Manual
Model **1226BL**

Brushless DC Permanent Magnet Motor Controller

» Software Device Profile: 6.9.0.0 «

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Read Instructions Carefully!

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TABLE OF CONTENTS

TABLE OF CONTENTS cont'd

TABLE OF CONTENTS cont'd

TABLE OF CONTENTS cont'd

TABLE OF CONTENTS cont'd

TABLE OF CONTENTS cont'd

FIGURES

TABLE OF CONTENTS cont'd

TABLES

The Curtis Difference

You feel it when you drive it

1 — OVERVIEW

The Curtis model 1226BL motor speed controllers provide efficient, optimal control of brushless DC motors for battery powered vehicles. The 1226BL is optimized for use on light duty Class III pallet trucks and sweeper scrubber floor care machines. Highly flexible programmability allows 1226BL controllers to be used in any low power BLDC motor application.

Figure 1
Curtis 1226BL Controller

KEY FEATURES

The following sections describe the 1226BL controller's features.

Easy Installation and Set-up

- Highly flexible programming allows you to configure a vehicle system using one of the Curtis programming devices listed in Curtis Programming Devices.
- Industry standard Molex Mini-fit Jr. logic connectors and heavier duty M5 threaded busbars for battery and motor wiring.

Smooth and Secure Control

- Linear cutback of current ensures smooth control with no sudden loss of power during undervoltage, overvoltage, or overtemperature.
- Emergency reverse inputs.
- Temporary "Boost Current" feature provides superior performance with transient loads such as starting on a hill, crossing thresholds, climbing obstacles, etc.

- Hydraulic lift lockout function protects the vehicle's batteries from damaging levels of discharge.
- Dynamic pot fault detection (open/short wiring fault detection).
- Electromagnetic brake driver.
- Hydraulic pump contactor driver.
- Main contactor driver (72V model).
- Embedded main relay (24V and 36/48V models).
- Supports a motor temperature sensor.
- Inputs are protected against shorts to B+ and B–.
- Short-circuit protected outputs.

Flexible I/Os

I/Os can be configured to provide up to:

- Two analog/digital inputs.
- One potentiometer input.
- Three 1.5A coil drivers.
- One motor temperature sensor input.
- +5V and +14V external power supplies (120mA total).

Valuable Additional Features

- CANbus option that complies with CANopen DS 301.
- Two programmable speed modes.
- Battery discharge indicator (BDI) output (0–5V).
- Adjustable brake holding voltage reduces heating of the brake coil.
- Integrated status LEDs.
- Charger inhibit input prevents driving while the charger is connected (24V and 36V/48V models).
- Precharge function reduces arcing that would otherwise occur when the main relay or contactor is closed with the internal capacitor bank discharged.
- 120° Hall position sensors.

Complies with Relevant US and International Regulations

For details on regulatory compliance, see Specifications.

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

USING THIS MANUAL

This manual provides information you need to get the most out of the controller. You can get started by reading the following chapters, which provide information regarding the features and operation of the 1226BL controller:

- Installation and Wiring
- Programmable Parameters
- Monitor Menu Variables
- Faults, Diagnostics, and Troubleshooting
- Initial Setup
- Tuning Vehicle Performance

If you are working with a CANbus model, see the following chapters:

- CANopen Communications
- CANopen Object Dictionary

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: • *nnn* • *nnnd*	• 127 • 127d
Hexadecimal	Either of the following: • *nnnh* • *0xnnn*	• 62Ah • 0x62A
Binary	*nnnb*	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 AND WIRING

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

MOUNTING THE CONTROLLER

The controller meets the IP54 requirements for environmental protection against dust and water. To prevent external corrosion and leakage paths, mount the controller in a location that will keep the controller clean and dry.

⚠ CAUTION **If you cannot find a clean, dry mounting location you must use a cover to shield the controller from water and contaminants.**

The following diagram shows the outline and mounting hole dimensions. The controller should be mounted by means of the two mounting holes at the opposing corners of the heatsink, using M5 screws.

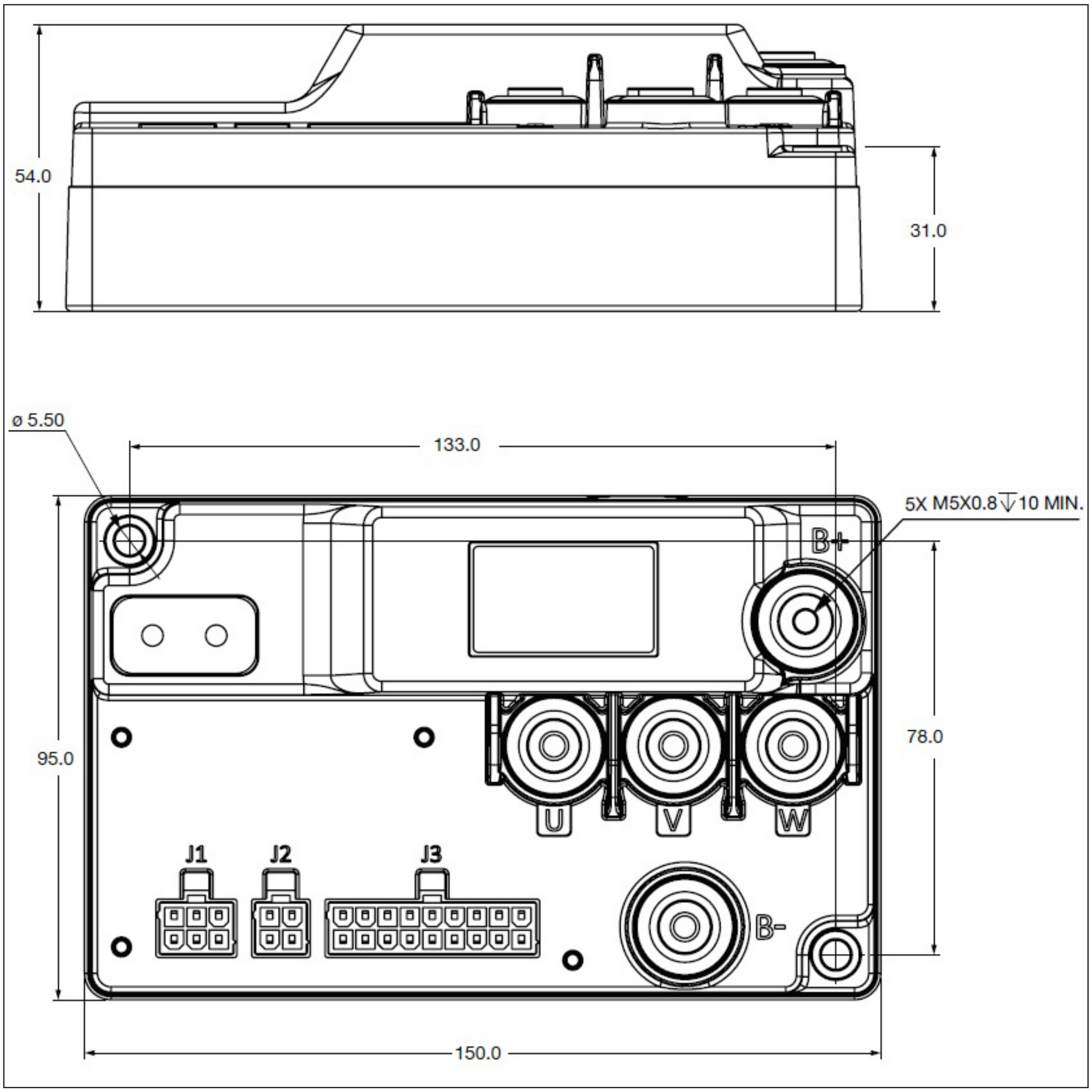


Figure 2

Mounting Dimensions, Curtis 1226BL Controller

⚠ WARNING

You must heed the following warnings:

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; suggestions are presented in 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 M5x0.8 bolt-on terminals for high current connections. The recommended torque is 3.5±0.4 Nm. The following table describes the terminals:

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

Note: 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 listed in the following table:

Connector	Description
J1	Motor connector
J2	Communication port
J3	Logic connector

The following topics describe the low current connectors.

Motor Connector (J1)

The six-pin motor connector (J1) is for the feedback signals from the BLDC motor. The mating connector is a Molex 39-01-2065 receptacle with appropriate 45750-series crimp terminals.

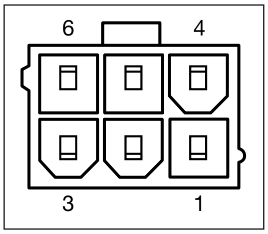


Figure 3

Motor Connector Pins (J1)

The following table describes the connector's pins:

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

Note: The motor 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 logic connector.

