **Map 1** | 0–FFFFFFFFh<br>*0–FFFFFFFFh* | 32-bit<br>RW | OEM Dealer | Specifies the PDO's first mapped object. |
| **Map 2** | 0–FFFFFFFFh<br>*0–FFFFFFFFh* | 32-bit<br>RW | OEM Dealer | Specifies the PDO's second mapped object. |
| **Map 3** | 0–FFFFFFFFh<br>*0–FFFFFFFFh* | 32-bit<br>RW | OEM Dealer | Specifies the PDO's third mapped object. |
| **Map 4** | 0–FFFFFFFFh<br>*0–FFFFFFFFh* | 32-bit<br>RW | OEM Dealer | Specifies the PDO's fourth mapped object. |
| **Map 5** | 0–FFFFFFFFh<br>*0–FFFFFFFFh* | 32-bit<br>RW | OEM Dealer | Specifies the PDO's fifth mapped object. |
| **Map 6** | 0–FFFFFFFFh<br>*0–FFFFFFFFh* | 32-bit<br>RW | OEM Dealer | Specifies the PDO's sixth mapped object. |
| **Map 7** | 0–FFFFFFFFh<br>*0–FFFFFFFFh* | 32-bit<br>RW | OEM Dealer | Specifies the PDO's seventh mapped object. |
| **Map 8** | 0–FFFFFFFFh<br>*0–FFFFFFFFh* | 32-bit<br>RW | OEM Dealer | Specifies the PDO's eighth mapped object. |

**Table 4-3 PDO Mapping Objects — CAN Indexes**

| Parameter | PDO | CAN Index |
|---|---|---|
| RPDO 1 Event Time | RPDO1 | 0x1400:05 |
| RPDO 1 COB ID | RPDO1 | 0x1400:01 |
| Length | RPDO1 | 0x1600:00 |
| Map 1 | RPDO1 | 0x1600:01 |
| Map 2 | RPDO1 | 0x1600:02 |
| Map 3 | RPDO1 | 0x1600:03 |
| Map 4 | RPDO1 | 0x1600:04 |
| Map 5 | RPDO1 | 0x1600:05 |
| Map 6 | RPDO1 | 0x1600:06 |
| Map 7 | RPDO1 | 0x1600:07 |
| Map 8 | RPDO1 | 0x1600:08 |
| TPDO 1 Event Time | TPDO1 | 0x1800:05 |
| TPDO 1 COB ID | TPDO1 | 0x1800:01 |
| Length | TPDO1 | 0x1A00:00 |
| Map 1 | TPDO1 | 0x1A00:01 |
| Map 2 | TPDO1 | 0x1A00:02 |
| Map 3 | TPDO1 | 0x1A00:03 |
| Map 4 | TPDO1 | 0x1A00:04 |
| Map 5 | TPDO1 | 0x1A00:05 |
| Map 6 | TPDO1 | 0x1A00:06 |
| Map 7 | TPDO1 | 0x1A00:07 |
| Map 8 | TPDO1 | 0x1A00:08 |
| RPDO 2 Event Time | RPDO2 | 0x1401:05 |
| RPDO 2 COB ID | RPDO2 | 0x1401:01 |
| Length | RPDO2 | 0x1601:00 |
| Map 1 | RPDO2 | 0x1601:01 |
| Map 2 | RPDO2 | 0x1601:02 |
| Map 3 | RPDO2 | 0x1601:03 |
| Map 4 | RPDO2 | 0x1601:04 |
| Map 5 | RPDO2 | 0x1601:05 |
| Map 6 | RPDO2 | 0x1601:06 |
| Map 7 | RPDO2 | 0x1601:07 |
| Map 8 | RPDO2 | 0x1601:08 |

Table 4-3 PDO Mapping Objects — CAN Indexes, cont'd

| Parameter | PDO | CAN Index |
|---|---|---|
| TPDO 2 Event Time | TPDO2 | 0x1801:05 |
| TPDO 2 COB ID | TPDO2 | 0x1801:01 |
| Length | TPDO2 | 0x1A01:00 |
| Map 1 | TPDO2 | 0x1A01:01 |
| Map 2 | TPDO2 | 0x1A01:02 |
| Map 3 | TPDO2 | 0x1A01:03 |
| Map 4 | TPDO2 | 0x1A01:04 |
| Map 5 | TPDO2 | 0x1A01:05 |
| Map 6 | TPDO2 | 0x1A01:06 |
| Map 7 | TPDO2 | 0x1A01:07 |
| Map 8 | TPDO2 | 0x1A01:08 |

## PASSWORD MENU

The Password menu is used to log on in order to change parameter values; for more information, see Password Protection. The menu also contains the Change Password menu.

**Note:** The Password menu is visible only if the Password Enable parameter indicates On.

The following table describes the parameters on the Password menu.

PASSWORD MENU

| PARAMETER CAN INDEX | VALUES RAW VALUES | DATA SIZE READ/WRITE | ACCESS LEVEL | DESCRIPTION |
|---|---|---|---|---|
| **Password Status** 0x5106:00 | Enumerated *0–2* | 8-bit RO | OEM Factory | Indicates the password status. The value is updated when the Password Enter parameter or the Change Password menu's New Password Enter parameter is set to On:<br>0 = Failed: Parameter values cannot be changed. The status is Failed if no one has attempted to log on or if an invalid password was specified.<br>1 = Passed: A valid password has been specified and thus parameter values can be changed.<br>2 = N/A: No one has ever attempted to log on. |
| **Password Input** 0x5104:00 | 0–9999 *0–9999* | 16-bit RW | OEM Factory | Specifies the password. |
| **Password Enter** 0x5105:00 | Off/On *0–1* | 8-bit RW | OEM Factory | Specify On to log on. If Password Input specifies a valid password, the Password Status indicates Passed. |

### Change Password Menu

The Change Password menu is used to change the password. The password can be changed only if the Password Status parameter on the Password menu indicates Passed.

The following table describes the Change Password parameters.

PASSWORD MENU — CHANGE PASSWORD MENU

| PARAMETER<br>CAN INDEX | VALUES<br>RAW VALUES | DATA SIZE<br>READ/WRITE | ACCESS<br>LEVEL | DESCRIPTION |
|---|---|---|---|---|
| **New Password**<br>`0x5102:00` | 0–9999<br>*0–9999* | 16-bit<br>RW | OEM Factory | Specifies the new password. |
| **New Password Enter**<br>`0x5103:00` | Off/On<br>*0–1* | 8-bit<br>RW | OEM Factory | Specify On to apply the New Password value. After On is specified, the Password Status parameter on the Password menu should indicate Passed. |

## MISC MENU

The following table describes the parameters contained by the Misc menu:

MISC MENU

| PARAMETER<br>CAN INDEX | VALUES<br>RAW VALUES | DATA SIZE<br>READ/WRITE | ACCESS<br>LEVEL | DESCRIPTION |
|---|---|---|---|---|
| **Password Enable**<br>`0x5100:00` | Off/On<br>*0–1* | 8-bit<br>RO | OEM Dealer | Indicates whether the feature to password-protect parameter values is enabled. |
| **Pump SRO Enable**<br>`0x3359:00` | Off/On<br>*0–1* | 8-bit<br>RW | OEM Dealer | Specifies whether the controller checks for the Pump SRO Fault. |
| **First On Mode**<br>`0x3908:00` | Off/On<br>*0–1* | 8-bit<br>RW | OEM Dealer | Specifies whether first on work mode is enabled.<br>First on work mode protects the battery by inhibiting the traction and lift from being active at the same time. |
| **Sleep Time**<br>`0x4E30:00` | 0–120min<br>*0–120* | 8-bit<br>RW | OEM Dealer | Specifies how long the controller can be idle before it enters the sleep state.<br>To disable the sleep feature, specify 0. |
| **Clear Hourmeter 1**<br>`0x4E13:00` | Off/On<br>*0–1* | 8-bit<br>RW | OEM Factory | Specify On to reset hourmeter 1, which indicates how many hours the keyswitch has been on since the hourmeter was last cleared.<br>The hourmeter's values are indicated by the Hourmeter 1 parameter on the Controller menu. |
| **Clear Hourmeter 2**<br>`0x4E17:00` | Off/On<br>*0–1* | 8-bit<br>RW | OEM Factory | Specify On to reset hourmeter 2, which indicates how many hours the interlock has been on since the hourmeter was last cleared.<br>The hourmeter's values are indicated by the Hourmeter 2 parameter on the Controller menu. |
| **Restore Parameters**<br>`0x4E18:00` | Off/On<br>*0–1* | 8-bit<br>RW | OEM Factory | Specify On to reset all parameters to their default values. |

# 5 — MONITOR MENU PARAMETERS

The Monitor menu contains read-only parameters that indicate real-time data. You can use this data when you are configuring or troubleshooting the application.

**Note:** For descriptions of the columns in this chapter's parameter description tables, see Programming Menu Parameters. Since most of the Monitor menu parameters are read-only, the tables include the Read/Write column only for menus that contain writable parameters.

## CONTROLLER MENU

The following table describes the parameters on the Controller menu.

**Note:** The Controller menu contains the State menu.

CONTROLLER MENU

| PARAMETER NAME<br>CAN INDEX | VALUES<br>RAW VALUES | DATA SIZE | ACCESS LEVEL | DESCRIPTION |
|---|---|---|---|---|
| **Controller Temperature**<br>`0x3000:00` | –50°C to +200°C<br>*–500 to +2000* | 16-bit | Field Basic | Indicates the controller's heatsink temperature. |
| **Throttle Demand**<br>`0x3353:00` | –100% to +100%<br>*–32768 to +32767* | 16-bit | OEM Dealer | Indicates the throttle request. |
| **Speed Demand**<br>`0x3826:00` | –100% to +100%<br>*–32768 to +32767* | 16-bit | Field Basic | Indicates the speed command. |
| **Armature PWM**<br>`0x3538:00` | –100% to +100%<br>*–32768 to +32767* | 16-bit | Field Basic | Indicates the controller output's PWM duty cycle. |
| **Armature Current**<br>`0x3456:00` | –100A to +100A<br>–400 to +400 | 16-bit | Field Basic | Indicates the controller's phase current. |
| **Controller Temp Cutback**<br>`0x3436:00` | 0–100%<br>*0–4096* | 16-bit | Field Basic | Indicates the current available as a result of the temperature cutback function. The value is a percentage of the Drive Current Limit parameter.<br>100% indicates no cutback. |
| **Overvoltage Cutback**<br>`0x3439:00` | 0–100%<br>*0–4096* | 16-bit | Field Basic | Indicates the current available due to overvoltage cutback.<br>100% indicates no cutback. |
| **Undervoltage Cutback**<br>`0x343A:00` | 0–100%<br>*0–4096* | 16-bit | Field Basic | Indicates the current available due to undervoltage cutback.<br>100% indicates no cutback. |
| **Hourmeter 1**<br>`0x4E11:00` | 0–999999.9 hours<br>*0–9999999* | 32-bit | Field Basic | Indicates how many hours the keyswitch has been on since the hourmeter was last cleared. |
| **Hourmeter 2**<br>`0x4E15:00` | 0–999999.9 hours<br>*0–9999999* | 32-bit | Field Basic | Indicates how many hours the interlock has been on since the hourmeter was last cleared. |

## State Menu

The following table describes the parameters on the State menu.

### CONTROLLER MENU — STATE MENU

| PARAMETER NAME<br>CAN INDEX | VALUES<br>RAW VALUES | DATA SIZE | ACCESS LEVEL | DESCRIPTION |
|---|---|---|---|---|
| **Boost**<br>`0x3430:00` | Off/On<br>*0–1* | 8-bit | Field Basic | Indicates whether the boost function is on. |
| **Emergency Reverse**<br>`0x3491:00` | Off/On<br>*0–1* | 8-bit | Field Basic | Indicates whether emergency reverse is on. |
| **Push State**<br>`0x3866:00` | Off/On<br>*0–1* | 8-bit | OEM Dealer | Indicates whether push mode is on. |
| **Relay State**<br>`0x34C9:00` | Enumerated<br>*0–11* | 16-bit | Field Basic | Indicates the main relay state:<br>0 = Relay is open<br>1 = Precharge<br>2 = Main Relay Welded fault check<br>3 = Closing delay. The relay has closed but its status is being confirmed.<br>4 = Missing check. The controller is verifying whether the relay has closed.<br>5 = Relay is closed<br>6 = Delay. The relay has received the open command but remains closed until the Open Delay expires.<br>7 = Arc check<br>8 = Open delay. The relay is open but is within a delay interval before the relay can be closed again.<br>9 = Fault<br>10 = Enable<br>11 = Main Relay Welded fault check delay |

## MOTOR MENU

The following table describes the parameters on the Motor menu.

### MOTOR MENU

| PARAMETER NAME<br>CAN INDEX | VALUES<br>*RAW VALUES* | DATA SIZE | ACCESS LEVEL | DESCRIPTION |
|---|---|---|---|---|
| **Hall Input State**<br>`0x3532:00` | 0–7<br>*0–7* | 16-bit | Field Basic | Indicates the Hall sensor state. |
| **Motor RPM**<br>`0x3530:00` | –32768 to +32767 RPM<br>*–32768 to +32767* | 16-bit | Field Basic | Indicates the motor speed and direction detected by the controller. A positive number indicates the forward direction.<br>If the Speed Demand parameter indicates the wrong direction, toggle the Swap Speed Direction parameter. |
| **Motor Temperature**<br>`0x3004:00` | –50ºC to +200ºC<br>*–500 to +2000* | 16-bit | Field Basic | Indicates the temperature measured by the motor temperature sensor. |
| **Motor Temp Cutback**<br>`0x3438:00` | 0–100%<br>*0–4096* | 16-bit | Field Basic | Indicates the current cutback that occurs if the Motor Temperature is within the range specified by the Temperature Hot and Temperature Max parameters. The value is a percentage of the maximum current, with 100% indicating no cutback. |
| **Energy Integral Cutback**<br>`0x3437:00` | 0–100%<br>*0–4096* | 16-bit | Field Basic | Indicates the current cutback that occurs due to motor heating and heat dissipation. The value is a percentage of the maximum current, with 100% indicating no cutback. |
| **Steering Angle**<br>`0x3849:00` | –90ºC to +90ºC<br>*–16384 to +16383* | 16-bit | Field Basic | Indicates the steering input's angle. |
| **Steering Speed Cutback**<br>`0x384A:00` | 0–100%<br>*0–32767* | 16-bit | Field Basic | Indicates the motor speed cutback that occurs at certain steering angles. The value is a percentage of the maximum speed, with 100% indicating no cutback.<br>**Note:** The parameters on the Steering Speed Limit menu configure the speed limits for various steering angles. |

## VOLTAGE MENU

The following table describes the parameters on the Voltage menu.

VOLTAGE MENU

| PARAMETER NAME<br>CAN INDEX | VALUES<br>RAW VALUES | DATA SIZE<br>READ/WRITE | ACCESS<br>LEVEL | DESCRIPTION |
|---|---|---|---|---|
| **Keyswitch Voltage**<br>`0x3398:00` | 0.0–105.0V<br>*0–10500* | 16-bit<br>RO | Field Basic | Indicates the keyswitch voltage, which will be approximately equal to the Battery Voltage. |
| **Keyswitch Voltage Supervisor**<br>`0x3370:00` | 0.0–105.0V<br>*0–10500* | 16-bit<br>RO | Field Basic | Indicates the keyswitch voltage as measured by the supervisor microprocessor. |
| **Battery Voltage**<br>`0x3396:00` | 0.0–108.0V<br>*0–10800* | 16-bit<br>RO | Field Basic | Indicates the voltage at the controller's B+ terminal. |
| **Capacitor Voltage**<br>`0x3397:00` | 0.0–108.0V<br>*0–10800* | 16-bit<br>RO | Field Basic | Indicates the voltage at the controller's internal capacitor bank. |
| **Five Volts Supply**<br>`0x3600:00` | 0.00–10.00V<br>*0–1000* | 16-bit<br>RO | Field Basic | Indicates the voltage at the +5V power supply (pin J1-1). |
| **BDI**<br>`0x33A4:00` | 0–100%<br>*0–100* | 8-bit<br>RO | Field Basic | Indicates the battery's state of charge. |
| **Battery Temperature**<br>`0x33C3:00` | –100ºC to +155ºC<br>*0–255* | 8-bit<br>RW | Field Basic | Indicates the battery temperature measured by the BMS. |
| **BMS Status**<br>`0x33C2:00` | 0–255<br>*0–255* | 8-bit<br>RW | Field Basic | Bit 7 indicates the BMS's charging status. 1 indicates that the battery is charging. |

## INPUTS MENU

The following table describes the parameters on the Inputs menu.

INPUTS MENU

| PARAMETER NAME<br>CAN INDEX | VALUES<br>RAW VALUES | DATA SIZE | ACCESS LEVEL | DESCRIPTION |
|---|---|---|---|---|
| **Interlock State**<br>`0x3300:00` | Off/On<br>*0–1* | 8-bit | Field Basic | Indicates whether the interlock input is on or off. |
| **Lift Input State**<br>`0x3301:00` | Off/On<br>*0–1* | 8-bit | Field Basic | Indicates whether the lift input is on or off. |
| **Lift Lockout Input State**<br>`0x330C:00` | Off/On<br>*0–1* | 8-bit | Field Basic | Indicates whether the lift lockout input is on or off. |
| **Lower Input State**<br>`0x3302:00` | Off/On<br>*0–1* | 8-bit | Field Basic | Indicates whether the lower input is on or off. |
| **Forward Input State**<br>`0x3303:00` | Off/On<br>*0–1* | 8-bit | Field Basic | Indicates whether the forward input is on or off. |
| **Reverse Input State**<br>`0x3304:00` | Off/On<br>*0–1* | 8-bit | Field Basic | Indicates whether the reverse input is on or off. |
| **EMR Input State**<br>`0x3306:00` | Off/On<br>*0–1* | 8-bit | Field Basic | Indicates whether the emergency reverse input is on or off. |
| **Mode Input State**<br>`0x3305:00` | Off/On<br>*0–1* | 8-bit | Field Basic | Indicates whether the mode input is on or off. |
| **Horn Input State**<br>`0x3309:00` | Off/On<br>*0–1* | 8-bit | Field Basic | Indicates whether the horn input is on or off. |
| **Inhibit Input State**<br>`0x330D:00` | Off/On<br>*0–1* | 8-bit | Field Basic | Indicates whether the inhibit input is on or off. |
| **Lift Inhibit Input State**<br>`0x330A:00` | Off/On<br>*0–1* | 8-bit | Field Basic | Indicates whether the lift inhibit input is on or off. |
| **Charger Inhibit Input State**<br>`0x330B:00` | Off/On<br>*0–1* | 8-bit | Field Basic | Indicates whether the charger inhibit input is on or off. |
| **Creep Input State**<br>`0x3307:00` | Off/On<br>*0–1* | 8-bit | Field Basic | Indicates whether the creep input is on or off. |
| **Push Input State**<br>`0x3308:00` | Off/On<br>*0–1* | 8-bit | Field Basic | Indicates whether the push input is on or off. |
| **Analog 1 Input Voltage**<br>`0x3375:00` | 0–20.00V<br>*0–2000* | 16-bit | Field Basic | Indicates the analog 1 input's voltage. |
| **Analog 2 Input Voltage**<br>`0x3376:00` | 0–20.00V<br>*0–2000* | 16-bit | Field Basic | Indicates the analog 2 input's voltage. |

# SWITCHES MENU

The Switches menu contains the Primary Switches and Supervisor Switches menus. Some functions, such as the interlock and emergency reverse functions, are represented by parameters on both of these menus. This reflects the controller's Designated Architecture 2 design; the supervisor microprocessor monitors circuits on the primary microprocessor.

## Primary Switches Menu

The following table describes the parameters on the Primary Switches menu:

SWITCHES MENU — PRIMARY SWITCHES MENU

| PARAMETER NAME<br>CAN INDEX | VALUES<br>RAW VALUES | DATA SIZE | ACCESS LEVEL | DESCRIPTION |
|---|---|---|---|---|
| **Input 1 Switch**<br>`0x3310:00` | Off/On<br>*0–1* | 8-bit | Field Basic | Indicates whether the switch 1/analog 1 input is on or off. |
| **Input 2 Switch**<br>`0x3311:00` | Off/On<br>*0–1* | 8-bit | Field Basic | Indicates whether the switch 2/analog 2 input is on or off. |
| **Input 3 Switch**<br>`0x3312:00` | Off/On<br>*0–1* | 8-bit | Field Basic | Indicates whether the switch 3 input is on or off. |
| **Input 4 Switch**<br>`0x3313:00` | Off/On<br>*0–1* | 8-bit | Field Basic | Indicates whether the switch 4 input is on or off. |
| **Forward Switch**<br>`0x3314:00` | Off/On<br>*0–1* | 8-bit | Field Basic | Indicates whether the forward input is on or off. |
| **Reverse Switch**<br>`0x3315:00` | Off/On<br>*0–1* | 8-bit | Field Basic | Indicates whether the reverse input is on or off. |
| **EMR NO Switch**<br>`0x3316:00` | Off/On<br>*0–1* | 8-bit | Field Basic | Indicates whether the emergency reverse NO input is on or off. |
| **Interlock Switch**<br>`0x3317:00` | Off/On<br>*0–1* | 8-bit | Field Basic | Indicates whether the interlock input is on or off. |
| **Mode Switch**<br>`0x3318:00` | Off/On<br>*0–1* | 8-bit | Field Basic | Indicates whether the mode input is on or off. |
| **Lift Inhibit Switch**<br>`0x3319:00` | Off/On<br>*0–1* | 8-bit | Field Basic | Indicates whether the lift inhibit input is on or off. |
| **Charger Inhibit Switch**<br>`0x331A:00` | Off/On<br>*0–1* | 8-bit | Field Basic | Indicates whether the charger inhibit input is on or off. |

### Supervisor Switches Menu

The following table describes the parameters on the Supervisor Switches menu:

SWITCHES MENU — SUPERVISOR SWITCHES MENU

| PARAMETER NAME<br>CAN INDEX | VALUES<br>RAW VALUES | DATA SIZE | ACCESS LEVEL | DESCRIPTION |
|---|---|---|---|---|
| **Interlock Switch Supervisor**<br>`0x3325:00` | Off/On<br>*0–1* | 8-bit | Field Basic | Indicates whether the supervisor microprocessor's interlock switch is on or off. |
| **Reverse Switch Supervisor**<br>`0x3326:00` | Off/On<br>*0–1* | 8-bit | Field Basic | Indicates whether the supervisor microprocessor's reverse switch is on or off. |
| **Forward Switch Supervisor**<br>`0x3327:00` | Off/On<br>*0–1* | 8-bit | Field Basic | Indicates whether the supervisor microprocessor's forward switch is on or off. |
| **EMR NO Switch Supervisor**<br>`0x3328:00` | Off/On<br>*0–1* | 8-bit | Field Basic | Indicates whether the supervisor microprocessor's emergency reverse NO switch is on or off. |
| **Input 3 Switch Supervisor**<br>`0x3329:00` | Off/On<br>*0–1* | 8-bit | Field Basic | Indicates whether the supervisor microprocessor's input 3 switch is on or off. |
| **Input 4 Switch Supervisor**<br>`0x332A:00` | Off/On<br>*0–1* | 8-bit | Field Basic | Indicates whether the supervisor microprocessor's input 4 switch is on or off. |
| **EM Brake Driver Feedback**<br>`0x332B:00` | Off/On<br>*0–1* | 8-bit | Field Basic | Indicates the feedback state of the electromagnetic brake driver. |
| **Lower Driver Feedback**<br>`0x332C:00` | Off/On<br>*0–1* | 8-bit | Field Basic | Indicates the feedback state of the lower driver. |
| **Lift Driver Feedback**<br>`0x332D:00` | Off/On<br>*0–1* | 8-bit | Field Basic | Indicates the feedback state of the lift driver. |

## OUTPUTS MENU

The following table describes the parameters on the Outputs menu.

OUTPUT MENU

| PARAMETER NAME<br>CAN INDEX | VALUES<br>RAW VALUES | DATA SIZE | ACCESS LEVEL | DESCRIPTION |
|---|---|---|---|---|
| **Main Relay Driver PWM**<br>`0x34D2:00` | 0–100%<br>*0–32767* | 16-bit | Field Basic | Indicates the main relay driver's PWM duty cycle. |
| **EM Brake Driver PWM**<br>`0x3400:00` | 0–100%<br>*0–255* | 8-bit | Field Basic | Indicates the electromagnetic brake driver's PWM duty cycle. |
| **Lift Driver PWM**<br>`0x3401:00` | 0–100%<br>*0–255* | 8-bit | Field Basic | Indicates the lift driver's PWM duty cycle. |
| **Lower Driver PWM**<br>`0x3402:00` | 0–100%<br>*0–255* | 8-bit | Field Basic | Indicates the lower driver's PWM duty cycle. |
| **Horn Driver State**<br>`0x340C:00` | Off/On<br>*0–1* | 8-bit | Field Basic | Indicates whether the horn driver is on or off. |

# 6 — FAULT HISTORY MENU

The Fault History menu lists the faults that have occurred since the fault history was last cleared. Each fault's history includes the Count, Time, First Time, and Type parameters, as shown in the following screenshots from the Curtis Integrated Toolkit™ (CIT) and the Curtis 1313 handheld programmer:

**Figure 6-1**
*Fault History Details — CIT*

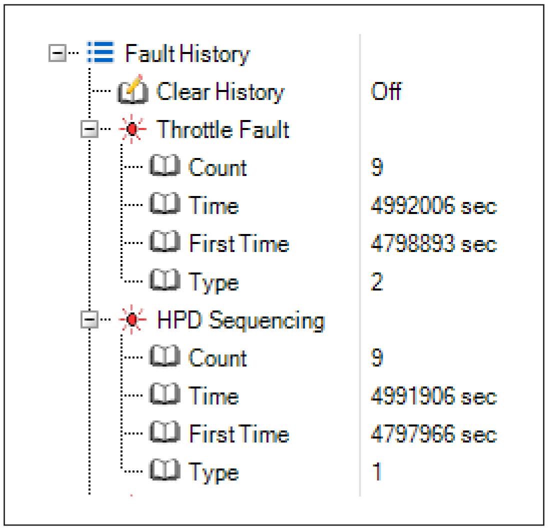
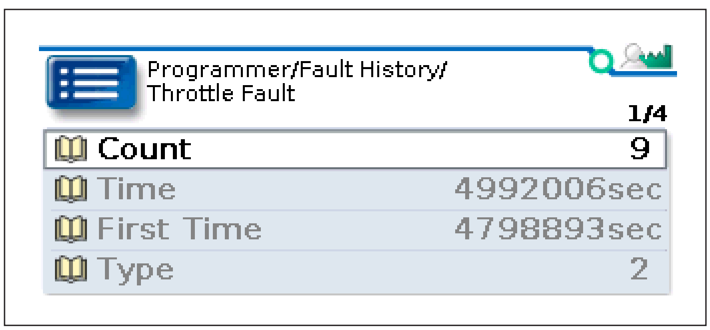



**Figure 6-2**
*Fault History Details — 1313 Programmer*




The menu also provides the Clear History parameter:

| PARAMETER<br>CAN INDEX | VALUES<br>RAW VALUES | DATA SIZE<br>READ/WRITE | ACCESS<br>LEVEL | DESCRIPTION |
|---|---|---|---|---|
| **Clear History**<br>`0x20F0:01` | Off/On<br>*0–1* | 16-bit<br>RW | Field Basic | Clears the fault history. To clear the history, specify On.<br>After the fault history has been cleared, the value reverts to Off. |

# 7 — FAULTS, DIAGNOSTICS, AND TROUBLESHOOTING

The controller provides diagnostic information to help technicians troubleshoot. You can view the diagnostic information using Curtis programming devices and the controller's status LED.

## PROGRAMMING DEVICE DIAGNOSTICS

The following list describes how Curtis programming devices display diagnostic information:

- Real-time data such as the statuses of inputs and outputs are displayed in the Monitor menu.
- A history of faults is displayed in the Fault History menu.
- Active faults are displayed above the parameter menus. The following examples from CIT and the Curtis 1313 handheld programmer show that Hardware and Supervision faults are active:

**Figure 7-1**
*Active Faults — CIT*

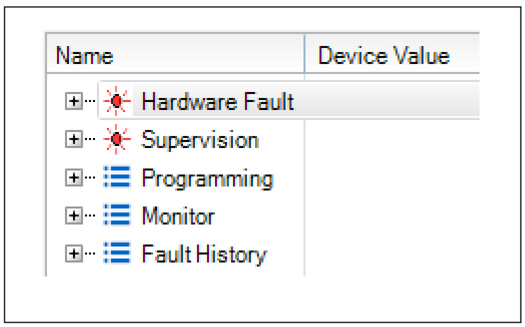
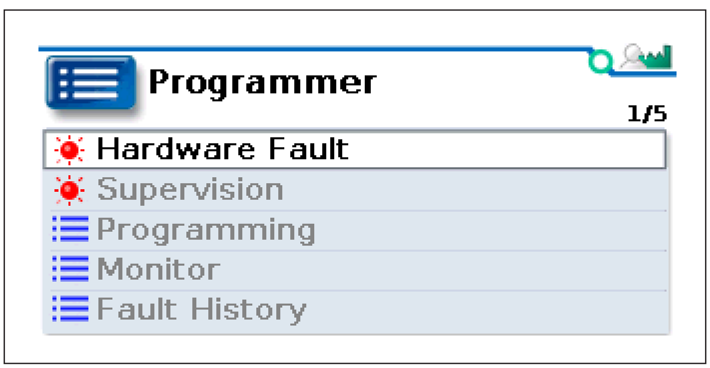



**Figure 7-2**
*Active Faults — 1313 Programmer*




**Tip:** To see a fault's fault type in CIT, expand the fault. To see a fault's fault type in the 1313 programmer, select the fault.