Communication Port (J2)

The four-pin communications port (J2) handles serial communications and the external +14V power supply. Some models provide a CANbus option. The mating connector is a Molex 39-01-2045 receptacle with appropriate 45750-series crimp terminals.

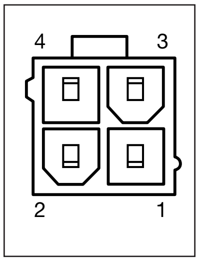


Figure 4

Communication Connector Pins (J2)

The following table describes the connector's pins:

Pin	Function
J2-1	Serial RX/CAN Low
J2-2	I/O ground
J2-3	Serial TX/CAN High
J2-4	External +14V power supply

Logic Connector (J3)

The 18-pin logic connector (J3) is used for inputs, outputs, and low power drivers. The mating connector is a Molex 39-01-2185 receptacle with appropriate 45750-series crimp terminals.

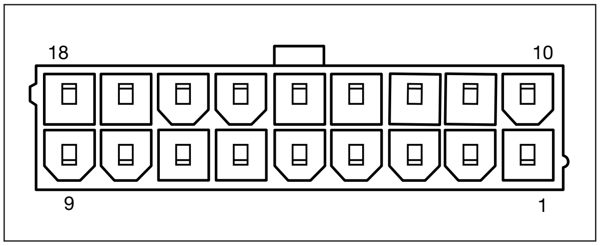


Figure 5

Logic Connector Pins (J3)

The following table describes the logic connector's pins and their typically used functions. The table also identifies which pins provide digital switches:

Table 1 Logic Connector Pins

Pin	Typical Function
J3-1	Keyswitch
J3-2	Valve driver/Status LED driver
J3-3	Interlock switch
J3-4	Emergency reverse normally closed (NC) switch/Analog 2/Digital 2
J3-5	BDI output
J3-6	Analog 1/Digital 1
J3-7	Pot wiper
J3-8	Reverse switch
J3-9	Lift switch
J3-10	Coil return
J3-11	Depends upon the model: • 1226BL-22XX and 1226BL-41XX: Pump contactor driver • 1226BL-61XX: Main contactor driver
J3-12	Electromagnetic brake (EM) driver
J3-13	I/O ground
J3-14	Emergency reverse normally open (NO) switch
J3-15	Charger inhibit **Note:** 1226BL-61XX models do not support charger inhibit.
J3-16	Pot high
J3-17	Forward switch
J3-18	Mode switch

I/O Ground Specifications

The following table describes the considerations for the I/O ground pins (J1-5, J2-2, and J3-13).

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

Specification	Value
Maximum Current	500mA
Maximum Voltage	*N/A*
Maximum Reverse Voltage	0V

WIRING DIAGRAM: STANDARD CONFIGURATION

Figure 6 is a representative wiring diagram for Curtis 1226BL models. The diagram is for a Class III Walkie that has the following characteristics:

- The operator controls are directly wired to the controller and other functional components.
- The lower valve is controlled by the controller.
- The horn is controlled by the tiller's horn switch.

Note: The wiring diagram is designed for typical Class III Walkies and may not fully meet your application's requirements. However, the 1226BL controller provides the flexible I/Os and programmable parameters needed to fulfill your requirements. To discuss how to implement your application, contact your Curtis distributor or support engineer.

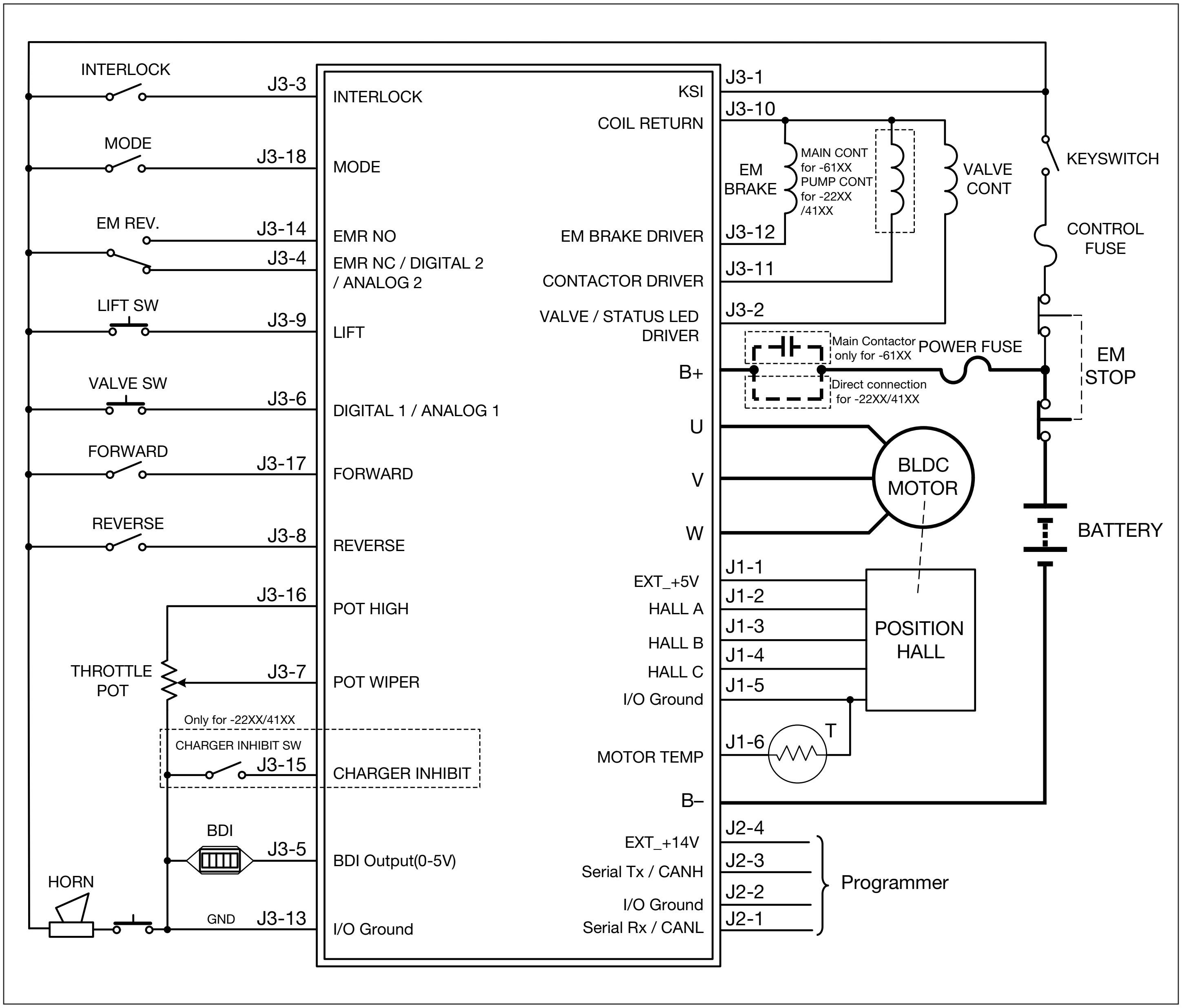


Figure 6

Wiring Diagram, Curtis 1226BL Models

INPUTS AND OUTPUTS (I/OS)

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

Note: 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.

Digital Inputs

The following pins provide digital inputs that typically are used for the functions listed in Table 1. However, you can use these inputs for any function that requires a digital signal:

- J3-3
- J3-4
- J3-6
- J3-8
- J3-9
- J3-14
- J3-15
- J3-17
- J3-18

Note: Pins J3-4 and J3-6 are analog/digital inputs. See Analog/Digital Inputs.

The following table describes the digital inputs' specifications:

Specification	Value
Low to High Threshold	Depends upon the model: • 8.1V for 1226BL-22XX • 13.9V for 1226BL-41XX • 19.7V for 1226BL-61XX
High to Low Threshold	Depends upon the model: • 2.2V for 1226BL-22XX • 3.7V for 1226BL-41XX • 5.3V for 1226BL-61XX
Open Pin Response	Low / Off (pulled to B–)
Maximum Voltage	Depends upon the model: • 1226BL-22XX: 34V • 1226BL-41XX: 63V • 1226BL-61XX: 105V
Maximum reverse voltage	–1V

Note: The Inputs menu includes variables that show the digital inputs' states.

Analog/Digital Inputs

Pins J3-4 and J3-6 are analog/digital inputs. The analog signals have 12-bit resolution and also are decoded as digital signals.

You can use parameters to specify the digital high and low thresholds. This allows you to connect the inputs to analog sensors and configure the digital high- and low-level thresholds to indicate conditions such as over/under pressure and high/low level points.

The following considerations apply to the analog/digital inputs:

- To specify the high and low thresholds of the analog/digital inputs, use the Digital/Analog Input 1 and Digital/Analog Input 2 menus.
- You can use pin J3-4 as a generic analog/digital input if the vehicle system does not use an emergency reverse NC switch and the EMR Input Type parameter is set to 0.