## STATUS LED

The 1212BL controller has a red LED that indicates the controller's status. When the controller is operating correctly, the LED flashes once per second.

If the controller detects a fault, the LED continuously flashes a two-digit fault code until the fault is corrected, with a delay following each flash sequence. If more than one fault is active, the LED continuously flashes the fault codes for all the faults.

For example, the following table shows the flash sequence when faults with fault codes 41 and 31 are active. An empty cell indicates a delay following a flash sequence:

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ●●●● | ● | | ●●● | ● | | ●●●● | ● | | ●●● | ● |

## FAULT RECORDS

Each fault is represented by a *Fault Record*. Fault Records are identified by the CAN indexes listed in Table 7-1. The following table describes the sub-indexes of Fault Records:

**Note:** The 03h–06h sub-indexes correspond to the fault history parameters shown in Figure 6-1.

| SUB-INDEX | FAULT HISTORY PARAMETER | DESCRIPTION | READ / WRITE | VALUES DATA SIZE |
|---|---|---|---|---|
| 01h | *N/A* | The status of the fault:<br>• 00h = The fault has never occurred.<br>• 01h = The fault is not active.<br>• 03h = The fault is active. | RO | 0–255<br>8-bit |
| 02h | *N/A* | *Reserved.* | *N/A* | *N/A* |
| 03h | Count | The number of times the fault has occurred since the fault history was cleared. | RO | 0–4294967295<br>32-bit |
| 04h | Time | The time, in seconds, of the fault's most recent occurrence since the fault history was cleared.<br>To calculate the number of seconds, divide the value by 10. | RO | 0–4294967295<br>32-bit |
| 05h | First Time | The time, in seconds, of the fault's first occurrence since the fault history was cleared.<br>To calculate the number of seconds, divide the value by 10. | RO | 0–4294967295<br>32-bit |
| 06h | Type | The fault's fault type.<br>If multiple instances of the fault have occurred and the instances have different fault types, sub-index 06h contains the most recent instance's fault type. | RO | 0–4294967295<br>32-bit |

## FAULTS

When the controller detects a fault, the controller operates in a manner that is safe in the presence of that fault. Depending on the severity of the fault, the controller's response can range from reducing current to shutting down the vehicle.

Some faults are set by multiple conditions. The controller uses *fault types* to distinguish these conditions. All faults have a fault type of 1; faults with multiple causes have additional fault types. Curtis programming devices indicate the fault type.

The emergency messages transmitted when faults occur include the fault type. See Emergency Message Format.

The following table describes the controller's faults.

Table 7-1 Fault Chart

| FLASH CODE NAME CAN INDEX | POSSIBLE CAUSES | FAULT TYPE | SET CONDITION | CLEAR CONDITION | FAULT ACTIONS |
|---|---|---|---|---|---|
| 11<br>Severe Undervoltage<br>0x2120 | • Defective controller<br>• Defective battery | 1 | The undervoltage cutback is 0 for 64ms with the main relay on. | Raise the Keyswitch Voltage above the brownout voltage for 100ms. | *Shut down throttle* |
| | | 2 | The Keyswitch Voltage is less than the allowed minimum voltage for 5ms. | | |
| 12<br>Undervoltage Cutback<br>0x2121 | Low battery | 1 | The undervoltage cutback is less than 100% with the main relay on. | Raise the Keyswitch Voltage above the user undervoltage threshold. | *Cut back the current limit* |
| 13<br>Severe Overvoltage<br>0x2130 | • Incorrect battery voltage<br>• Defective main relay<br>• Defective controller AD | 1 | The battery voltage is 10V above the allowed maximum voltage. | Cycle the keyswitch. | *Shut down motor*<br>*Shut down main contactor*<br>*Shut down EM brake*<br>*Shut down throttle*<br>*Shut down interlock* |
| | | 2 | The Keyswitch Voltage is 4V above the allowed maximum voltage. | | |
| 14<br>Overvoltage Cutback<br>0x2131 | • Incorrect battery voltage<br>• Defective main relay | 1 | The battery voltage is greater than the user overvoltage threshold for 64ms during the regen state or when the motor speed is greater than 100 RPM. | Lower the battery voltage until it is under the user overvoltage threshold. | *Cut back the current limit* |
| 15<br>Controller Severe Undertemp<br>0x2141 | • Defective temperature sensor<br>• Low ambient temperature | 1 | The controller temperature is less than or equal to 40°C for 48ms. | Raise the controller temperature above 40°C for 48ms. | *Shut down motor*<br>*Shut down main contactor*<br>*Shut down EM brake*<br>*Shut down throttle*<br>*Shut down interlock* |
| 16<br>Controller Overtemp Cutback<br>0x2140 | • Defective temperature sensor<br>• High current for an extended period | 1 | The controller temperature is greater than or equal to the temperature cutback point for 48ms. | Lower the controller temperature to under the temperature cutback point for 48ms. | *Cut back the current limit* |

### Table 7-1 Fault Chart, cont'd

| FLASH CODE NAME CAN INDEX | POSSIBLE CAUSES | FAULT TYPE | SET CONDITION | CLEAR CONDITION | FAULT ACTIONS |
|---|---|---|---|---|---|
| 17<br>Controller Severe Overtemp<br>0x2142 | Defective temperature sensor | 1 | The controller temperature is at least 15°C higher than the temperature cutback point for 48ms. | Lower the controller temperature to under the temperature cutback point for 48ms. | *Shut down motor*<br>*Shut down main contactor*<br>*Shut down EM brake*<br>*Shut down throttle*<br>*Shut down interlock* |
| 18<br>Motor Temperature Fault<br>0x2150 | • Defective motor temperature sensor<br>• Incorrect motor temperature sensor setting<br>• Motor is too hot | 1 | The motor temperature sensor's resistance is less than 50Ω for 400ms. | Lower the motor temperature to under the Temperature Hot parameter for 80ms. | *Cut back current limit*<br>*Shut down throttle* |
| | | 2 | The motor temperature is greater than the Temperature Hot parameter for 80ms. | | *Cut back current limit* |
| | | 3 | The motor temperature is greater than the Temperature Max parameter for 80ms. | | *Cut back current limit*<br>*Shut down throttle* |
| 21<br>Throttle Fault<br>0x2210 | • Throttle wiring fault<br>• Incorrect throttle type setting<br>• Incorrect throttle operation<br>• Steering angle pot wiring fault | 1 | The throttle AD data is out of range for 48ms. | Cycle the keyswitch. | *Shut down throttle* |
| | | 2 | The HPD Sequencing fault is active for 10s. | | |
| | | 3 | The steering angle AD data is out of range for 48ms. | | |
| 22<br>HPD Sequencing<br>0x2211 | • Incorrect throttle operation<br>• Defective throttle | 1 | At least 10% throttle is applied for 48ms before the interlock state changes to On. | Release the throttle for 10s. | *Shut down throttle* |
| 23<br>Main Relay Welded<br>0x2220 | Defective main relay | 1 | The Capacitor Voltage is greater than (Keyswitch Voltage – 1V), and the capacitor bank voltage drop is less than 1.5V after 15% PWM was applied to the motor for 96ms. | Cycle the keyswitch. | *Shut down motor*<br>*Shut down main contactor*<br>*Shut down EM brake*<br>*Shut down throttle*<br>*Shut down interlock* |
| 24<br>Main Relay Did Not Close<br>0x2221 | • Defective main relay<br>• Incorrect Pull In Voltage parameter value | 1 | The difference between the keyswitch voltage and capacitor voltage is greater than the DNC Voltage Threshold for 96ms when the relay is engaging. | Cycle the keyswitch. | *Shut down motor*<br>*Shut down main contactor*<br>*Shut down EM brake*<br>*Shut down throttle*<br>*Shut down interlock* |
| | | 2 | The difference between the keyswitch voltage and capacitor voltage is greater than the DNC Voltage Threshold for 96ms after the relay is on. | | |
| 25<br>Main Driver Fault<br>0x2222 | Defective main relay driver | 1 | Main relay feedback is low when the relay is off for 100ms. | Cycle the keyswitch. | *Shut down motor*<br>*Shut down main contactor*<br>*Shut down EM brake*<br>*Shut down throttle*<br>*Shut down interlock* |
| | | 2 | Main relay feedback is high when the relay is on for 100ms. | | |

### Table 7-1 Fault Chart, cont'd

| FLASH CODE<br>NAME<br>CAN INDEX | POSSIBLE CAUSES | FAULT TYPE | SET CONDITION | CLEAR CONDITION | FAULT ACTIONS |
|---|---|---|---|---|---|
| 26<br>Precharge Failed<br>0x2223 | The PTC resistor in the precharge circuit is defective. | 1 | The Capacitor Voltage is less than 65% of the Keyswitch Voltage for 500ms after the Keyswitch Voltage is greater than 70% of the nominal voltage. | Cycle the keyswitch. | *Shut down motor*<br>*Shut down main contactor*<br>*Shut down EM brake*<br>*Shut down throttle*<br>*Shut down interlock* |
| | | 2 | The Capacitor Voltage is less than (Keyswitch Voltage – 5V) before the relay is engaged. | | |
| 31<br>Stall Detected<br>0x2231 | • Defective motor<br>• Defective Hall sensor<br>• Defective controller | 1 | The motor speed is less than the Stall Speed parameter for the duration specified with the Stall Fault Time parameter and one of the following conditions occurs:<br>• The motor PWM is greater than the Stall Fault PWM parameter.<br>• The armature current is greater than 90% of the current limit. | Cycle the keyswitch. | *No action* |
| 32<br>Motor Fault<br>0x2240 | • The motor is open or shorted.<br>• Invalid Max Speed parameter value (Motor menu). | 1 | The capacitor voltage drop is greater than 1V after adding 10% PWM to the motor for 500µs at startup. | Cycle the keyswitch. | *Shut down motor*<br>*Shut down main contactor*<br>*Shut down EM brake*<br>*Shut down throttle*<br>*Shut down interlock*<br>*Open armature* |
| | | 2 | The motor is open at startup for 500µs. | | |
| | | 3 | The controller detects that the motor is shorted. | | |
| | | 4 | The motor is open for 32ms while the vehicle is in a still state. | | |
| 33<br>Hall Sensor Fault<br>0x2320 | • Defective Hall sensor<br>• Signal interference | 1 | The Hall sensor input is 0 or 7 for 24ms. | Cycle the keyswitch. | *Shut down motor*<br>*Shut down main contactor*<br>*Shut down EM brake*<br>*Shut down throttle*<br>*Shut down interlock*<br>*Open armature* |
| | | 2 | The Hall sensor input does not equal the expected Hall pattern. | | |

**Table 7-1 Fault Chart, cont'd**

| FLASH CODE NAME CAN INDEX | POSSIBLE CAUSES | FAULT TYPE | SET CONDITION | CLEAR CONDITION | FAULT ACTIONS |
|---|---|---|---|---|---|
| 34<br>EM Brake Failed To Set<br>0x2321 | Defective EM brake | 1 | The motor speed is greater than the Fault Motor Revs parameter for 80ms when the EM brake is disengaged. | The throttle is applied. | *No action* |
| 41<br>Speed Supervision<br>0x2531 | The speed is outside of the allowed range. | 1 | The motor speed is greater than 120% of the motor's Max Speed for more than 200ms. | Cycle the keyswitch. | *Shut down motor*<br>*Shut down main contactor*<br>*Shut down EM brake*<br>*Shut down throttle*<br>*Shut down interlock*<br>*Open armature* |
| | | 2 | Either of the following conditions:<br>• The motor speed is greater than (Ramped throttle command percentage * motor Max Speed + 20% of motor Max Speed) for more than 2s.<br>• During deceleration, the motor speed is greater than the ramped speed curve for more than 64ms. | | |
| | | 3 | During interlock braking, the motor speed is greater than the ramped speed curve for more than 64ms. | | |
| | | 4 | During emergency reverse deceleration, the motor speed is greater than the ramped speed curve for more than 64ms. | | |
| 42<br>Interlock SRO Fault<br>0x2532 | • Incorrect operation sequence<br>• Defective controller | 1 | The interlock input is on when the keyswitch is turned on and the Interlock Type parameter is not set to KSI Switch. | Cycle the keyswitch. | *Shut down motor*<br>*Shut down main contactor*<br>*Shut down EM brake*<br>*Shut down throttle*<br>*Shut down interlock* |
| 43<br>Low BDI<br>0x2630 | Low battery | 1 | The BDI percentage is less than the Low BDI Threshold parameter value. | Charge the battery until the BDI percentage is greater than Low BDI Threshold. | *Reduce maximum speed to Low BDI Max Speed* |

### Table 7-1 Fault Chart, cont'd

| FLASH CODE NAME CAN INDEX | POSSIBLE CAUSES | FAULT TYPE | SET CONDITION | CLEAR CONDITION | FAULT ACTIONS |
|---|---|---|---|---|---|
| 51<br>Over Current Fault<br>0x2241 | • Defective controller<br>• Defective current sensor | 1 | The armature current is greater than 120% of the current limit for 160ms. | Cycle the keyswitch. | *Shut down motor*<br>*Shut down main contactor*<br>*Shut down EM brake*<br>*Shut down throttle*<br>*Shut down interlock*<br>*Open armature* |
| 52<br>Current Sense<br>0x2250 | Defective current sampling circuit | 1 | The zero current point is out of range for 48ms (the range is 814±32). | Cycle the keyswitch. | *Shut down motor*<br>*Shut down main contactor*<br>*Shut down EM brake*<br>*Shut down throttle*<br>*Shut down interlock* |
| 53<br>Driver Fault<br>0x2410 | • Driver is open or shorted<br>• Incorrect parameter value. For example, this fault occurs if the Lift Driver Fault Enable parameter specifies On but the application does not use the lift function. | 1 | EM Brake driver is open or shorted. | Cycle the keyswitch | *Shut down motor*<br>*Shut down main contactor*<br>*Shut down EM brake*<br>*Shut down throttle*<br>*Shut down interlock* |
| | | 2 | Lift driver is open or shorted. | | *Shut down lift* |
| | | 3 | Lower driver is open or shorted. | | *Shut down lower* |
| | | 4 | Horn driver is shorted. | | *Shut down horn* |
| 54<br>Pump SRO Fault<br>0x2330 | • Incorrect operation sequence<br>• Defective switch<br>• Incorrect parameter value. For example, this fault occurs if the Lift Input Source or Lower Input Source parameter is specified incorrectly. | 1 | The lift is active when the keyswitch is turned on. | The Lift Input State and Lower Input State must both be Off. | *Shut down lift* |
| | | 2 | The lower is active when the keyswitch is turned on. | | *Shut down lift and lower* |
| | | 3 | The controller did not receive CAN lift or CAN lower PDO messages for 2s after startup. | | *Shut down lift and lower* |
| | | 4 | The Lift On Interlock parameter specifies On and the lift input is active when the interlock state changes to On. | | *Shut down lift* |
| | | 5 | The Lower On Interlock parameter specifies On and the lower input is active when the interlock state changes to On. | | *Shut down lift and lower* |

**Table 7-1 Fault Chart, cont'd**

| FLASH CODE NAME CAN INDEX | POSSIBLE CAUSES | FAULT TYPE | SET CONDITION | CLEAR CONDITION | FAULT ACTIONS |
|---|---|---|---|---|---|
| 55<br>EMR SRO Fault<br>0x2340 | • Defective emergency reverse switch<br>• Incorrect operation sequence<br>• Incorrect parameter value. For example, this fault occurs if the EMR Input Type parameter is specified incorrectly. | 1 | The emergency reverse switch is active when the keyswitch is turned on. | Cycle the keyswitch. | *Shut down motor*<br>*Shut down main contactor*<br>*Shut down EM brake*<br>*Shut down throttle*<br>*Shut down interlock* |
| | | 2 | The emergency reverse switch is active when the interlock input is turned on. | Turn off the emergency reverse switch. | |
| | | 3 | The absolute value of the throttle demand is greater than 10% after an emergency reverse operation. | Release the throttle. | |
| 56<br>Creep SRO Fault<br>0x2350 | • Incorrect operation sequence of the creep input.<br>• Incorrect value specified for the Creep Input Source parameter. | 1 | The creep input is on before the keyswitch is turned on. | Turn off the creep input. | *Shut down throttle* |
| | | 2 | The creep input is on but the interlock has been off for 40ms. | Turn off the creep input. | |
| | | 3 | The interlock is on for 40ms during creep mode. | Turn off creep mode and the interlock. | |
| | | 4 | The controller cannot abort the creep brake state after the Interlock Brake Timeout expires. | Turn off creep mode and the interlock. | |
| 61<br>PDO Timeout<br>0x2541 | • CANbus is overloaded.<br>• Incorrect parameter value, such as specifying an incorrect value for an RPDO *n* Event Time parameter | 1 | During the operational NMT state, RPDO1 did not receive a message before the RPDO1 Event Time expired. | Cycle the keyswitch or send an NMT reset command. | *Shut down throttle*<br>*Clear related data* |
| | | 2 | During the operational NMT state, RPDO2 did not receive a message before the RPDO2 Event Time expired. | | |
| | | 5 | During the operational NMT state, the BMS RPDO did not receive a message before the BMS PDO Timeout expired. | | |
| 62<br>PDO Mapping Error<br>0x2542 | • Incorrect data size<br>• Incorrect read/write setting<br>• Invalid CAN index | An SDO abort code | • Incorrect data size specified for an object<br>• Incorrect access mode<br>• Invalid CAN index | Cycle the keyswitch. | *No action* |

### Table 7-1 Fault Chart, cont'd

| FLASH CODE NAME CAN INDEX | POSSIBLE CAUSES | FAULT TYPE | SET CONDITION | CLEAR CONDITION | FAULT ACTIONS |
|---|---|---|---|---|---|
| 71<br>Hardware Fault<br>0x2610 | • Defective MOSFET<br>• Defective microprocessor | 1 | Motor open was detected at startup while the voltage on the UVW terminals was either less than 0.5V or greater than (Capacitor Voltage – 3V). | Cycle the keyswitch. | *Open armature (fault type 1 only)*<br>*Shut down motor*<br>*Shut down main contactor*<br>*Shut down EM brake*<br>*Shut down throttle*<br>*Shut down interlock* |
| | | 2 | Switch 4 is configured for the Flex Node ID function and the Switch 4 wiring is broken. | | |
| | | 3 | Switch 3 is configured for the belly button check and the emergency reverse NO input voltage is less than 1.5V for 100ms. | | |
| | | 4 | UID encryption failed or the microprocessors are not in productive mode. | | |
| | | 5 | The CAN programming device's OEM code differs from the hardware's OEM code. | | |
| | | 6 | The 5V supply is greater than 6V or less than 4.5V for 80ms. | | |
| 72<br>Software Fault<br>0x2620 | • Internal communication failed<br>• Incorrect firmware<br>• Controller mode changed from test mode to work mode | 1 | Unmatched supervisor firmware. | Cycle the keyswitch. | *Shut down motor*<br>*Shut down main contactor*<br>*Shut down EM brake*<br>*Shut down throttle*<br>*Shut down interlock* |
| | • Internal communication failed<br>• Incorrect firmware<br>• Controller mode changed from test mode to work mode | 2 | Test mode was exited. | | |
| | Received an NMT Node Reset command while the vehicle was operating. | 3 | The Node Reset command was received when the Motor RPM is greater than 100 or the Armature Current is greater than (1/16 * Drive Current Limit). | | |
| 81<br>Parameter Out Of Range<br>0x2811 | Invalid parameter value | CAN index of para-meter | A parameter's value is outside of the allowed data range. | Cycle the keyswitch. | *Shut down motor*<br>*Shut down main contactor*<br>*Shut down EM brake*<br>*Shut down throttle*<br>*Shut down interlock* |

**Table 7-1 Fault Chart, cont'd**

| FLASH CODE NAME CAN INDEX | POSSIBLE CAUSES | FAULT TYPE | SET CONDITION | CLEAR CONDITION | FAULT ACTIONS |
|---|---|---|---|---|---|
| 82<br>Parameter Fault<br>0x2812 | • Invalid parameter value<br>• Defective FRAM | 1 | The value of a parameter marked as [PCF] in the Programming Menu Parameters chapter was changed, but the keyswitch has not been cycled. | Cycle the keyswitch. | *Shut down motor*<br>*Shut down main contactor*<br>*Shut down EM brake*<br>*Shut down throttle*<br>*Shut down interlock* |
| | | 2 | The sum of the Hall State *n* Driving Phase parameters does not equal 21. | Cycle the keyswitch. | |
| | | 3 | Either of the following conditions:<br>• Armature PWM is greater than 5% and Armature Current is greater than 2A, but the speed is less than (–25% * motor Max Speed) for 0.5 seconds.<br>• Armature PWM is less than –5% and Armature Current is less than –2A, but the speed is greater than (25% * motor Max Speed) for 0.5 seconds. | Toggle the Swap Speed Direction parameter, then cycle the keyswitch. | |
| | | 4 | Two or more flexible switch inputs are assigned to the same function. | Reconfigure the flexible switch inputs, then cycle the keyswitch. | |
| | | 5 | • The Steering Angle 1 parameter is greater than or equal to Steering Angle 2.<br>• The Steering Angle 1 or Steering Angle 2 parameter is greater than Steering Angle Max.<br>• The speed mode's Max Speed parameter is less than or equal to Min Speed.<br>• The speed mode's Rev Max Speed parameter is less than or equal to Rev Min Speed.<br>• Speed Limit HPD specifies On and mode 1's Max Speed is greater than mode 2's Max Speed and mode 1's Rev Max Speed is less than mode 2's Rev Max Speed, or vice versa. | Adjust the parameter, then cycle the keyswitch. | |

**Table 7-1 Fault Chart, cont'd**

| FLASH CODE NAME CAN INDEX | POSSIBLE CAUSES | FAULT TYPE | SET CONDITION | CLEAR CONDITION | FAULT ACTIONS |
|---|---|---|---|---|---|
| | | 6 | • The EMR Input Type parameter specifies NC Switch, but the emergency reverse NC function has not been assigned to a flexible switch input.<br>• The Steering Input Type parameter specifies NC Switch Input, but the Steering Speed Limit function has not been assigned to a flexible switch input. | Assign the function to a flexible switch input, then cycle the keyswitch. | |
| | | 7 | Commissioning failed. | Cycle the keyswitch. | |
| 83<br>NV Failure<br>0x2830 | FRAM operation failed | Block num-ber | Read FRAM failed. | Cycle the keyswitch. | *Shut down motor*<br>*Shut down main contactor*<br>*Shut down EM brake*<br>*Shut down throttle*<br>*Shut down interlock* |
| | | 2 | Write FRAM failed. | | |
| | | 3 | Data recovery failed after the Restore Parameters parameter was set to On. | | |
| | | 4 | Saving the brownout flag failed. | | |
| | | 5 | Block number is out of range. | | |
| 84<br>Supervision<br>0x2840 | Cross check failed. | See Table 7-2 | Cross check failed | Cycle the keyswitch. | *Shut down motor*<br>*Shut down main contactor*<br>*Shut down EM brake*<br>*Shut down throttle*<br>*Shut down interlock* |

The following table lists the fault types for the Supervision fault.

**Table 7-2 Supervisor Fault Types**

| Fault Type | Fault Type Variable |
|---|---|
| 8 | SUPERVISOR_HARDWARE_FAULT |
| 9 | SUPERVISOR_PDO_MAPPING_ERROR |
| 10 | SUPERVISOR_SOFTWARE_FAULT |
| 11 | PRIMARY_INIT_CAN_OBJ |
| 12 | PRIMARY_INIT_ILLEGAL_CAN_SIZE |
| 13 | PRIMARY_INIT_CAN_SIZE |
| 14 | PRIMARY_INIT_TIMEOUT |
| 15 | PRIMARY_WRITE_OBJECT |

Table 7-2 Supervisor Fault Types, cont'd

| Fault Type | Fault Type Variable |
|---|---|
| 16 | PRIMARY_WRITE_SIZE |
| 17 | PRIMARY_WRITE_TIMEOUT |
| 18 | PRIMARY_WRITE_CRC |
| 19 | PRIMARY_WRITE_ACK |
| 20 | PRIMARY_TASK_QUEUE_FAIL |
| 21 | PRIMARY_FAULT_ACTIONS |
| 22 | PRIMARY_ALU_FAIL |
| 23 | PRIMARY_MESSAGE_WATCHDOG |
| 24 | PRIMARY_FAULT_ACK |
| 25 | SUPERVISOR_INIT_CAN_OBJ |
| 26 | SUPERVISOR_INIT_ILLEGAL_CAN_SIZE |
| 27 | SUPERVISOR_INIT_CAN_SIZE |
| 28 | SUPERVISOR_INIT_TIMEOUT |
| 29 | SUPERVISOR_WRITE_OBJECT |
| 30 | SUPERVISOR_WRITE_SIZE |
| 31 | SUPERVISOR_TASK_QUEUE_FAIL |
| 32 | SUPERVISOR_ALU_FAIL |
| 33 | SUPERVISOR_MESSAGE_WATCHDOG |
| 34 | SUPERVISOR_KSI |
| 35 | SUPERVISOR_INPUT_1_SWITCH |
| 36 | SUPERVISOR_INPUT_2_SWITCH |
| 37 | SUPERVISOR_INPUT_3_SWITCH |
| 38 | SUPERVISOR_INPUT_4_SWITCH |
| 39 | SUPERVISOR_FORWARD_SWITCH |
| 40 | SUPERVISOR_REVERSE_SWITCH |
| 41 | SUPERVISOR_EMR_NO_SWITCH |
| 42 | SUPERVISOR_INTERLOCK_SWITCH |
| 46 | PRIMARY_INPUT_1_SWITCH |
| 47 | PRIMARY_INPUT_2_SWITCH |
| 48 | PRIMARY_INPUT_3_SWITCH |
| 49 | PRIMARY_INPUT_4_SWITCH |
| 50 | PRIMARY_FORWARD_SWITCH |
| 51 | PRIMARY_REVERSE_SWITCH |
| 52 | PRIMARY_EMR_NO_SWITCH |
| 53 | PRIMARY_INTERLOCK_SWITCH |
| 58 | SUPERVISOR_BB_CHECK_FAILURE |

# 8 — CANopen COMMUNICATIONS

The controller complies with the CAN in Automation (CiA) CANopen 301 specification. This chapter describes the controller's CANopen features.

Some familiarity with CANopen is a prerequisite. For CANopen information, see the following pages on the CiA web site:

- Overview: https://www.can-cia.org/canopen/
- Specifications: https://www.can-cia.org/groups/specifications/

## BYTE AND BIT SEQUENCE ORDER

CANopen message byte sequences are transmitted with the least significant byte first (little-endian format).

**Note:** This manual uses the LSB 0 Numbering convention when referring to byte and bit numbers.

For example, the following table shows an SDO that writes the data 04E2h to the object with the index and sub-index 334C-01h:

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Control Byte | Index | | Sub-index | Data | | | |
| 2Bh | 4Ch | 33h | 01h | E2h | 04h | 00h | 00h |

Strings are read from left to right. The following example shows how the controller transmits an SDO segment for the string "1212BL-":

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Control Byte | Data | | | | | | |
| 00h | 31h = "1" | 32h = "2" | 31h = "1" | 32h = "2" | 42h = "B" | 4Ch = "L" | 2Dh = "-" |

Bit sequences are transmitted from most significant to least significant bit (big-endian format). The following example shows how the controller transmits the bits for the value 2Bh:

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| 0 | 0 | 1 | 0 | 1 | 0 | 1 | 1 |

## CAN PROGRAMMING CONSIDERATIONS

To program the controller, use a Curtis programming device. The following considerations apply when programming the controller:

- When a Curtis programming device is connected, the programmer uses 127 as the node ID.
- When you change parameter values with a Curtis programming device, you do not need to use the CANopen Store Parameters object (1010h). Instead, the controller saves parameter changes to NVM.

## NODE IDs

The controller provides an option for two node IDs, which are configured by the CAN Node ID 1 and CAN Node ID 2 parameters on the CAN Interface menu.

The CAN Node ID 1 parameter indicates the controller's first node ID. If the Switch 4 Function parameter does not specify Flex Node ID, CAN Node ID 1 is always the controller's node ID.

Some applications, such as dual traction applications, may require the controller to provide multiple node IDs. The Flex Node ID function enables the application to use either the CAN Node ID 1 or CAN Node ID 2 parameter as the node ID, depending upon the state of switch input 4. When switch input 4 is active at start up, CAN Node ID 2 is used, otherwise CAN Node ID 1 is used.

**Note:** If the controller detects broken wiring in switch input 4 when the input is configured as a Flex Node ID, a Hardware Fault (type 2) occurs.

To enable the Flex Node ID function, set the Switch 4 Function parameter to Flex Node ID.

## MESSAGE CAN-IDs

The controller's CAN messages are identified by 11-bit CAN IDs. The controller does not use 29-bit CAN IDs.