The following table describes the analog specifications for the analog/digital inputs:

Specification	Value
Measurement Range	0–10V (±10%)
Input Impedance	> 5kΩ
Time Constant	< 1ms

Note: For the digital specifications, see Digital Inputs.

Driver Outputs

The controller provides three low-side coil drivers. Each driver supports a continuous 1.5A load and can be configured to operate in Direct PWM or Voltage Compensated PWM mode. The following table describes the PWM modes:

Mode	Description
Direct PWM	The output voltage is not adjusted to account for fluctuations in battery voltage.
Voltage Compensated PWM	The output voltage is adjusted to compensate for fluctuations in battery voltage, maintaining a near-constant average voltage at the pin.

The following table describes the drivers.

Note: To configure a pin's PWM mode, use the parameter listed in the last column.

Pin	Typical Function	Pin Mode Parameter
J3-2	Valve driver/Status LED driver	Valve Driver Compensation, MISC menu
J3-11	Depends upon the model: • 1226BL-22*XX* and 1226BL-41*XX:* Pump contactor driver • 1226BL-61*XX:* Main contactor driver	Depends upon the model: • 1226BL-22*XX* and 1226BL-41*XX:* Pump Contactor Driver Compensation, MISC menu • 1226BL-61*XX*: Battery Voltage Compensated, Main Relay(Contactor) menu
J3-12	EM brake driver	Battery Voltage Compensated, EM Brake menu

The following list describes considerations for the drivers:

- The drivers provide diagnostic faults for open coils. To enable a driver's fault protection, use the MISC menu parameters that have names ending with "Checks Enable".
- You can use the Outputs menu to monitor the outputs' values.

The following table describes the drivers' specifications.

Table 2 Driver Specifications

Specification	Value
Active level	Low = On
Max Current	1.5A continuous
Output Low Voltage	< 0.5V at full current and 100% PWM
Frequency	16 KHz
Pulse Width Resolution	0.5% minimum over a 2% to 99% duty cycle range (8 bit resolution)
Maximum Voltage	125% of nominal battery voltage +5V
Maximum Reverse Voltage	–0.5V
Open Pin Response	Low / Off (pulled to B–)
Logic High Threshold	Depends upon the model: • 1226BL-22*XX:* 7V • 1226BL-41*XX:* 12V • 1226BL-61*XX:* 17V
Logic Low Threshold	Depends upon the model: • 1226BL-22*XX:* 4V • 1226BL-41*XX:* 7V • 1226BL-61*XX:* 10V
Input Impedance	Depends upon the model: • 1226BL-22*XX:* > 50KΩ • 1226BL-41*XX:* > 100KΩ • 1226BL-61*XX:* > 150KΩ

Throttle Inputs

The controller supports the following types of throttles:

- 0–5kΩ 2-wire potentiometer
- 5k–0Ω 2-wire potentiometer
- 3-wire potentiometer
- Wigwag 3-wire potentiometer
- 0–5V voltage source
- Wigwag 0–5V voltage source
- CAN (CAN models)

The pot wiper and pot high inputs (pins J3-7 and J3-16) 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 voltage source throttles, it is the responsibility of the OEM to provide any fault protection that the vehicle system requires.**

Use the Throttle Type parameter value to specify the vehicle's throttle.

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

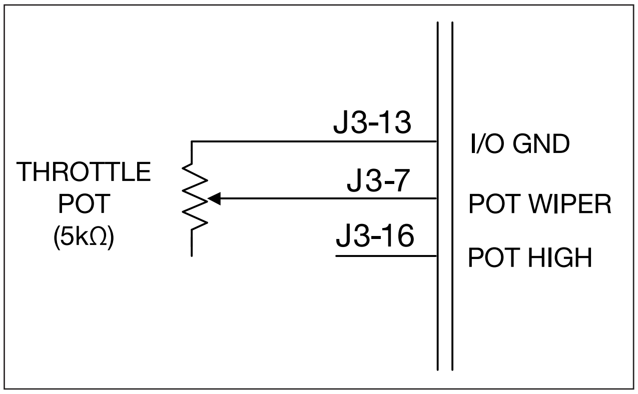
Specification	Value
Input Voltage Range	0~5.0V
Input Impedance	> 20KΩ
Maximum Voltage	105V
Maximum Reverse Voltage	–1V

You can monitor the amount of throttle requested and the controller output with the Throttle Pot Percent and Throttle Command variables.

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

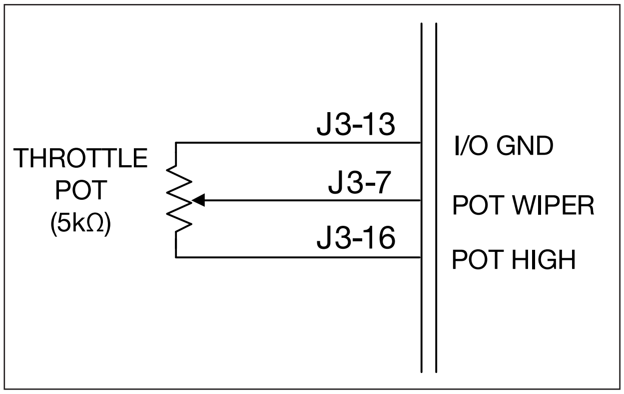
2-Wire Pot Throttles

Connect 2-wire pot throttles to the pot wiper input and I/O ground as shown in the following diagram:



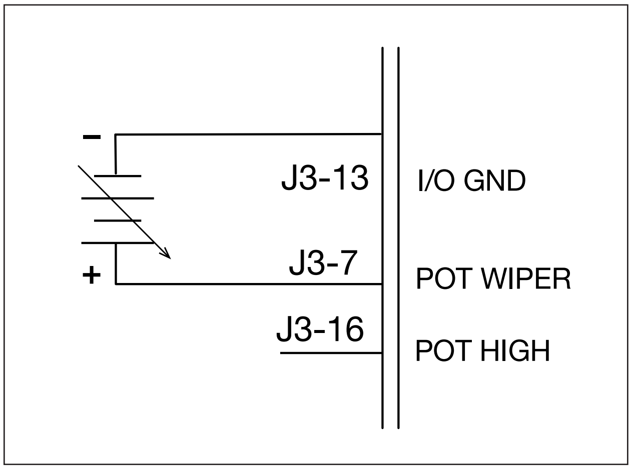
3-Wire Pot Throttles

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



0–5V Voltage Source Throttles

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



Keyswitch

The keyswitch is connected to pin J3-1. The keyswitch can be used as the interlock 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 **Note:** This is at full range battery voltage and does not include current draw from coil loads and external power supplies.
Maximum Voltage	Depends upon the model: • 1226BL-22*XX:* 34V • 1226BL-41*XX:* 63V • 1226BL-61*XX:* 105V
Maximum Reverse Voltage	–(125% of nominal battery voltage +5V)

Coil Return Pin

The Coil Return pin (J3-10) supplies the current for the coil drivers. The pin provides reverse polarity protection. If power is reversed the controller will prevent coil activation. For a wiring example, see Figure 6.

Note: The Coil Return pin is not protected against shorts to B–.

The following table describes the Coil Return pin's specifications:

Specification	Value
Maximum Output Current	8A (maximum pin rating)
Maximum Voltage	Depends upon the model: • 1226BL-22*XX:* 34V • 1226BL-41*XX:* 63V • 1226BL-61*XX:* 105V
Maximum Reverse Voltage	–0.5V

Interlock Input

The interlock input signals whether the operator intends to drive the vehicle:

- When the interlock is on, the operator intends to drive.
- When the interlock is off, the operator doesn't intend to drive. The controller thus doesn't allow the vehicle to start or continue driving.

You can use an interlock switch or the keyswitch for the interlock input. The Interlock Type parameter specifies which switch is used.

If the vehicle uses an interlock switch, connect the switch to pin J3-3.

The following considerations apply to the interlock:

- If the vehicle is driving when the interlock is turned off, the Interlock Brake Enable parameter defines whether the controller directly stops the vehicle or turns off the motor and allows the vehicle to roll until the operator manually applies the brake.
- Before turning the interlock input on, the operator must turn off the direction switch(es) and reduce the throttle to under 25% of its maximum voltage, otherwise an HPD Sequencing fault will occur.

Valve Input

You can use either of the analog/digital inputs as a valve input. To do so, set the input's Type parameter to 1 (Lower Valve Input). The menu containing the Type parameter to set depends upon which pin is used for the valve:

- Pin J3-6 = Digital/Analog 1 menu
- Pin J3-4 = Digital/Analog 2 menu

Note: If the vehicle has 2 lower valve switches on the tiller head, specify Lower Valve Input for the Type parameters on both the Digital/Analog Input 1 and Digital/Analog Input 2 menus. With that configuration, if the operator presses either or both switches the controller will engage the driver to lower the fork.