## NMT STATE CONFIGURATION

The Auto Operational parameter indicates whether the controller automatically enters the operational or pre-operational state after initialization.

NMT, emergency, SDO, and heartbeat messages are available in both states. PDO messages are available only in the operational state.

# EMERGENCY MESSAGES AND FAULTS

The controller transmits an emergency message when a fault is generated or cleared. An emergency message is sent once per fault.

## Emergency Message Format

Emergency messages consist of 8 bytes, which are described in the following table:

| Byte(s) | Name | Description |
|---|---|---|
| 0–1 | Error Code | Indicates the fault code and the error category:<br>Byte 0 indicates the fault code, which is in the following format:<br>• The four most significant bits contains the fault code's first digit.<br>• The four least significant bits contains the fault code's second digit.<br>For example, if the fault code is 82, the byte's value would be 82h.<br>**Note:** Fault codes are listed in Table 7-1.<br>Byte 1 indicates one of the following error categories:<br>• FFh = Active fault<br>• 00h = Cleared fault |
| 2 | Error Register | Indicates whether any faults are active on the transmitting device:<br>• 00h = No active faults<br>• 01h = At least one active fault<br>The value equals the value of the least significant bit in the Error Register object. |
| 3–4 | Fault Record Object Index | Indicates the CAN index of the Fault Record. |
| 5 | Fault Type | Indicates the fault's fault type. |
| 6–7 | *N/A* | *Reserved.* |

The following emergency message indicates that a fault with fault code 82 is active. The fault's CAN index is 2812h and the fault type is 1:

```
82 FF 01 12 28 01 00 00
```

## EXPEDITED SDOs

The least significant byte of an expedited SDO is known as the *control byte*. The following table describes the control byte fields:

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| *Command Specifier* | | | 0b | *n* | | *e* | *s* |

The following list describes the control byte:

- The *Command Specifier* field indicates the SDO's transfer type, which is described in the following table:

| Transfer Type | Value |
|---|---|
| Write data to a device | 001b |
| Confirm a write | 011b |
| Request data from a device | 010b |
| Device responds with requested data | 010b |
| Abort SDO | 100b |

- Bit 4 is always 0b.
- The values of bits 0–3 depend upon whether the SDO transfers data. If the SDO does **not** transfer data, these bits are always 0b. If the SDO transfers data, the bit values are as follows:
  - *n* indicates the number of unused data bytes.
  - *e* = 1b, which indicates the message contains data.
  - *s* = 1b, which indicates that the *n* field specifies the number of unused data bytes.

The following table lists the control byte values for the various transfer types:

| Transfer Type | Control Byte |
|---|---|
| Write data to a device | Depends upon the data size:<br>• 1 byte = 2Fh<br>• 2 bytes = 2Bh<br>• 3 bytes = 27h<br>• 4 bytes = 23h |
| Confirm a write | 60h |
| Request data from a device | 40h |
| Device responds with requested data | Depends upon the data size:<br>• 1 byte = 4Fh<br>• 2 bytes = 4Bh<br>• 3 bytes = 47h<br>• 4 bytes = 43h |
| Abort SDO | 80h |

## PDOs

The controller provides the following preconfigured PDOs:

- RPDO1, TPDO1, and TPDO2 are for communicating with a CAN tiller head.
- An RPDO that receives data transmitted by a battery monitoring system (BMS).

If the application does not require the functions provided by RPDO1, TPDO1, and TPDO2, the PDOs can be mapped to other CAN objects. The BMS RPDO cannot be modified. The following topics describe the controller's PDOs.

### PDO Timing

The controller's PDOs are asynchronous and are periodically transmitted and received. The controller does not support synchronous PDOs.

A PDO's Event Time parameter indicates when the PDO transmits or expects to receive data:

- A TPDO transmits periodically using the specified time interval. A TPDO also transmits data when the value of a mapped object changes.
- A PDO Timeout fault occurs if an RPDO does not receive data before its Event Time expires.

### PDO Mapping Objects

The objects for which a PDO transfers data are specified with the sub-indexes of the PDO's mapping object. Each sub-index specifies a CAN object's index, sub-index, and data length.

The following table describes the mapping objects' sub-indexes:

| Sub-Index | Description | PDO Mapping Menu Parameter |
|---|---|---|
| 00h | Indicates the number of objects for which the PDO transfers data. | Length |
| 01h–08h | Each sub-index specifies a CAN object that is mapped to the PDO. The bytes specify the CAN object's index, sub-index, and length. | Map 1 through Map 8 |

The mapped objects consist of four data bytes, which are described in the following table:

**Table 8-1 Mapped PDO Bytes**

| Byte(s) | Description |
|---|---|
| 0 | The size of the object's data, in bits. The allowed values are:<br>• 08h (8 bits)<br>• 10h (16 bits)<br>• 18h (24 bits)<br>• 20h (32 bits)<br>The controller does not support mapping of individual bits. |
| 1 | The object's sub-index. |
| 2–3 | The object's index. |

### PDO Data Bytes

A PDO transfers a maximum of 8 data bytes. The order of the bytes corresponds to the order of the PDO's mapped objects.

For example, consider the following PDO map, which contains two 8-bit objects:

| Name | | | Device Value |
|---|---|---|---|
| TPDO 2 Event Time | ⊖ | ⊕ | 40 ms |
| TPDO 2 COB ID | ⊖ | ⊕ | 400002ACh |
| Length | ⊖ | ⊕ | 2 |
| Map 1 | ⊖ | ⊕ | 4E020008h |
| Map 2 | ⊖ | ⊕ | 4E050008h |
| Map 3 | ⊖ | ⊕ | 50008h |

Suppose the PDO transmits the following data:

```
82h 04h
```

The least significant byte transfers the data (82h) for the object specified with the Map 1 parameter, and the next byte transfers the data for the second mapped object.

### Map CAN Objects to a PDO

Take the following steps to use a Curtis programming device to map CAN objects to a PDO.

**Note:** The screen shots are from CIT.

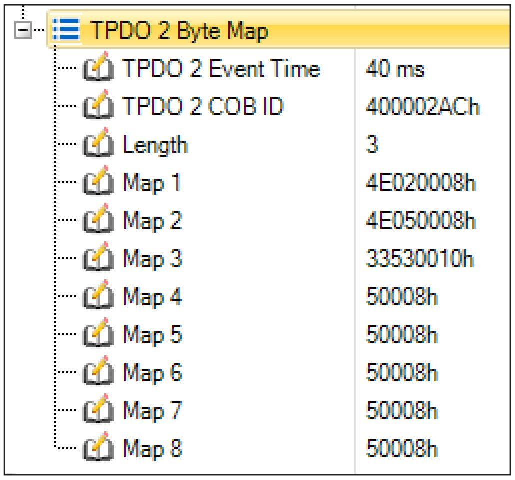
1. Send an NMT message that changes the device to the Pre-operational state.
2. Disable the PDO by changing the COB-ID's most significant bit to 1.
3. Change the Length parameter to 0.

   The following example shows the disabled PDO:

| TPDO 2 Byte Map | |
|---|---|
| TPDO 2 Event Time | 40 ms |
| TPDO 2 COB ID | C00002ACh |
| Length | 0 |
| Map 1 | 4E020008h |
| Map 2 | 4E050008h |
| Map 3 | 50008h |
| Map 4 | 50008h |
| Map 5 | 50008h |
| Map 6 | 50008h |
| Map 7 | 50008h |
| Map 8 | 50008h |

4. For each object to be mapped, specify the object's data in a Map *n* parameter. The data is described in Table 8-1.
5. Set the Length parameter to the number of mapped objects.
6. Enable the PDO by changing its COB-ID's most significant bit to 0.

   The following example shows the enabled PDO, which now contains three mapped objects:




7. Send an NMT message that changes the device to the Operational state.

### CAN Tiller Head (RPDO1, TPDO1, TPDO2)

RPDO1, TPDO1, and TPDO2 are preconfigured to communicate with a CAN tiller head:

- RPDO1: Receives messages from the tiller head.
- TPDO1: Transmits data such as the controller's actions and switch states.
- TPDO2: Transmits data describing active faults.

The following tables describe the objects with which these PDOs are preconfigured.

Table 8-2 RPDO1 Mapped Bytes

| Byte(s) | Description |
|---|---|
| 0–1 | Switch statuses from the tiller head. The switches are represented by the following bits, with 0 = inactive and 1 = active:<br>• 0 = Reverse<br>• 1 = Forward<br>• 2 = Mode<br>• 3 = Belly button<br>• 4 = Lift<br>• 5 = Lower<br>• 6 = Creep mode<br>• 7 = Push<br>• 8 = Interlock<br>• 9 = Horn<br>• 10 = Lift Lockout<br>• 11 = Inhibit |
| 2–3 | The throttle request. The CAN Throttle Min and CAN Throttle Max parameters specify the allowed data range. |
| 4–5 | The tiller head angle, which can be 0–90°. (The raw data range is 0–16383.) |
| 6–7 | The CAN steering angle. The angle can be –90.0° to 90.0°. (The raw data range is –16384 to +16383). |

Table 8-3 TPDO1 Mapped Bytes

| Byte(s) | Description |
|---|---|
| 0 | The controller's system actions. The actions are represented by the following bits, with 0 = inactive and 1 = active:<br>• 0 = Shut down motor<br>• 1 = Shut down main relay<br>• 2 = Shut down EM brake<br>• 3 = Shut down throttle<br>• 4 = Shut down interlock<br>• 5 = Shut down lift driver<br>• 6 = Shut down lower driver<br>• 7 = Shut down horn driver |
| 1 | The controller's switch statuses. The switches are represented by the following bits, with 0 = inactive and 1 = active:<br>• 0 = Charger inhibit<br>• 1 = Emergency reverse normally open (NO)<br>• 2 = Mode<br>• 3 = Interlock<br>• 4 = Creep mode<br>• 5 = Reverse<br>• 6 = Forward<br>• 7 = Switch 1/Analog input 1 |
| 2–3 | The Analog 1 Input Voltage parameter value. |
| 4–7 | The Hourmeter 2 parameter value. |

Table 8-4 TPDO2 Mapped Bytes

| Byte(s) | Description |
|---|---|
| 0 | Indicates the fault code, which is in the following format:<br>• The 4 most significant bits indicate the fault code's first digit.<br>• The 4 least significant bits indicate the fault code's second digit.<br>For example, if the fault code is 82, the byte's value would be 82h. |
| 1 | Indicates the fault type. |

To use the data received by RPDO1, set the following parameters to the following values:

Table 8-5 Parameters for RPDO1 Inputs

| Input | Parameter | Value |
|---|---|---|
| Throttle | Throttle Type | One of the following values:<br>• CAN Throttle<br>• CAN Throttle Wigwag |
| | CAN Throttle Min and CAN Throttle Max | The minimum and maximum values for the throttle data.<br>If the throttle data is outside of the specified range, a Throttle Fault (Type 1) occurs. |
| Forward | *N/A* | **Note:** CAN throttles transmit direction data. |
| Reverse | *N/A* | |
| Steering Speed Limit | Steering Input Type | CAN Input |
| Mode | Mode Input Source | CAN Mode |
| Belly button | EMR Input Type | CAN Switch |
| Lift | Lift Input Source | CAN Lift |
| Lower | Lower Input Source | CAN Lower |
| Creep mode | Creep Input Source | CAN Creep |
| Push | Push Input Source | CAN Push |
| Interlock | Interlock Type | CAN Interlock |
| Lift Lockout | Lift Lockout Input Source | CAN Lift Lockout |
| Inhibit | Inhibit Input Source | CAN Inhibit |

## BMS RPDO

The controller provides an RPDO for messages transmitted by a BMS. The BMS Node ID parameter specifies the BMS's node ID.

**Note:** The timeout interval for receiving BMS messages is specified with the BMS PDO Timeout parameter. If the timeout expires, a PDO Timeout (type 5) fault occurs.

The following table describes the BMS RPDO.

### Table 8-6 BMS RPDO Bytes

| Byte(s) | Description |
|---|---|
| 0–3 | *Reserved.* |
| 4 | The state-of-charge, which can be 0–100%. (The CAN data is 0–255.) |
| 5 | *Reserved.* |
| 6 | The BMS status. Bit 7 indicates the battery charging status, with 0 indicating charging is off. The other bits are not used.<br>If the battery charging status is On, the controller activates the charger inhibit function. |
| 7 | The BMS temperature, which can be –100°C to +155°C. (The raw data range is 0–255.) |

## STANDARD CANopen OBJECTS

The following table describes objects required by the CANopen standard:

| Name | Index | Sub-Index | Description | Read / Write | Values<br>Data Size |
|---|---|---|---|---|---|
| Device Type | 1000h | 00h | Indicates whether a device follows a standard CiA device profile. | RO | 0<br>32-bit |
| Error Register | 1001h | 00h | Indicates if a fault is active:<br>0 = No active fault<br>1 = One or more active faults | RO | 0–1<br>16-bit |
| Manufacturer Status Register | 1002h | 00h | *Reserved.* | *N/A* | *N/A* |
| Error History | 1003h | Contains data for the 4 most recent faults. | | | |
| | | 00h | Indicates how many faults are in the fault history. Writing 0 to sub-index 00h clears the fault log. | RW | 0–4<br>8-bit |
| | | 01h–04h | Provide data on the most recent faults. For details, see Error History Object (1003h). | RO | 0–2147483647<br>32-bit |
| Manufacturer Device Name | 1008h | 00h | Initiates a segmented SDO that uploads the model name and number as an ASCII string. | RO | String |
| Store Parameters | 1010h | Saves changed parameter values to NVM. | | | |
| | | 00h | Indicates the size of the object. | RO | 0–127<br>8-bit |
| | | 01h | Saves the current parameter values to NVM. The data bytes must represent the string "save". | RW | 0–2147483647<br>32-bit |
| Restore Default Parameters | 1011h | Resets parameters to their default values. | | | |
| | | 00h | Indicates the size of the object. | RO | 0–127<br>8-bit |
| | | 01h | Restores parameters to their default values. The data bytes must represent the string "load". | RW | 0–2147483647<br>32-bit |

| Name | Index | Sub-Index | Description | Read / Write | Values Data Size |
|---|---|---|---|---|---|
| Emergency COB ID | 1014h | 00h | Indicates the Emergency Message COB-ID:<br>• 0: The COB-ID consists of the emergency message function code (0001b) and the node ID.<br>• Non-zero: The COB-ID consists of the emergency message function code (0001b) and the specified value.<br>The COB-ID's four most significant bits represent the emergency message function code. | RO | 0–16777215<br>32-bit |
| Heartbeat Rate | 1017h | 00h | Specifies the cyclic rate of the controller's heartbeat messages.<br>**Note:** This object is identical to the Heartbeat Rate parameter. | RW | 100–1000<br>16-bit |
| Identity Object | 1018h | Provides information on the controller. | | | |
| | | 00h | Indicates the size of the object. | RO | 0–127<br>8-bit |
| | | 01h | Indicates the CiA-assigned identifier of Curtis Instruments. The identifier is 4349h. | RO | 0–2147483647<br>32-bit |
| | | 02h | Indicates the controller's product code. | RO | 0–2147483647<br>32-bit |
| | | 03h | Indicates the controller's Curtis CAN protocol version. The upper 2 bytes contain the major version and the lower 2 bytes contain the minor version. | RO | 0–2147483647<br>32-bit |
| | | 04h | Indicates the controller's serial number. | RO | 0–2147483647<br>32-bit |
| EDS | 1021h | 00h | Initiates a block upload of the EDS. | RO | *N/A* |
| EDS Storage Format | 1022h | 00h | Indicates the EDS file's storage format. The value is 80h, which indicates the ZIP format. | RO | *N/A* |

### Error History Object (1003h)

The CANopen Error History object at index 1003h provides data on the four most recently detected faults. The sub-indexes correspond to the order in which the faults occurred. Sub-index 01h records the most recent fault, sub-index 02h records the second most recent fault, etc.

The fault data consists of four bytes, which are described in the following table:

| Byte(s) | Description |
|---|---|
| 0–1 | Contains an error category and the fault code:<br>Byte 0 indicates the fault code, which is in the following format:<br>• The 4 most significant bits indicate the fault code's first digit.<br>• The 4 least significant bits indicate the fault code's second digit.<br>For example, if the fault code is 82, the byte's value would be 82h.<br>Byte 1 indicates the error category, which will be one of the following:<br>• FFh = Active fault<br>• 00h = All faults are cleared |
| 2–3 | Indicates how many hours the fault occurred after hourmeter 1 was set to 0. Hourmeter 1 is set to 0 when the controller is first powered up, and can be reset to 0 with the Clear Hourmeter 1 parameter. For information on hourmeter 1, see the Hourmeter 1 parameter description. |

## EM BRAKE OVERRIDE OBJECT

If the EM Brake Type parameter specifies EM Brake Disable, the controller's EM brake function can be controlled by the EM Brake Override object:

| CAN Index | Values<br>Raw Values | Data Size |
|---|---|---|
| 0x340B:00 | 0–100%<br>*0–4294967295* | 32-bit |

## BDI PERCENTAGE OBJECT

If the BDI Source parameter specifies CAN BDI, the BDI data is received by the BDI Percentage object:

| CAN Index | Values<br>Raw Values | Data Size |
|---|---|---|
| 0x33AF:00 | 0–100%<br>*0–100* | 8-bit |

## CUSTOM CANopen OBJECT REMAPPING

The controller can be configured with a custom CANopen object map. A custom object map consists of customer-specific CANopen addresses that are mapped to objects in the controller's object dictionary. Remapped objects can also specify read-only permissions for read-write objects.

A read-only remapped object can specify a data length other than that of the underlying object. However, if a remapped object will be written to, it must have the same data length as the underlying object.

A custom CANopen map consists of two input files that are packaged in a CIT project:

- A VCL source file that defines aliases for all remapped objects.
- A CSV file that specifies the custom CAN addresses, data types, and read/write permissions for all remapped objects.

**Note:** Object remapping requires CIT version 1.5.6 or later.

The following topics describe the VCL aliases, CSV file, and CIT packaging.

### VCL Aliases

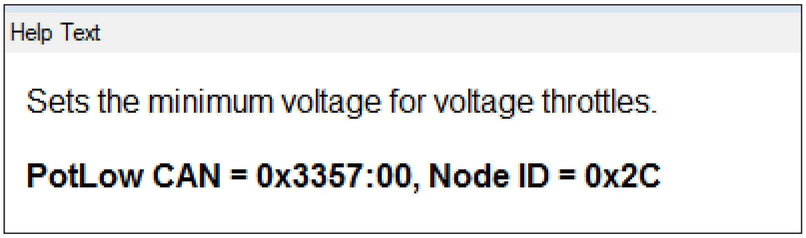
Custom object mapping requires a VCL source file that assigns a VCL alias to each remapped object. Alias assignments must use the `equals` keyword and must map to objects in the controller's object dictionary.

Make sure that remapped objects correspond to your intended use. For example, if a custom object maps to a controller object that is read-only, you cannot use the remapped object to write to the underlying controller object. For another example, if the value must persist after power is cycled, the custom object must be mapped to a non-volatile controller object.

The following example defines three VCL aliases. (The comments describe the attributes of the objects that will be remapped and the new object addresses.)

```
;Keyswitch_Voltage(UINT16,read-only access, 0x3398:00), remap to
0x2000:00, which is named remap_var_A
remap_var_A  equals  Keyswitch_Voltage
;nv_param.PotHigh(UINT16, read/write access, 0x3356:00), remap to
0x2000:10, which is named remap_var_B
remap_var_B  equals  PotHigh
;nv_param.PotLow(UINT16, read/write access, 0x3357:00), remap to
0x2002:00, which is named remap_var_C
remap_var_C  equals  PotLow
main:
goto main
```

**Tip:** To find an object's VCL variable name, select the parameter in CIT, then examine the Help Text window. The VCL variable name precedes the CAN index. In the following example, the VCL variable name is PotLow:




## Remapping CSV File

The remapping CSV file specifies the attributes of the remapped objects. The CSV file must meet the following requirements:

- The filename must have a file extension of `.remap.csv`.
- The file must consist of four columns, with the first row containing the column headings described in the following table.

| Column | Description |
|---|---|
| VclAlias | A VCL alias that's contained by the VCL source. |
| RemapAddressCAN | The remapped CAN object index and sub-index, in hexadecimal. `0x` must be prepended to the value.<br>If the remapped address is the same as the CAN index of a controller's object, the controller's object will no longer be accessible. |
| RemapDataType | The data type for the remapped object. SDO writes must match the specified data type. |
| GenericWrite | Indicates whether the remapped object is writable:<br>• 0 = Read-only<br>• 1 = Read-write<br>If the underlying object is read-only, the remapped object cannot make it writable. |

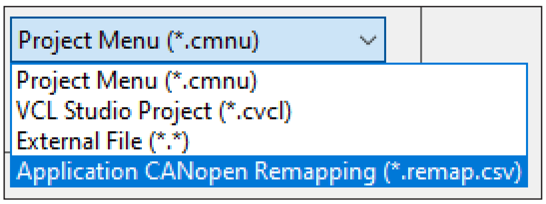
The following example is a CSV file that defines the remapped objects for the aliases defined in the VCL Aliases section's example:

```
VclAlias,RemapAddressCAN,RemapDataType,GenericWrite
remap_var_A,0x200000,UINT16,0
remap_var_B,0x200100,UINT16,1
remap_var_C,0x200200,UINT16,1
```

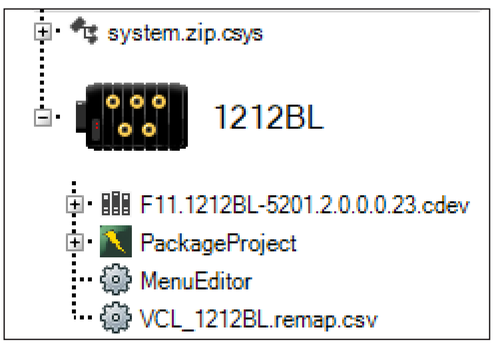
## Add the Remapped Objects to a CIT Project

Take the following steps to update the controller with the remapped objects:

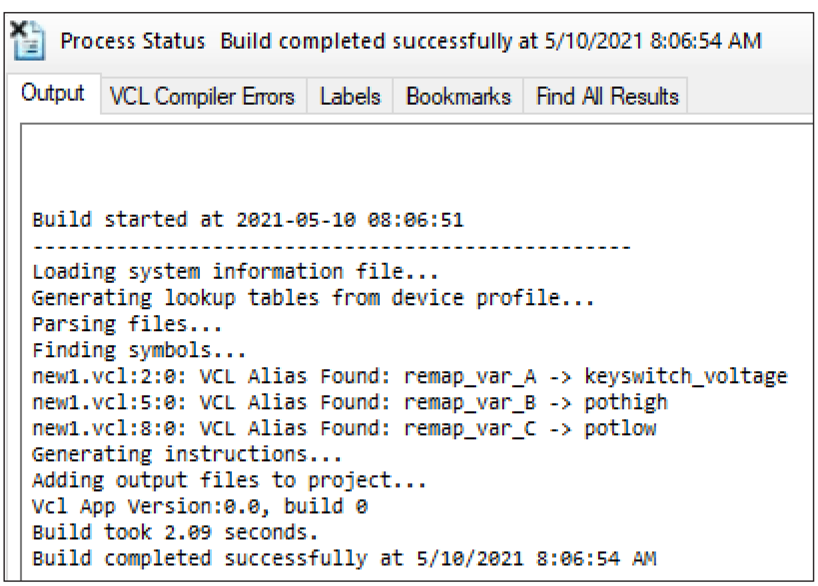
1. If CIT is connected to the controller, disconnect it.
2. If any CIT applications other than Launchpad are open, close them.
3. Select Project » Project Explorer.
4. Select the device whose objects are being remapped.
5. Click the Import button.
6. From the drop-down list for file types, select Application CANopen Remapping (*.remap.csv).



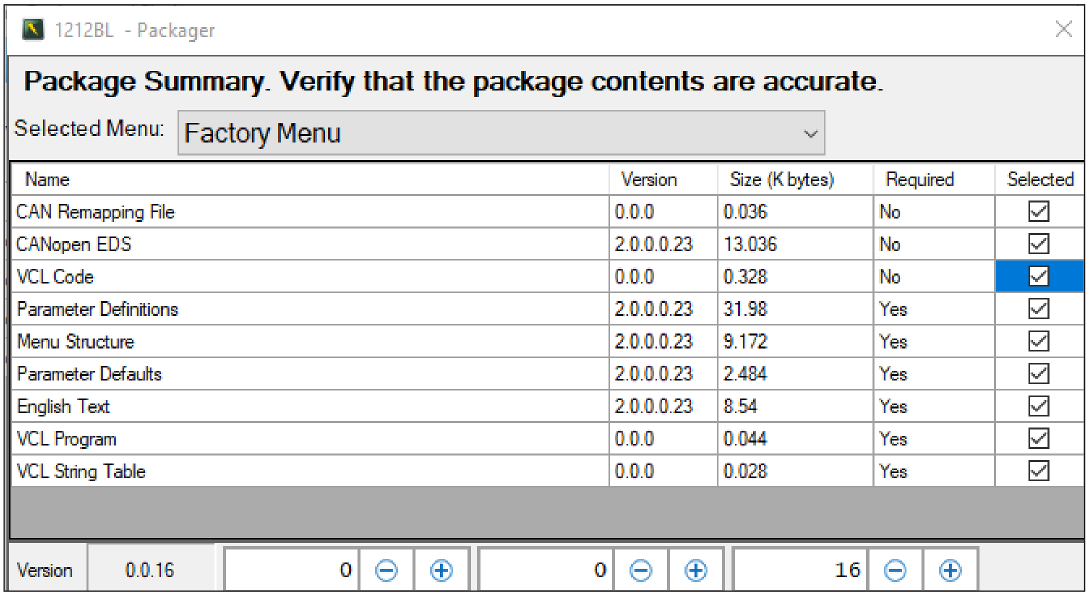

7. Navigate to and select the CSV file. This adds the CSV file to the controller's node:




8. Press the OK button to return to Launchpad.
9. Use VCL Studio to compile the VCL code that contains the VCL aliases. The Output panel's Output tab displays the compilation results, which for each alias should include a line that contains the text "VCL Alias Found", the alias, and the variable name:



10. Connect CIT to the controller.
11. Use the Package and Flash application to flash the remapped objects onto the controller. In the Package Summary dialog, make sure that the checkboxes for CAN Remapping File and VCL Code are selected:



# 9 — COMMISSIONING

After you have wired the I/Os and set the parameters that apply to the vehicle system, use the following topics to configure the motor, throttle, minimum and maximum speeds, and acceleration and deceleration rates:

- Specify the Controller Mode
- Characterize the Hall Sensors and UVW Output
- Tune the Throttle
- Tune Vehicle Performance

## SPECIFY THE CONTROLLER MODE

The controller mode specifies whether the throttle input corresponds to the motor torque output or the motor speed output. There are two controller modes:

- **Throttle control mode** is for vehicles that require the throttle input to correspond to the motor torque output.
- **Speed control mode** is for vehicles that require the throttle input to correspond to the motor speed reported by the Hall sensors.

For example, the controller mode determines how the vehicle responds if it encounters an obstacle such as an incline:

- Throttle control mode: The vehicle speed changes when the obstacle is encountered. To maintain speed, the vehicle operator must adjust the throttle.
- Speed control mode: The vehicle maintains its speed when the obstacle is encountered.

**Before** you perform the steps in this chapter, specify the controller mode that applies to the vehicle system.

**Note:** If you change the controller mode after you perform the steps in this chapter, repeat the steps for the new controller mode.

Take the following steps to specify the controller mode:

1. Select Programming » Speed.
2. Set the Controller Mode parameter to Throttle Control Mode or Speed Control Mode.

## CHARACTERIZE THE HALL SENSORS AND UVW OUTPUT

The Hall sensors provide the controller with the *Hall sensor state*, which describes the BLDC motor rotor's position. The controller drives the motor by outputting the *UVW drive phase* that corresponds to the Hall sensor state.

The parameters on the Motor Driving Phases menu associate the UVW drive phases with the Hall sensor states. The parameter values are numbers known as *output steps*; the output steps identify the UVW drive phases. For example, if the Driving Phase At Hall State 5 parameter is set to 2, the controller will generate the UVW drive phase identified by output step 2 when the Hall state is 5.

The following table describes the UVW drive phases represented by the output steps:

| Output Step | Drive Phase | | |
|---|---|---|---|
| | U | V | W |
| 1 | PWM | Ground | Float |
| 2 | PWM | Float | Ground |
| 3 | Float | PWM | Ground |
| 4 | Ground | PWM | Float |
| 5 | Ground | Float | PWM |
| 6 | Float | Ground | PWM |

The controller provides an automatic characterization function that identifies the motor's phase settings and sets the applicable parameters. Characterization can also be done manually. The following sections describe procedures for automatic and manual Hall sensor characterization.

### Automatically Characterize the Hall Sensors

Take the following steps to automatically characterize the Hall sensors.

1. Verify that the controller is correctly wired and that all electrical and mechanical connections are tight. This includes connecting the motor's UVW wires to the high current connections and the Hall sensors to the J1 connector as shown in Figure 2-2.

   The sequence in which the motor's wires are connected to the controller's U, V, and W outputs does not matter.