Emergency Reverse Inputs

When emergency reverse is activated, 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 a Normally Open (NO) switch, a Normally Closed (NC) switch, or both NO and NC switches used as complementary switches. Use the EMR Input Type parameter to specify the switch(es).

The following pins are used for NO and NC switches:

- NO switch: J3-14
- NC switch: J3-4

Note: If the vehicle system doesn't use an NC switch for emergency reverse, you can use pin J3-4 as the Analog 2/Digital 2 input. See Digital Inputs.

When complementary switches are used for emergency reverse, the controller continually checks both switches for conditions such as shorts and broken connections.

Use the Emergency Reverse menu to configure features such as those in the following list:

- Whether the operator can activate emergency reverse while driving in reverse.
- How long the vehicle will operate while an emergency reverse switch is active.
- The rate at which the vehicle decelerates to a stop.
- The rate at which the vehicle accelerates in the reverse direction.

Note: The EMR SRO Enable parameter specifies whether the vehicle can be driven if emergency reverse is active when the keyswitch is turned on.

Electromagnetic Brake

If the vehicle uses an electromagnetic (EM) brake, pin J3-12 provides the EM brake driver output. For specifications on the driver, see Table 2.

The EM brake should also be connected to the Coil Return pin (J3-10) as shown in Figure 6.

Set the EM Brake Type parameter to specify whether the vehicle system uses an EM brake, as well as the conditions under which the controller applies the EM brake. The controller also provides a brake holding voltage feature that reduces brake coil heating. See EM Brake Menu.

Use the EM Brake Driver Checks Enable parameter to specify whether a fault is generated if the controller detects an open condition in the driver's wiring.

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 6.

Mode Switch

Vehicles can include a mode switch that allows operators to choose from the 1226BL controller's speed modes. One mode can be configured for faster outdoor driving and the other for slower indoor driving.

If the vehicle uses a mode switch, connect the switch to pin J3-18.

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.

Note: For information on configuring speed modes, see Mode 1 and Mode 2 Menus.

Charger Inhibit

The charger inhibit function prevents driving while the vehicle is being charged.

Note: Charger inhibit is not available on 1226BL-61XX models.

The charger inhibit input (pin J3-15) is an active low input. To configure the charger inhibit function, connect one of the following charger terminals to pin J3-15:

- If the charger has a dedicated third terminal that automatically provides charger inhibit, connect that terminal.
- Otherwise, connect the charger's B– terminal.

Battery Discharge Indicator (BDI)

The 1226BL controller can drive a BDI panel meter that displays the battery's state-of-charge. The battery must go through a full charge cycle before the BDI begins operating.

If the vehicle system uses a BDI, connect the BDI to the BDI Output pin (J3-5).

Note: For information on configuring the controller's BDI output, see Battery Menu and Calibrating the Battery Discharge Indicator (BDI) Output.

The following table describes the BDI output specifications.

Specification	Value
Output Voltage	0~5.0V. The voltage is linear to the BDI percentage, with a 2% tolerance.
Load capacity	15mA
Maximum Voltage	105V
Maximum reverse voltage	–1V

Circuitry Protection Fuses

To protect against accidental shorts, the following fuses are recommended:

- A low current fuse, appropriately sized for the maximum control circuit current draw, should be connected in series with the B+ logic supply. See the control fuse in Figure 6.
- A power fuse, appropriately sized for the controller's maximum rated current, should be connected in series from the battery to the controller's B+ terminal. This fuse will protect the power system from external shorts.

Valve Driver or External Status LED Driver

Pin J3-2 can drive a valve contactor or an external status LED. When used for an external status LED, the driver will output the controller status and any fault codes.

The External Status LED Enable parameter specifies whether pin J3-2 is used as a valve driver or external status LED driver.

External Power Supply

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

External Power Supply Voltage	Pin
+5V	J1-1
+14V	J2-4

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

Specification	+5V Supply	+14V Supply
Nominal Output	5.2V	14V
Output Range	4.5V~6.0V	12V~16.5V
Maximum Current	50mA	70mA
Maximum Voltage	Depends upon the model: • 1226BL-22*XX* and 1226BL-41*XX*: 63V • 1226BL-61*XX*: 105V	
Maximum Reverse Voltage	–1V	

Hydraulic Pump Contactor Driver

1226BL-22*XX* and 1226BL-41*XX* models provide a driver for a hydraulic pump contactor. If the vehicle includes a hydraulic pump that will be managed by the controller, connect it to pin J3-11.

To configure the driver, use the parameters on the MISC Menu that begin with the word "Pump".

For the driver's specifications, see Table 2.

Main Contactor Driver

1226BL-61*XX* models provide a driver for a main contactor.

If the controller will be driving a main contactor, use pin J3-11 for the driver output. The Main Enable parameter specifies whether the controller drives a main contactor; see Main Relay (Contactor) Menu.

The Main Relay(Contactor) menu also contains parameters for configuring the following:

- Contactor opening delay
- PWM mode
- Pull-in and holding voltages
- Precharge
- Whether the controller checks the driver for the open condition

For the driver's specifications, see Table 2.

Forward and Reverse Switches

If the vehicle uses a dual switch throttle, connect the reverse switch to pin J3-8 and the forward switch to pin J3-17.

Hall Position Sensors

The 1226BL controller supports 120° Hall position sensors. Connect Hall A, B, and C to pins J1-2, J1-3, and J1-4, respectively.

The following table lists specifications for the Hall sensor inputs.

Specification	Value
Input range	0–15V
Max Input Frequency	1 KHz
Low to High Threshold	1.2V
High to Low Threshold	0.4V
Maximum Voltage	Depends upon the model: • 1226BL-22*XX* and 1226BL-41*XX:* 63V • 1226BL-61*XX:* 105V
Maximum reverse voltage	–1V

The controller relies on the Hall sensors to provide the motor rotor position. To configure the vehicle system so that the Hall sensors accurately signal the position, perform the steps in Characterize the Hall Sensors and UVW Output.

Motor Temperature Sensor

The 1226BL controller provides an input for a motor temperature sensor. The input measures the sensor's resistance, then uses the measured resistance to calculate the 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.

The controller supports the following types of motor temperature sensors:

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

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.

Note: If the predefined sensor types are unsuitable for your vehicle's sensor, you can add a custom sensor type. Please contact your Curtis Instruments distributor or support engineer.

To connect a motor temperature sensor input, use pin J1-6.

To enable and configure the motor temperature sensor function, use Motor Temperature Control menu's parameters.

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

Specification	Value
Temperature Range	–40 – +200°C
Resistance Measurement Range	250Ω~5kΩ
Resistance Measurement Accuracy	• ± 20Ω @ 2kΩ and below • ± 100Ω @ 2kΩ and above
Maximum sensor current	2.5mA

CANbus

CANbus models implement the CANopen protocol. CAN connections use the following pins:

- CAN Low: J2-1
- CAN High: J2-3

The controller does not have an internal 120Ω CAN terminating resistor. CANbus nodes typically are wired using a daisy chain topology with 120Ω terminating resistors at each end. If the controller is the last node in the chain, you should include an external 120Ω terminating resistor in the wiring harness.

Use the CAN Interface menu to specify the baud rate, Node ID, and heartbeat rate.

The following table describes the specifications for the CAN pins.

Specification	Value
Baud Rate	Following are the minimum and maximum rates: • Minimum: 125 kb/s • Maximum: 1 MB/s
Input Impedance	> 1kΩ and < 1000pF
Maximum Voltage	Depends upon the model: • 1226BL-22*XX* and 1226BL-41*XX:* 58V • 1226BL-61*XX:* 100V
Maximum Reverse Voltage	–0.5V

For information on the controller's CANopen features, see the following topics:

- CANopen Communications
- CANopen Object Dictionary

Serial Port

Serial port models implement the Enhanced Serial Port (ESP) protocol. Serial connections use the following pins:

- Serial RX: J2-1
- Serial TX: J2-3

The following table describes the specifications for the serial port pins.

Specification	Value
Input Impedance (RX)	> 1kΩ and < 1000pF
Maximum Voltage	15.5V
Maximum Reverse Voltage	–1V

3 — PROGRAMMABLE PARAMETERS

The 1226BL controller has numerous parameters that you can program using 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.

Some parameters require you to cycle the keyswitch after changing the parameter value. If you do not cycle the keyswitch, the controller generates a Parameter Change Fault. To clear a Parameter Change Fault, cycle the keyswitch.

Note: In this chapter, the parameters that require cycling the keyswitch are denoted with [PCF].