2. Jack the wheels off the ground so that they can spin freely at high speed.
3. Turn on the keyswitch.
4. Select Programming » Motor.
5. Set the following parameters on the Motor menu to the values provided by the motor manufacturer:
   - Max Speed
   - Pole Pairs
6. If you changed the Pole Pairs parameter, cycle the keyswitch to clear the Parameter Fault (type 1) that was generated.
7. Select Programming » Speed.

8. Set the Controller Mode parameter to Commissioning Mode.
9. Cycle the keyswitch to clear the Parameter Fault (type 1) that was generated.
10. Select Programming » Speed » Commissioning.
11. Set the following parameters on the Commissioning menu to the values that apply to your application:
    - Speed Command Limit
    - Current Limit
12. Set the Commissioning Enable parameter to On.
13. Turn on the interlock and apply throttle in the forward direction so that the Throttle Demand is greater than the Speed Command Limit. The wheels will spin at various speeds while the controller processes the Hall sensor signals.
14. If automatic characterization fails, a Parameter Fault (type 7) occurs. If this happens, cycle the keyswitch and repeat these steps. However, if automatic characterization fails again, skip the rest of this procedure and instead use the manual characterization procedure.

    **Note:** If automatic characterization is successful, the controller will set the Swap Motor Direction parameter and the parameters on the Motor Driving Phases menu.
15. Release the throttle and turn off the interlock.
16. Select Programming » Speed.
17. Set the Controller Mode parameter to Throttle Control Mode.
18. Cycle the keyswitch to clear the Parameter Fault (type 1) that was generated.
19. Confirm the results by turning on the interlock and applying throttle. If the motor spins at a speed that approximates the motor's maximum speed, the automatic characterization was successful.
20. Check the throttle input direction of the tiller head by taking the following steps:

    20.1. Turn on the interlock.

    20.2. Apply throttle in the forward direction.

    20.3. Check the Throttle Demand parameter.

    If Throttle Demand indicates a positive number, the throttle input direction is correct and you should skip ahead to step 21.

    20.4. If Throttle Demand is negative, select Programming » Throttle.

    20.5. Toggle the Swap Throttle Direction parameter value.

    20.6. Cycle the keyswitch to clear the Parameter Fault (type 1) that was generated.
21. Check whether the motor is running in the forward direction by applying throttle in the forward direction. If the motor is running in the forward direction, the Motor RPM parameter value will be positive. However, if the motor is running in reverse, take the following steps:

    21.1. Select Programming » Motor.

    21.2. Toggle the Swap Motor Direction parameter value.

    21.3. Cycle the keyswitch to clear the Parameter Fault (type 1) that was generated.

21.4. Apply throttle in the forward direction and check whether the motor is running in the forward direction. If it is, skip ahead to step 23.

21.5. Select Programming » Speed » Speed Settings.

21.6. Toggle the Swap Speed Direction parameter value.

21.7. Cycle the keyswitch to clear the Parameter Fault (type 1) that was generated.

If the speed direction is incorrect, a Parameter Fault (type 3) occurs.

22. Restore the Controller Mode parameter to the value it specified before you performed this procedure.

23. Power off the vehicle and put the wheels down.

## Manually Characterize the Hall Sensors

Take the following steps to manually characterize the Hall sensors.

1. Verify that the controller is correctly wired and that all electrical and mechanical connections are tight. This includes connecting the motor's UVW wires to the high current connections and the Hall sensors to the J1 connector as shown in Figure 2-2.

   The sequence in which the motor's wires are connected to the controller's U, V, and W outputs does not matter. This procedure will determine the correct sequence.

2. Jack the wheels off the ground so that they can spin freely at high speed.
3. Select Programming » Motor.
4. Set the Max Speed parameter to the value provided by the motor manufacturer.
5. Select Programming » Current.
6. Set the Drive Current Limit parameter to 20%.
7. Select Programming » Speed.
8. Set the Controller Mode parameter to Throttle Control Mode.
9. Select Programming » Speed » Speed Settings.
10. Set the Swap Speed Direction parameter to Off.
11. Cycle the keyswitch to clear the Parameter Fault (type 1) that was generated.
12. Turn on the interlock.
13. Select Monitor » Controller so that you can monitor the Armature Current parameter in the next step.
14. Apply the throttle slowly and watch the motor. If the motor is driving smoothly and the Armature Current parameter indicates that the current is lower than approximately 5A without a load, the sensors are wired and configured correctly and you can skip ahead to step 18.
15. Set the Swap Speed Direction parameter to On, then repeat steps 11 through 14.
16. Change the wiring of the motor to the controller's U, V, and W outputs.

    **Note:** There are six possible sequences for wiring the motor to the U, V, and W outputs: UVW, UWV, VUW, VWU, WVU, and WUV.

17. Repeat steps 9 through 16 until you discover the correct sequence of wiring and the correct value of the Swap Speed Direction parameter.
18. Check the throttle input direction of the tiller head by taking the following steps:
    18.1. Turn on the interlock.
    18.2. Apply throttle in the forward direction.
    18.3. Check the Throttle Demand parameter, then perform one of the following steps:
        - If Throttle Demand indicates a positive number, the throttle input direction is correct and you should skip ahead to step 19.
        - If Throttle Demand is negative, select Programming » Throttle.
    18.4. Toggle the Swap Throttle Direction parameter value.
    18.5. Cycle the keyswitch to clear the Parameter Fault (type 1) that was generated.
19. Check whether the motor is running in the forward direction by applying throttle in the forward direction. If the motor is running in the forward direction, the Motor RPM parameter value will be positive. However, if the motor is running in reverse, take the following steps:
    19.1. Select Programming » Motor.
    19.2. Toggle the Swap Motor Direction parameter value.
    19.3. Cycle the keyswitch to clear the Parameter Fault (type 1) that was generated.
    19.4. Apply throttle in the forward direction and check whether the motor is running in the forward direction. If it is, skip ahead to step 21.
    19.5. Select Programming » Speed » Speed Settings.
    19.6. Toggle the Swap Speed Direction parameter value.
    19.7. Cycle the keyswitch to clear the Parameter Fault (type 1) that was generated.

        If the speed direction is incorrect, a Parameter Fault (type 3) occurs.
20. Restore the Drive Current Limit and Controller Mode parameters to the values they specified before you performed this procedure.
21. Power off the vehicle and put the wheels down.

## TUNE THE THROTTLE

It is important to tune the throttle so that it operates over the throttle's full range. When you tune the throttle, include a buffer around the absolute full range of the throttle mechanism. This will allow for throttle resistance variations over time and temperature and for variations in the tolerance of potentiometer values between individual throttle mechanisms.

Take the following steps to configure the throttle so that it is compatible with your vehicle's requirements:

Step 1. Prepare the Vehicle

Step 2. Tune the Deadband

Step 3. Tune the Throttle Demand

Step 4. Confirm Throttle Operation

Step 5. Verify the Vehicle's Configuration

### Step 1 Prepare the Vehicle

Take the following steps before tuning the throttle.

**⚠ CAUTION**

**It is critical that you perform these steps.**

1. Jack the vehicle drive wheels up off the ground so that they spin freely.
2. Make sure the vehicle is stable.
3. Double-check all wiring to ensure that it is consistent with the wiring guidelines. See Installation, Wiring, and Configuration.
4. Make sure all connections are tight.
5. Put the throttle in neutral.
6. Turn off the forward/reverse switches.
7. Turn on the controller.

   **Note:** If you are using the 1313 handheld programmer, it should power up with an initial display and the status LED should be on without flashing. If neither happens, check for continuity in the keyswitch circuit and controller ground.

### Step 2 Tune the Deadband

Check whether the throttle's deadband range provides a good balance. The deadband should be wide enough for the throttle to return to neutral when released, but also should not allow an excessive amount of travel in the neutral zone.

If the deadband needs tuning, perform the following steps.

1. Adjust the Forward Deadband as follows:
    - If the throttle travels too far when starting out of neutral before the brake disengages, decrease the Forward Deadband value.
    - If the brake sometimes doesn't engage when the throttle is returned to neutral, increase the Forward Deadband value.
2. If a wigwag throttle assembly is being used, repeat the previous step using the Reverse Deadband parameter; otherwise, set Reverse Deadband to the same value as Forward Deadband.

### Step 3 Tune the Throttle Demand

Take the following steps to ensure the controller output is 100% when full throttle is applied:

1. In the Monitor menu, select Monitor » Controller.
2. Apply full throttle and observe the Throttle Demand value. This value should be 100% at full throttle. If the Throttle Demand value is less than 100%, perform the following steps:
    2.1. Select Programming » Throttle.
    2.2. Decrease the Forward Max value.
    2.3. Apply full throttle and observe the Throttle Demand value.
    2.4. If the value is less than 100%, repeat these steps until the value is 100%.
3. Slowly reduce the throttle until the Throttle Demand value drops below 100%, then note the throttle position.
   The throttle position represents the extra range of motion allowed by the throttle mechanism. You can increase the throttle's active range and provide more vehicle control by taking the following steps.
    3.1. Select Programming » Throttle.
    3.2. Increase the Forward Max value.
    3.3. Select Monitor » Controller.
    3.4. Slowly reduce the throttle until the Throttle Demand value drops below 100%, then note the throttle position.
    3.5. Repeat this step until you are satisfied with the throttle's active range.
4. If a wigwag throttle is being used, repeat these steps using the Reverse Max parameter; otherwise, set Reverse Max to the same value as Forward Max.

### Step 4 Confirm Throttle Operation

To confirm the throttle is operating correctly, select a direction and operate the throttle. The motor should rotate in the direction you selected. If it does not, verify the wiring to the throttle and motor. The motor should run proportionally faster with increasing throttle. If not, use the Throttle menu to adjust the throttle parameters.

### Step 5 Verify the Vehicle's Configuration

Take the following steps to verify that critical parameters are correctly set.

1. Select Monitor » Inputs.
2. Cycle each switch and make sure that the switch state changes from on to off, or vice versa.
3. Apply the throttle, then verify that the Throttle Demand parameter changes.
4. Verify that you've correctly set the functions meeting the vehicle's requirements, such as emergency reverse, HPD, and so on.
5. After you have validated the parameter settings, lower the vehicle drive wheels onto the ground.

## TUNE VEHICLE PERFORMANCE

You can customize many aspects of vehicle performance by configuring the controller's parameters. Once you have tuned a vehicle system, you can make the parameter values standard for that system or vehicle model.

⚠ **CAUTION**

**If the system's motor, vehicle drive system, or controller changes, you must retune the system to provide optimum performance.**

Take the following steps to tune vehicle performance:

Step 1. Set the Maximum and Minimum Speeds.

Step 2. Set the Acceleration and Deceleration Rates.

It is important to perform these steps in order, because each step builds upon the previous steps.

### Step 1 Set the Maximum and Minimum Speeds

For each speed mode, you can configure maximum and minimum speeds for both the forward and reverse directions. Use the following parameters to define the maximum and minimum speeds. For information on these parameters, see Mode 1 and Mode 2 Menus:

- Max Speed
- Rev Max Speed
- Min Speed
- Rev Min Speed

Each of these speeds is programmed as a percentage of the motor's maximum speed.

### Step 2 Set the Acceleration and Deceleration Rates

The controller's acceleration and deceleration features provide smooth throttle response when maneuvering at low speeds and snappy throttle response when traveling at high speeds. For more information, see Low and High Speed Acceleration Rates.

To configure your vehicle's acceleration and deceleration rates, take the following steps.

1. Select Programming » Speed.
2. Set the Low Speed parameter to the percentage of motor speed at or below which the controller should apply the low speed acceleration rate.
3. Set the High Speed parameter to the percentage of motor speed at or above which the controller should apply the high speed acceleration rate.
4. Select Programming » Speed, then perform the following steps:
   4.1. Select the Mode 1 menu.
   4.2. Set the Full Accel Rate LS parameter to the rate at which the vehicle should accelerate when full throttle is applied while the vehicle is traveling at low speed.
   4.3. Drive the vehicle at a low speed, then apply full throttle. Adjust Full Accel Rate LS until you are satisfied with the vehicle's low speed acceleration.

   For low speed testing, we recommend that you drive in a confined area such as an office where low speed maneuverability is crucial.

   4.4. Set the Neutral Decel Rate LS parameter to the rate at which the vehicle should decelerate when the throttle is released to neutral while traveling at low speed.
   4.5. Drive the vehicle at a low speed, then release the throttle to neutral. Adjust Neutral Decel Rate LS until you are satisfied with the vehicle's low speed deceleration.
   4.6. Set the Full Accel Rate HS parameter to the rate at which the vehicle should accelerate when full throttle is applied while traveling at high speed.
   4.7. Drive the vehicle at a high speed, then apply full throttle. Adjust Full Accel Rate HS until you are satisfied with the vehicle's high speed acceleration.
   4.8. Set the Neutral Decel Rate HS parameter to the rate at which the vehicle should decelerate when the throttle is released to neutral while traveling at high speed.
   4.9. Drive the vehicle at a high speed, then release the throttle to neutral. Adjust Neutral Decel Rate HS until you are satisfied with the vehicle's high speed deceleration.
   4.10. Select the Mode 2 menu.
   4.11. Repeat steps 4.2 through 4.9.

   The following list describes additional functions that might require tuning:

   - Use the Forward Map and Reverse Map parameters to adjust the relationship between the throttle input and the acceleration rate. By default, the throttle input and acceleration rate have a linear relationship. Some applications require adjusting this relationship. For more information, see Throttle Response Parameters.
   - You can extend the throttle's gentle acceleration range to further enhance maneuverability in confined areas. For more information, see Low and High Speed Acceleration Rates.

# 10 — MAINTENANCE

There are no user-serviceable parts in the controller. Do not attempt to open, repair, or otherwise modify the controller. Doing so may damage the controller and will void the warranty.

It is recommended that the controller's fault history be checked and cleared periodically as part of routine vehicle maintenance.

## DIAGNOSTIC HISTORY

You can use a Curtis programming device to access the controller's fault history. The programming device shows the faults that have occurred since the fault history was last cleared. The faults may be intermittent faults, faults caused by loose wires, or faults caused by operator errors. Faults such as HPD or overtemperature may be caused by operator habits or by overloading.

After a problem has been diagnosed and corrected, clearing the fault history is recommended. This allows the controller to accumulate a new fault history. By checking the new fault history at a later date, you can determine whether the problem was fixed.

# APPENDIX A — VEHICLE DESIGN CONSIDERATIONS REGARDING ELECTROMAGNETIC COMPATIBILITY (EMC)

Electromagnetic compatibility (EMC) encompasses two areas: emissions and immunity. Emissions are radio frequency (RF) energy generated by a product. This energy has the potential to interfere with communications systems such as radio, television, cellular phones, dispatching, aircraft, etc. Immunity is the ability of a product to operate normally in the presence of RF energy.

EMC is ultimately a system design issue. Part of the EMC performance is designed into or inherent in each component; another part is designed into or inherent in end product characteristics such as shielding, wiring, and layout; and, finally, a portion is a function of the interactions between all these parts. The design techniques presented below can enhance EMC performance in products that use Curtis motor controllers.