The following columns in the parameter description tables contain multiple types of information:

- Parameter and CAN Index: The parameter name and the CAN index and sub-index. This column also identifies parameters marked as [PCF].
- Values and Default: The allowed values as displayed in Curtis programming devices, followed by the default value.
- Raw Values and Data Size. The allowed values in raw units suitable for CAN, followed by the object's data size.

SPEED MODE MENU

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

The speed mode parameters let you configure speed-related functions such as minimum and maximum speeds and acceleration and deceleration rates.

Quick Link:
Fine Tuning Menu p.26

The following topics describe the menus contained by the Speed Mode menu:

- Mode 1 and Mode 2 Menus
- Fine Tuning Menu

Mode 1 and Mode 2 Menus

Use the Mode 1 and Mode 2 menus to configure speed modes 1 and 2, respectively. 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. All parameters ending in "HS" or "LS" depend upon the HS (High Speed) and LS (Low Speed) parameter values; see Fine Tuning Menu.

MODE 1 AND MODE 2 MENUS

PARAMETER CAN INDEX	VALUES DEFAULT	RAW VALUES DATA SIZE	DESCRIPTION
Max Speed 0x380001 0x380701	0%–100% 100%	0–8192 16-bit	Specifies the vehicle speed when full throttle is applied while the vehicle is moving forward.
Min Speed 0x380101 0x380801	0%–100% 0%	0–8192 16-bit	Specifies the vehicle speed when the throttle is first rotated out of the Forward Deadband.
Rev Max Speed 0x380201 0x380901	0%–100% 100%	0–8192 16-bit	Specifies the vehicle speed when full throttle is applied while the vehicle is moving in reverse.
Rev Min Speed 0x380301 0x380A01	0%–100% 0%	0–8192 16-bit	Specifies the vehicle speed when the throttle is first rotated out of the Reverse Deadband.
Full Accel Rate HS 0x381201 0x381B01	0.1s–8.0s 3.0s	50–4000 16-bit	Specifies the rate at which the vehicle accelerates when full throttle is applied at high vehicle speeds. Larger values represent slower response. See Low and High Speed Acceleration Rates.
Full Accel Rate LS 0x381301 0x381C01	0.1s–8.0s 3.0s	50–4000 16-bit	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 0x381901 0x382201	0.1s–8.0s 3.0s	50–4000 16-bit	Specifies the rate at which the vehicle accelerates when a small amount of throttle is applied. Adjust this parameter if you need to tune the vehicle for low speed maneuverability.
Neutral Decel Rate HS 0x381401 0x381D01	0.1s–8.0s 3.0s	50–4000 16-bit	Specifies the rate at which the vehicle decelerates when the throttle is released to neutral at high speed.
Neutral Decel Rate LS 0x381501 0x381E01	0.1s–8.0s 3.0s	50–4000 16-bit	Specifies the rate at which the vehicle decelerates when the throttle is released to neutral at low speed.
Full Brake Rate HS 0x381601 0x381F01	0.1s–8.0s 3.0s	50–4000 16-bit	Specifies the rate at which the vehicle decelerates from high speeds when full throttle is applied in the opposite direction. See Low and High Speed Brake Deceleration Rates.
Full Brake Rate LS 0x381701 0x382001	0.1s–8.0s 3.0s	50–4000 16-bit	Specifies the rate at which the vehicle decelerates from low speeds when full throttle is applied in the opposite direction.
Low Brake Rate 0x381A01 0x382301	0.1s–8.0s 3.0s	50–4000 16-bit	Specifies the rate at which the vehicle decelerates when a small amount of throttle is applied in the opposite direction.
Partial Decel Rate 0x381801 0x382101	0.1s–8.0s 3.0s	50–4000 16-bit	Specifies the rate at which the vehicle decelerates when the throttle is reduced without being released to neutral. Larger values provide a slower response.

Fine Tuning Menu

Use the Fine Tuning menu's parameters to define the high and low speed thresholds for all parameters with names ending in HS and LS. For examples, see the following topics:

- Low and High Speed Acceleration Rates
- Low and High Speed Brake Deceleration Rates

The following table describes the menu's parameters.

FINE TUNING MENU

PARAMETER CAN INDEX	VALUES DEFAULT	RAW VALUES DATA SIZE	DESCRIPTION
HS (High Speed) 0x382401	0%–100% 90%	0–32767 16-bit	Specifies the percentage of the active speed mode's Max Speed parameter above which the high speed parameters are used.
LS (Low Speed) 0x382501	0%–100% 90%	0–32767 16-bit	Specifies the percentage of the active speed mode's Max Speed parameter below which the low speed parameters are used.

Low and High Speed Acceleration Rates

You can optimize a vehicle's throttle response by configuring acceleration rates for low and high speeds. These rates are defined with the Full Accel Rate LS and Full Accel Rate HS parameters. You can configure different acceleration rates for each speed mode.

The acceleration rates are relative to the values of the HS (High Speed) and LS (Low Speed) parameters; see Fine Tuning Menu.

When full 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.

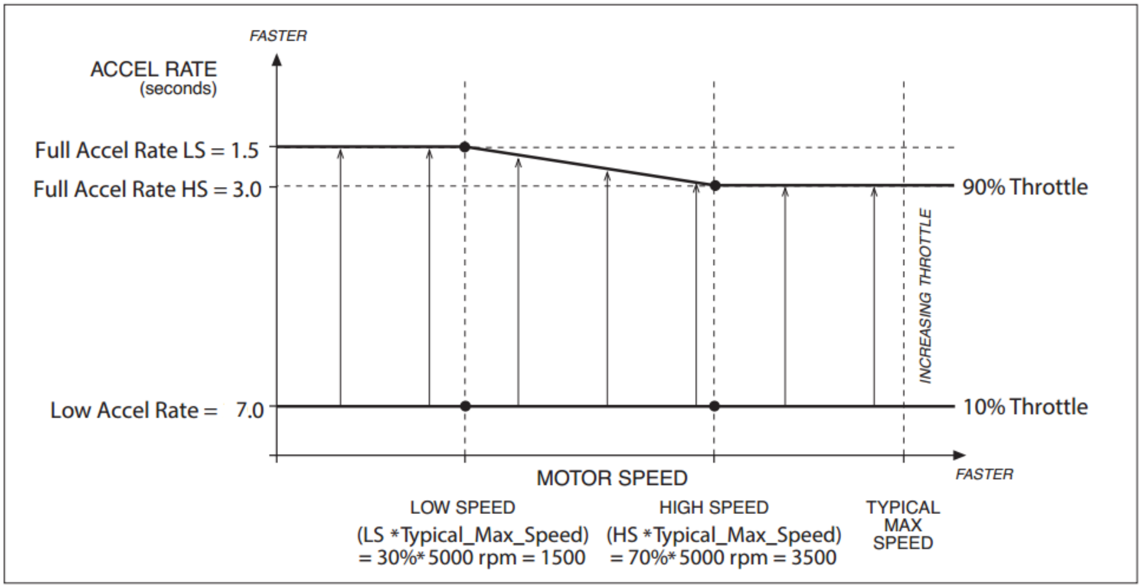
Note: These acceleration rates apply to both forward and reverse.

Example

Suppose you set the following parameters to the following values:

Parameter	Value
LS (Low Speed)	30%
HS (High Speed)	70%
Full Accel Rate LS	1.5s
Full Accel Rate HS	3.0s

The following diagram shows the acceleration rate when full throttle is applied.



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

Low and High Speed Brake Deceleration Rates

You can optimize the rates at which a vehicle decelerates when full throttle is applied in the opposite direction. These deceleration rates are configured with the Full Brake Rate HS and Full Brake Rate LS parameters. You can configure different deceleration rates for each speed mode.

The deceleration rates are relative to the values of the HS (High Speed) and LS (Low Speed) parameters; see Fine Tuning Menu.

When full throttle is applied in the opposite direction while the vehicle is traveling between the specified low and high speeds, the deceleration rate is linearly scaled between the low and high speed deceleration rates.

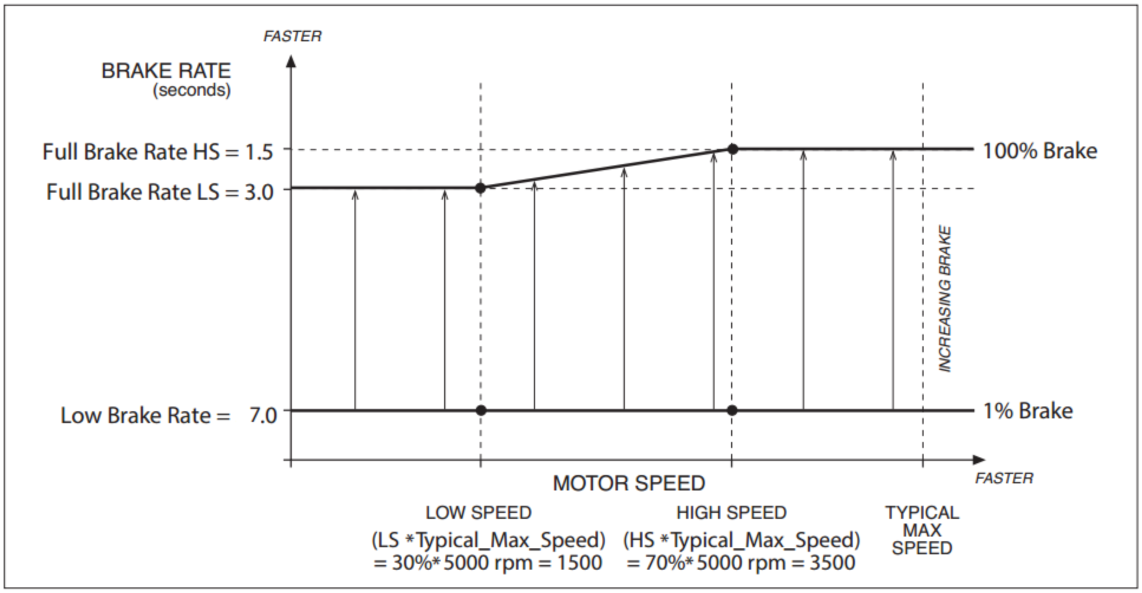
Note: The deceleration rates apply to forward and reverse.

Example

Suppose you set the following parameters to the following values:

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

The following diagram shows the deceleration rates when full throttle is applied in the opposite direction.



Note: This section discusses brake deceleration at low and high speeds. However, the same concepts apply to any deceleration-related parameter with a name ending in HS or LS.

THROTTLE MENU

Use the Throttle menu to specify the type of throttle used by the vehicle, configure the throttle's responsiveness, and specify whether the HPD/SRO feature is enabled. The following table describes the menu's parameters.

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

THROTTLE MENU

PARAMETER CAN INDEX	VALUES DEFAULT	RAW VALUES DATA SIZE	DESCRIPTION
Throttle Type **[PCF]** `0x334001`	1–7 2	1–7 16-bit	Specifies the throttle type: 1 = 0–5kΩ 2-wire pot 2 = 3-wire pot 3 = 5k–0Ω 2-wire pot 4 = Wigwag 3-wire pot 5 = 0–5V voltage source 6 = 0–5V wigwag 7 = CAN throttle (CAN version only). If the vehicle uses a CAN throttle, the Direction Type parameter indicates the input or object that commands direction.
Direction Type (CAN models) `0x336001`	0–1 1	0–1 8-bit	Indicates whether the CAN Throttle object commands both direction and throttle or only throttle: 0 = The CAN Throttle object commands both throttle and direction. 1 = The CAN Throttle object commands throttle but not direction. The CAN Inputs Configuration parameter specifies whether forward and reverse direction are commanded by the controller's switches or CAN.
Forward Deadband `0x334101`	0%–100% 10%	0–1000 16-bit	Defines the wiper voltage at the deadband threshold while the vehicle is moving forward. Increasing Forward Deadband increases the neutral range.
Forward Max `0x334201`	0%–100% 90%	0–1000 16-bit	Defines the wiper voltage that generates 100% controller output while the vehicle is moving forward. For a description of the how the Deadband, Max, Offset, and Map parameters work, see Throttle Response Parameters.
Forward Offset `0x334301`	0%–100% 0%	0–32767 16-bit	Specifies the throttle command that is generated when the throttle is first rotated out of the neutral deadband while the vehicle is moving forward. For most vehicles, a setting of 0% is appropriate. For heavy vehicles, however, increasing the offset may improve controllability by reducing the amount of throttle required to start moving the vehicle.
Forward Map `0x334401`	0%–100% 50%	0–32767 16-bit	Specifies the controller output that is generated at 50% throttle input. The following list provides guidelines for setting Forward Map: • 50% provides a linear output response to the throttle position. • Values below 50% reduce the controller output at low throttle settings, providing enhanced slow speed maneuverability. • Values above 50% give the vehicle a faster, more responsive feel at low throttle settings.

THROTTLE MENU, cont'd

PARAMETER CAN INDEX	VALUES DEFAULT	RAW VALUES DATA SIZE	DESCRIPTION
Reverse Deadband `0x334501`	0%–100% 10%	0–1000 16-bit	**These parameters work just like the corresponding Forward parameters, except that they apply when the vehicle is moving in reverse.**
Reverse Max `0x334601`	0%–100% 90%	0–1000 16-bit	
Reverse Offset `0x334701`	0%–100% 0%	0–32767 16-bit	
Reverse Map `0x334801`	0%–100% 50%	0–32767 16-bit	
Throttle Filter `0x334901`	0.5–125.0Hz 50Hz	131–32767 16-bit	Specifies the low pass filter cutoff frequency for the pot wiper input. Lower values provide a slower response.
HPD/SRO Type **[PCF]** `0x334B01`	0–1 1	0–1 16-bit	Specifies whether the HPD/SRO function is enabled: 0 = Disabled 1 = Enabled If the parameter is enabled and one of the following conditions occurs, the controller generates an HPD Sequencing fault: • The throttle input is greater than 25% when the interlock switch is turned on. • A direction input is on when the interlock switch is turned on.
Sequencing Delay `0x334C01`	0.0–5.0s 0.5s	0–1250 16-bit	Specifies the time during which the interlock cycles before an HPD/Sequencing Fault occurs. 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.

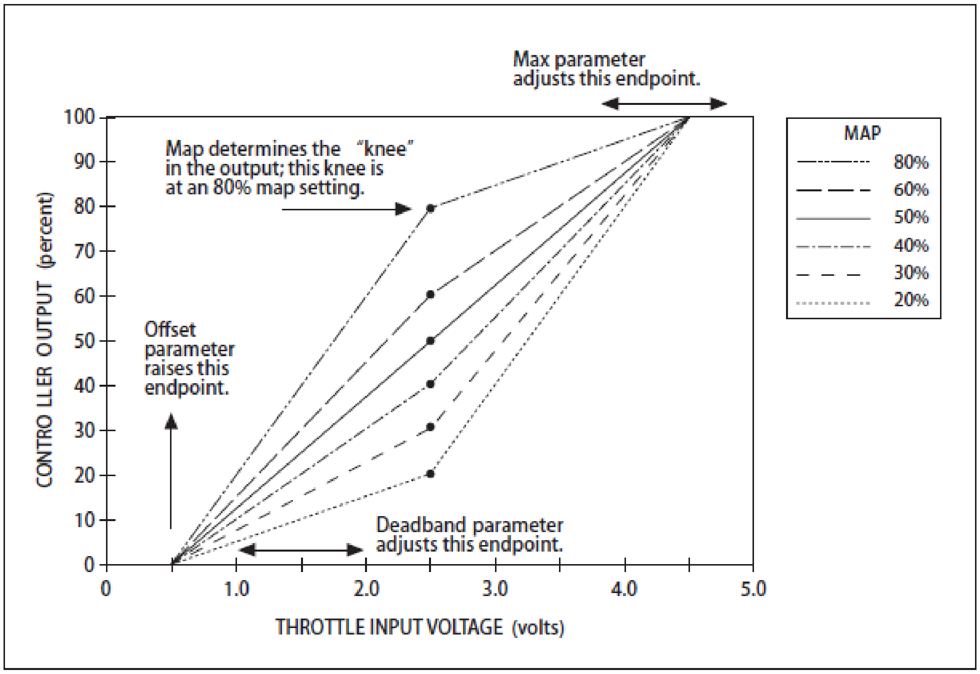
Throttle Response Parameters

The Forward and Reverse Deadband, Max, and Map parameters specify the controller output that is generated at various throttle voltages. The Forward and Reverse Offset parameters define the output generated by the controller when the throttle is first rotated out of the neutral deadband. These parameters define the throttle's responsiveness.

The following diagram shows the relationship between these parameters, the throttle's wiper voltage, and the controller output. The diagram is for a throttle with a 5.0V maximum voltage.

Figure 7

Throttle Response Parameters



The following list describes the parameters to which the diagram refers:

- Deadband = 10%. The vehicle is in neutral until the throttle's voltage is 0.5 volts (10% of 5.0V)
- Offset = 0%. A 0% value means there is no controller output when the throttle's voltage first exceeds 0.5 volts.
- Max = 90%. The controller output reaches 100% when the throttle is at 4.5V (90% of 5.0V)
- The points in the Map parameter lines represent the controller outputs for various Map values when the throttle's voltage equals 2.5V (50% of 5.0V).

Note: You can use the Throttle Pot Percent and Throttle Command variables to monitor the throttle voltage and controller output.

INTERLOCK MENU

The following table describes the interlock parameters.