## EMISSIONS

Signals with high frequency content can produce significant emissions if connected to a large enough radiating area (created by long wires spaced far apart). Contactor drivers and the motor drive output from Curtis controllers can contribute to RF emissions. Both types of output are pulse width modulated square waves with fast rise and fall times that are rich in harmonics. (Note: Contactor drivers that are not modulated will not contribute to emissions.) The impact of these switching waveforms can be minimized by making the wires from the controller to the contactor or motor as short as possible and by placing the wires near each other (bundle contactor wires with Coil Return; bundle motor wires separately).

For applications requiring very low emissions, the solution may involve enclosing the controller, interconnect wires, contactors, and motor together in one shielded box. Emissions can also couple to battery supply leads and throttle circuit wires outside the box, so ferrite beads near the controller may also be required on these unshielded wires in some applications. It is best to keep the noisy signals as far as possible from sensitive wires.

## IMMUNITY

Immunity to radiated electric fields can be improved either by reducing overall circuit sensitivity or by keeping undesired signals away from this circuitry. The controller circuitry itself cannot be made less sensitive, since it must accurately detect and process low level signals from sensors such as the throttle potentiometer. Thus immunity is generally achieved by preventing the external RF energy from coupling into sensitive circuitry. This RF energy can get into the controller circuitry via conducted paths and radiated paths.

Conducted paths are created by the wires connected to the controller. These wires act as antennas and the amount of RF energy coupled into them is generally proportional to their length. The RF voltages and currents induced in each wire are applied to the controller pin to which the wire is connected. Curtis controllers include bypass capacitors on the printed circuit board's throttle wires to reduce the impact of this RF energy on the internal circuitry. In some applications, additional filtering in the form of ferrite beads may also be required on various wires to achieve desired performance levels.

Radiated paths are created when the controller circuitry is immersed in an external field. This coupling can be reduced by placing the controller as far as possible from the noise source or by enclosing the controller in a metal box. Some Curtis controllers are enclosed by a heatsink that also provides shielding around the controller circuitry, while others are partially shielded or unshielded.

In some applications, the vehicle designer will need to mount the controller within a shielded box on the end product. The box can be constructed of just about any metal, although steel and aluminum are most commonly used.

Most coated plastics do not provide good shielding because the coatings are not true metals, but rather a mixture of small metal particles in a non-conductive binder. These relatively isolated particles may appear to be good based on a DC resistance measurement but do not provide adequate electron mobility to yield good shielding effectiveness. Electroless plating of plastic will yield a true metal and can thus be effective as an RF shield, but it is usually more expensive than the coatings.

A contiguous metal enclosure without any holes or seams, known as a Faraday cage, provides the best shielding for the given material and frequency. When a hole or holes are added, RF currents flowing on the outside surface of the shield must take a longer path to get around the hole than if the surface was contiguous. As more "bending" is required of these currents, more energy is coupled to the inside surface, and thus the shielding effectiveness is reduced. The reduction in shielding is a function of the longest linear dimension of a hole rather than the area. This concept is often applied where ventilation is necessary, in which case many small holes are preferable to a few larger ones.

Applying this same concept to seams or joints between adjacent pieces or segments of a shielded enclosure, it is important to minimize the open length of these seams. Seam length is the distance between points where good ohmic contact is made. This contact can be provided by solder, welds, or pressure contact. If pressure contact is used, attention must be paid to the corrosion characteristics of the shield material and any corrosion-resistant processes applied to the base material. If the ohmic contact itself is not continuous, the shielding effectiveness can be maximized by making the joints between adjacent pieces overlapping rather than abutted.

The shielding effectiveness of an enclosure is further reduced when a wire passes through a hole in the enclosure; RF energy on the wire from an external field is re-radiated into the interior of the enclosure. This coupling mechanism can be reduced by filtering the wire where it passes through the shield boundary. Given the safety considerations involved in connecting electrical components to the chassis or frame in battery powered vehicles, such filtering will usually consist of a series inductor (or ferrite bead) rather than a shunt capacitor. If a capacitor is used, it must have a voltage rating and leakage characteristics that will allow the end product to meet applicable safety regulations.

The B+ (and B–, if applicable) wires that supply power to a control panel should be bundled with the other control wires to the panel so that all these wires are routed together. If the wires to the control panel are routed separately, a larger loop area is formed. Larger loop areas produce more efficient antennas which will result in decreased immunity performance.

Keep all low power I/O separate from the motor and battery leads. When this is not possible, cross them at right angles.

# APPENDIX B — EN 13849 COMPLIANCE

Since January 1, 2012, conformance to the European Machinery Directive has required that the Safety Related Parts of the Control System (SRPCS) be designed and verified upon the general principles outlined in EN 13849. EN 13849 supersedes the EN 954 standard and expands upon it by requiring the determination of the safety Performance Level (PL) as a function of Designated Architecture plus Mean Time To Dangerous Failure ($MTTF_d$), Common Cause Faults (CCF), and Diagnostic Coverage (DC). These figures are used by the OEM to calculate the overall PL for each of the safety functions of their vehicle or machine.

The OEM must determine the hazards that are applicable to their vehicle design, operation, and environment. Standards such as EN 13849-1 provide guidelines that must be followed in order to achieve compliance. Some industries have developed further standards (called type-C standards) that refer to EN 13849 and specifically outline the path to regulatory compliance. EN 1175 is a type-C standard for battery-powered industrial trucks. Following a type-C standard provides a presumption of conformity to the Machinery Directive.

Curtis controllers comply with these directives using advanced active supervisory techniques.

The controller is designed to the requirements of EN 13849-1:2015. To mitigate the hazards typically found in machine operations, EN 13849-1:2015 requires that safety functions be defined; these must include all the input, logic, outputs, and power circuits that are involved in any potentially hazardous operation. The following safety functions are defined for the controller:

- Crushing due to unintended or uncontrolled traction motion.
- Crushing due to unintended or uncontrolled load handling motion.

Curtis has analyzed each safety function and calculated its Mean Time To Dangerous Failure ($MTTF_d$) and Diagnostic Coverage (DC), and designed them against Common Cause Faults (CCF). The safety-related performance of the controller is summarized in the following table:

**Table B-1 Safety-Related Performance**

| Hazard | $PL_r$ | Category | $MTTF_d$ | Diagnostic Coverage | TE $MTTF_d$ |
|---|---|---|---|---|---|
| Crushing by unintended or uncontrolled movement | c | 2 | > 22 years | > 60% | > 11 years |
| | | | > 16 years | > 90% | > 8 years |

EN 1175 specifies that traction and hydraulic electronic control systems must use Designated Architecture 2 or greater. This design employs input, logic, and output circuits that are monitored and tested by independent circuits and software to ensure a high level of safety performance (up to PL=d).

Mean Time To Dangerous Failure ($MTTF_d$) is related to the expected reliability of the safety related parts used in the controller. Only failures that can result in a dangerous situation are included in the calculation.

**Note:** Test Equipment Mean Time To Dangerous Failure (TE $MTTF_d$) must be at least 50% of the $MTTF_d$.

Diagnostic Coverage (DC) is a measure of the effectiveness of the control system's self-test and monitoring measures to detect failures and provide a safe shutdown.

Common Cause Faults (CCF) are so named because some faults within a controller can affect several systems. EN 13849-1:2015 provides a checklist of design techniques that should be followed to achieve sufficient mitigation of CCFs. All circuits used by a safety function must be designed in such a way as to score 65 or better on the CCF score sheet as provided by EN 13849-1:2015, table F.1.

Performance Level (PL) categorizes the quality or effectiveness of a safety channel to reduce the potential risk caused by dangerous faults within the system, with "a" being the lowest and "e" being the highest achievable performance.

Contact Curtis technical support for more details.

# APPENDIX C — CURTIS PROGRAMMING DEVICES

Curtis programming devices provide programming, diagnostic, and test capabilities for Curtis CAN devices. Two programming devices are available for the controller:

- 1313 handheld programmer
- Curtis Integrated Toolkit™ (CIT)

CIT has the advantage of a large, easy-to-read screen. On the other hand, the 1313 handheld programmer is more portable, making it convenient for working in the field.

The programming devices include the following features:

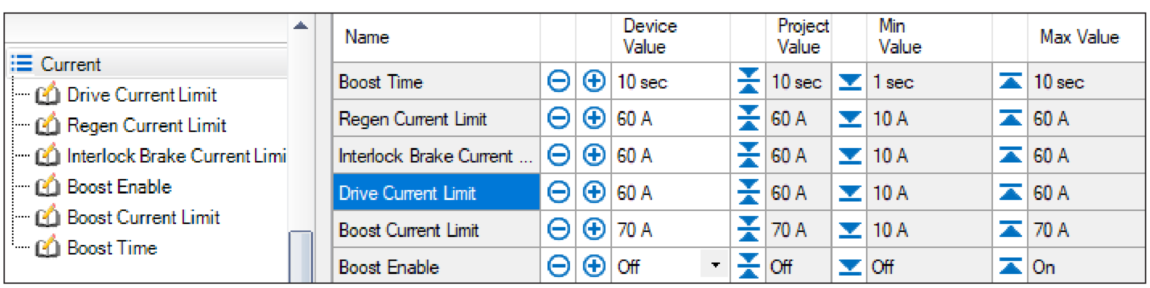
- Parameter adjustment. Save and restore the values of programmable parameters.
- Monitoring: Display real-time values during vehicle operation. These values include data for inputs and outputs.
- Diagnostics and troubleshooting: Display active faults and the fault history, and allow users to clear the fault history.
- Flashing: Update firmware of Curtis devices.

The programmers are available for the following access levels. The bullets are sorted from the highest to lowest access level:

- OEM Factory
- OEM Dealer
- Field Advanced
- Field Intermediate
- Field Basic

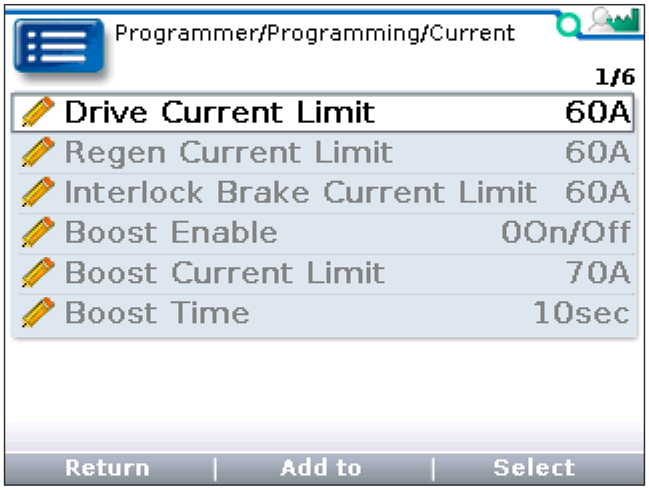
A Curtis programmer can perform the actions available at or below its access level. For example, a Field Basic programmer can only perform actions available for the Field Basic access level, while an OEM Factory programmer can perform all actions available for any of these access levels.

The following example shows the Current menu in the CIT Programmer application. You can view or edit a parameter by selecting it on the left-hand side. You can also view and edit all of a menu's parameters in one window by selecting the menu as shown below:

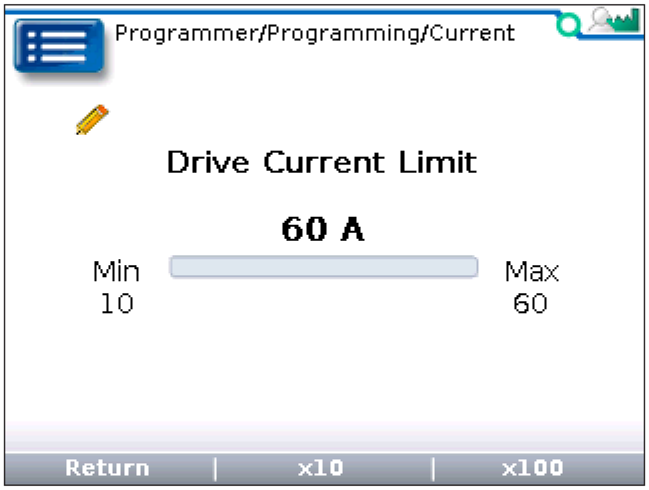



| Name | Device Value | Project Value | Min Value | Max Value |
|---|---|---|---|---|
| Boost Time | 10 sec | 10 sec | 1 sec | 10 sec |
| Regen Current Limit | 60 A | 60 A | 10 A | 60 A |
| Interlock Brake Current ... | 60 A | 60 A | 10 A | 60 A |
| Drive Current Limit | 60 A | 60 A | 10 A | 60 A |
| Boost Current Limit | 70 A | 70 A | 10 A | 70 A |
| Boost Enable | Off | Off | Off | On |

The following example shows the same menu in the Curtis 1313 handheld programmer:




To edit a parameter with the 1313 programmer, select the parameter:




For more information on the 1313 handheld programmer and CIT, see https://www.curtisinstruments.com/products/programming/.

# APPENDIX D — SPECIFICATIONS

| | |
|---|---|
| **PWM operating frequency** | 15.6 kHz |
| **Electrical isolation to heatsink** | 500 VAC (minimum) |
| **Weight** | 0.5 kg |
| **Dimensions (W × L × H)** | 90mm × 150mm × 44 mm |
| **Mounting** | 2x ø5.0 mm |
| **I/O connections** | 6 pin, 8 pin, and 16 pin connectors. Mates with TE Connectivity Mini-Universal Mate-N-Lok connectors. |
| **Power connections** | 5x M4X0.7 |
| **Storage ambient temperature range** | –40°C to 85°C |
| **Operating ambient temperature range** | –40°C to 50°C |
| **Environmental rating** | Electronics are sealed to IP65. The connectors' protections depend upon whether sealed or unsealed parts are used:<br>• **Sealed:** IP54<br>• **Unsealed:** IP40 |
| **EMC** | Designed to the requirements of EN 12895:2015+A1:2019 |
| **Safety** | Designed to the requirements of EN 1175:2020 and EN 13849-1:2015 |
| **UL** | Recognized Component as per UL 583 |
| **Communications** | CANopen |

***Note:*** *Regulatory compliance of the complete vehicle system with the controller installed is the responsibility of the vehicle OEM.*

Table D-1 Model Chart

| Model | Voltage | 10s Current Rating | 1 Min. Current Rating | 1 Hour Current Rating |
|---|---|---|---|---|
| 1212BL-52*XX* | 36V/48V | 70A | 60A | 25A |

*The current ratings are based on mounting the controller on an aluminum plate (180mm x 200mm x 8mm). The initial heat sink temperature is 25°C. The motor current is held at the rating being tested for a minimum of 120% of the rated time before thermal limiting begins. The current ratings have a 5% error tolerance.*