INTERLOCK MENU

PARAMETER CAN INDEX	VALUES DEFAULT	RAW VALUES DATA SIZE	DESCRIPTION
Interlock Type **[PCF]** 0x34B401	0–1 0	0–1 16-bit	Specifies the input used as the interlock switch: 0 = Interlock input 1 = Keyswitch
Interlock SRO Enable 0x34B901	Off/On On	0–1 8-bit	Specifies whether the controller will generate an Interlock SRO fault if the interlock switch is on before the keyswitch is turned on. On indicates that the controller should generate the fault.
Interlock Brake Enable 0x34B501	Off/On On	0–1 16-bit	Specifies whether the interlock braking function stops the vehicle when the interlock signal is turned off: On = The controller uses regen braking to stop the vehicle. Off = The controller turns the motor off and lets the vehicle roll freely. This option is typically used only when the vehicle includes a user controlled mechanical or hydraulic brake.
Decel Rate 0x34B601	0.1–8.0s 1.0s	50–4000 16-bit	Specifies the rate at which the vehicle decelerates when the interlock is released. Larger values represent slower response times.
Interlock Brake Timeout 0x34B701	0.1–8.0s 2.0s	50–4000 16-bit	Specifies the maximum allowable duration of an interlock braking event. The timer starts when the interlock state changes to off. If the time expires before the vehicle has stopped, the controller engages the EM brake. This timeout allows parallel usage of regen braking and the EM brake to reduce stopping distance. If the timeout expires and the motor is still moving, regen braking will continue to slow vehicle motion in conjunction with the EM brake.

CURRENT LIMITS MENU

Use the Current Limits parameters to limit the current supplied by the controller during driving, regenerative braking, and emergency reverse operations.

The Current Limits menu also contains the Power Limiting Map menu.

The following table describes the menu's parameters.

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

CURRENT LIMITS MENU

PARAMETER CAN INDEX	VALUES DEFAULT	RAW VALUES DATA SIZE	DESCRIPTION
Drive Current Limit `0x344101`	10–100% 100%	3276–32767 16-bit	Specifies the maximum current the controller supplies to the motor during driving. **Note:** Reducing the current limit reduces the maximum drive torque.
Regen Current Limit `0x344501`	10–100% 50%	3276–32767 16-bit	Specifies the maximum current the controller supplies to the motor when regenerative braking occurs.
EMR Current Limit `0x344301`	10–100% 50%	3276–32767 16-bit	Specifies the maximum current the controller supplies to the motor during emergency reverse.
Boost Enable `0x343301`	Off/On On	0–1 8-bit	Indicates whether the boost current function is enabled. Boost current provides a brief increase of current to improve performance with transient loads such as starting on a hill, crossing a threshold, climbing obstacles, etc.
Boost Time `0x343501`	1.0–10.0s 10.0s	63–625 16-bit	Specifies the maximum duration of a boost current event.

Power Limiting Map Menu

The power limiting maps limit the current supplied by the controller at various motor speed thresholds. The speed thresholds and the current limits for those thresholds are configurable.

There are two power limiting maps:

- A drive limiting map to reduce the drive current.
- A regen limiting map to reduce the regenerative braking current.

The following equation shows how the PL Nominal Speed and Delta Speed parameters define speed thresholds:

```
Speed Threshold = PL Nominal Speed + (Delta Speed * n)
```

PL Nominal Speed and Delta Speed are measured in RPM. There are five speed thresholds, for which *n* equals 0, 1 2, 4, and 8, respectively.

The Power Limiting Map menu defines the base speed and the increment. The Drive Limiting Map and Regen Limiting Map menus define the current limits for the speed thresholds.

Note: For an example, see Drive Limit Map Example.

The following table describes the Power Limiting Map menu's parameters:

POWER LIMITING MAP MENU

PARAMETER CAN INDEX	VALUES DEFAULT	RAW VALUES DATA SIZE	DESCRIPTION
PL Nominal Speed `0x344E01`	100–4000 RPM 1500 RPM	100–4000 16-bit	Specifies the base speed for the drive limiting and regen limiting maps.
Delta Speed `0x344801`	50–1000 RPM 500 RPM	50–1000 16-bit	Specifies the size of the increment for the drive limiting and regen limiting maps.

Drive Limiting Map Menu

The drive limiting map limits the drive current when the motor reaches the speed thresholds specified by the Power Limiting Map parameters. Limiting the drive current reduces motor heating at the expense of decreased performance.

The following table describes the menu's parameters.

Note: The parameter values are percentages of the maximum drive current. The Drive Current Limit parameter defines the maximum drive current.

DRIVE LIMITING MAP MENU

PARAMETER CAN INDEX	VALUES DEFAULT	RAW VALUES DATA SIZE	DESCRIPTION
Nominal `0x344901`	0–100% 100%	0–32767 16-bit	Specifies the percentage of drive current that the controller supplies when the motor speed is less than the PL Nominal Speed parameter.
Plus Delta `0x344D01`	0–100% 100%	0–32767 16-bit	Specifies the percentage of drive current that the controller supplies at the following motor speed: `PL Nominal Speed + Delta Speed`
Plus 2xDelta `0x344A01`	0–100% 100%	0–32767 16-bit	Specifies the percentage of drive current that the controller supplies at the following motor speed: `PL Nominal Speed + (2 * Delta Speed)`
Plus 4xDelta `0x344B01`	0–100% 100%	0–32767 16-bit	Specifies the percentage of drive current that the controller supplies at the following motor speed: `PL Nominal Speed + (4 * Delta Speed)`
Plus 8xDelta `0x344C01`	0–100% 100%	0–32767 16-bit	Specifies the percentage of drive current that the controller supplies at the following motor speed: `PL Nominal Speed + (8 * Delta Speed)`

Drive Limit Map Example

Suppose that you've set the Power Limiting Map and Drive Limiting Map parameters to the values in the following table:

Parameter	Value
PL Nominal Speed	4000 RPM
Delta Speed	200 RPM
Nominal	100%
Plus Delta	100%
Plus 2xDelta	100%
Plus 4xDelta	95%
Plus 8xDelta	80%

The controller will limit the drive current to 95% of the maximum drive current when the motor speed reaches 4800 RPM and to 80% when the motor speed reaches 5600 RPM.

Regen Limiting Map Menu

The regen limiting map limits the regen braking current when the motor reaches the speed thresholds specified by the Power Limiting Map parameters. Reducing the regen current at a given motor speed limits the torque that is available at that speed.

The following table describes the menu's parameters.

Note: The parameter values are percentages are of the maximum regen current. The Regen Current Limit parameter defines the maximum regen current.

REGEN LIMITING MAP MENU

PARAMETER CAN INDEX	VALUES DEFAULT	RAW VALUES DATA SIZE	DESCRIPTION
Nominal `0x345901`	0–100% 100%	0–32767 16-bit	Specifies the percentage of regen current that the controller supplies when the motor speed is less than the PL Nominal Speed parameter.
Plus Delta `0x345A01`	0–100% 100%	0–32767 16-bit	Specifies the percentage of regen current that the controller supplies at the following motor speed: `PL Nominal Speed + Delta Speed`
Plus 2xDelta `0x345B01`	0–100% 100%	0–32767 16-bit	Specifies the percentage of regen current that the controller supplies at the following motor speed: `PL Nominal Speed + (2 * Delta Speed)`
Plus 4xDelta `0x345C01`	0–100% 100%	0–32767 16-bit	Specifies the percentage of regen current that the controller supplies at the following motor speed: `PL Nominal Speed + (4 * Delta Speed)`
Plus 8xDelta `0x345D01`	0–100% 100%	0–32767 16-bit	Specifies the percentage of regen current that the controller supplies at the following motor speed: `PL Nominal Speed + (8 * Delta Speed)`

MOTOR TEMPERATURE CONTROL MENU

The following table describes the parameters on the Motor Temperature Control menu. For more information, see Motor Temperature Sensor.

MOTOR TEMPERATURE CONTROL MENU

PARAMETER CAN INDEX	VALUES DEFAULT	RAW VALUES DATA SIZE	DESCRIPTION
Sensor Enable `0x368601`	Off/On Off	0–1 16-bit	Specifies whether the motor temperature control function is enabled. When the temperature sensor is enabled, the controller applies the motor temperature control features when the motor temperature is between the Temperature Hot and Temperature Max temperatures.
Sensor Type `0x368801`	1–5 3	1–5 16-bit	Specifies the type of temperature sensor used by the vehicle. The following values represent the controller's predefined sensor types: 1 = KTY83–122 2 = 2 KTY83–122 sensors, in series 3 = KTY84–130 or KTY84–150 4 = 2 KTY84–130 or KTY84–150 sensors, in series 5 = PT1000 **Note:** 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 `0x368701`	–20 – +20°C 0°C	–200 – +200 16-bit	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: • The sensor is placed in the motor at a location with a known offset to the critical temperature. • The sensor itself has a known offset.
Braking Thermal Cutback Enable `0x368001`	Off/On Off	0–1 8-bit	Specifies whether the controller cuts back regen braking current if the motor reaches the Temperature Hot threshold: On = The controller cuts back current for all forms of regen braking, including emergency reverse braking, interlock braking, neutral braking, and speed limit braking. Off = The controller does not cut back regen braking current. Regardless of the parameter value, the controller cuts back the drive current if the motor reaches the Temperature Hot threshold. **Note:** If the vehicle has mechanical brakes, enabling this cutback might reduce motor heating.
Temperature Hot `0x368301`	0–250°C 145°C	0–2500 16-bit	Specifies the temperature at which the controller starts cutting back current.
Temperature Max `0x368501`	0–250°C 160°C	0–2500 16-bit	Specifies the temperature at which the controller cuts back all current.
Motor Temp LOS Max Speed `0x368401`	0–100% 50%	0–8192 16-bit	Specifies the maximum speed after a Motor Temp Sensor fault occurs. The value is a percentage of the active speed mode's Max Speed parameter. When a Motor Temp Sensor fault occurs, the controller applies a limited operating strategy (LOS) that reduces the maximum speed by the specified percentage.

MAIN RELAY(CONTACTOR) MENU

The Main Relay(Contactor) parameters apply to the main contactor in models that use a main contactor. For other models, the parameters apply to the internal relay.

Note: The menu name depends upon whether the controller is an internal relay or main contactor model.

The following table describe the Main Relay(Contactor) parameters.

MAIN RELAY (CONTACTOR) MENU

PARAMETER CAN INDEX	VALUES DEFAULT	RAW VALUES DATA SIZE	DESCRIPTION
Main Enable (1226BL-61XX models only) **[PCF]** 0x34C501	Off/On On	0–1 16-bit	Specifies whether the main contactor is controlled by the controller or by other controllers: On = Controlled by the controller Off = Controlled by other controllers
Pull In Voltage 0x34C801	0%–100% 100%	0–8192 16-bit	Specifies the initial voltage of the relay or contactor when the driver is first turned on. The controller allows a high initial voltage to ensure the relay or contactor closes. After 1 second, the voltage decreases to the specified Holding Voltage. If the Pull In Voltage value is too low to engage the relay or contactor, a Main Contactor Did Not Close fault will occur.
Holding Voltage 0x34C601	0%–100% 80%	0–8192 16-bit	Specifies the voltage the controller applies to the relay or contactor coil after the relay or contactor closes. Set the Holding Voltage high enough so that the relay or contactor remains closed under all shock and vibration conditions that the vehicle is expected to encounter. **Note:** Use the Main Relay/Contactor Driver PWM variable to monitor the pull-in and holding voltages.
Battery Voltage Compensated 0x34C401	Off/On On	0–1 8-bit	Specifies whether the controller adjusts pull-in and holding voltages to compensate for differences between the nominal and actual voltages.
Open Delay 0x34CA01	0.0–40.0s 0.0s	0–10000 16-bit	Specifies how long the main relay or contactor should remain closed when the interlock switch is opened. **Note:** A delay prevents unnecessary cycling of the relay or contactor.
Precharge Enable (1226BL-61*XX* models only) 0x34CC01	Off/On On	0–1 16-bit	Turns the precharge feature on and off. When precharge is on, the controller provides a limited current charge to its internal capacitor bank before the main contactor closes. The precharge decreases the arcing that would otherwise occur if the contactor closes with the capacitor bank discharged.

EM BRAKE MENU

Use the EM Brake menu to configure electromagnetic braking (EM). The following table describes the menu's parameters.

EM BRAKE MENU

PARAMETER CAN INDEX	VALUES DEFAULT	RAW VALUES DATA SIZE	DESCRIPTION
EM Brake Type [PCF] 0x347901	0–2 2	0–2 16-bit	Specifies how the EM brake responds to the interlock input, throttle, and motor speed: 0 = EM braking is disabled. 1 = The interlock controls EM braking. 2 = The interlock, throttle, and motor speed control EM braking. For information on the conditions that cause the controller to engage and release the EM brake, see Table 3.
Pull In Voltage 0x347301	0%–100% 100%	0–32767 16-bit	Specifies the electromagnetic braking system's initial voltage when the EM brake is first turned on. To ensure that the electromagnetic brake is released, the controller allows a high initial voltage when the electromagnetic brake turns on. After 1 second, this peak voltage decreases to the specified Holding Voltage.
Holding Voltage 0x347201	0%–100% 80%	0–32767 16-bit	Specifies the reduced voltage the controller applies to the brake coil once the brake has been released. 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. **Note:** Use the EM Brake Driver PWM variable to monitor the pull-in and holding voltages.
Battery Voltage Compensated 0x341E01	Off/On Off	0–1 8-bit	Specifies whether the controller adjusts pull-in and holding voltages to compensate for differences between the nominal and actual voltages. On enables the voltage compensation.
Set Speed Threshold 0x347601	5–100 RPM 20 RPM	5–100 16-bit	Specifies the speed below which the controller engages the EM brake. Setting this speed too high can cause an abrupt stop when the EM brake is engaged.
Release Delay 0x347401	40–2000ms 40	5–250 16-bit	Specifies how long it takes before the controller applies the pull-in voltage. A delay ensures that torque buildup is complete before the controller releases the EM brake. If the delay is too short, the vehicle might roll back when the EM brake is released.
EM Brake Fault Motor Revs 0x347101	10–200 RPM 100 RPM	10–200 16-bit	Specifies the maximum number of motor revolutions that can occur after the EM brake is engaged. If the number of motor revolutions exceeds the specified value, the controller will generate an EM Brake Failed to Set fault.
EM Brake Delay 0x347501	0.0–2.0s 1.0s	0–250 8-bit	Specifies how long it takes for the controller to engage the EM brake when the duty cycle is reduced to zero.

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

- Interlock Brake Enable
- EM Brake Type
- Set Speed Threshold
- Sequencing Delay

Table 3 EM Brake Response

EM Brake Type Parameter	Release	Engage
1	The interlock is on.	Depends upon whether interlock braking is enabled: • Interlock braking enabled: The EM brake engages when the interlock turns off, the motor speed is less than the Set Speed Threshold value, and the sequencing delay expires. • Interlock braking disabled: The EM brake engages when the interlock turns off and the sequencing delay expires.
2	The interlock is on and the throttle is not in neutral.	The EM brake engages when the throttle command is 0 and the motor speed is less than the Set Speed Threshold value.

BATTERY MENU

The Battery menu parameters allow you to configure the Battery Discharge Indicator (BDI) output for the system's battery, charger, and expected drive cycle. There also are parameters that specify how the controller handles overvoltage and undervoltage conditions.

The following list defines terms used when discussing battery parameters:

- **BDI percentage:** Indicates how charged the battery is, based on the range between the Empty Volts Per Cell and Full Volts Per Cell parameters' voltages.

  Note: When the controller measures voltage for BDI purposes, it uses the keyswitch voltage. The controller decreases the BDI percentage (discharge) only when the main relay or contactor is closed.

- **Cell:** Several of the parameters are expressed in volts per cell. To calculate a battery's number of cells, divide the battery's nominal voltage by 2. For example, a 24V battery has 12 cells.

For steps on calibrating the BDI for your vehicle system, see Calibrating the Battery Discharge Indicator (BDI) Output.

The following table describes the Battery menu's parameters.

Note: Some parameters configure the controller's overvoltage and undervoltage protection, which is described in Overvoltage and Undervoltage Protection.

BATTERY MENU

PARAMETER CAN INDEX	VALUES DEFAULT	RAW VALUES DATA SIZE	DESCRIPTION
Nominal Voltage (1226BL-41*XX* models only) `0x33AA01`	36.0–48.0V 48.0V	2304–3072 16-bit	Specifies the battery's nominal voltage.
Kp UV `0x338B01`	0–100% 20%	0–1024 16-bit	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: • Kp UV specifies the 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. • Ki UV specifies the 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. **Note:** Typically, the Kp UV and Ki UV parameters are configured together to provide the best response. If the linear response of the undervoltage controller is preferred, set Ki UV to 0%.
Ki UV `0x338901`	0–100% 0%	0–1024 16-bit	
User Overvoltage `0x33A001`	105%–200% 120%	269–512 16-bit	Specifies the overvoltage threshold. The value is a percentage of the battery's nominal voltage.
User Undervoltage `0x33A101`	0%–95% 80%	0–242 16-bit	Specifies the undervoltage threshold. The value is a percentage of the battery's nominal voltage.
Reset Volts Per Cell `0x33A701`	0.900–3.000V 2.090V	900–3000 16-bit	Specifies the battery cell voltage at or above which the controller resets the BDI percentage to 100% if both of the following conditions are true when the vehicle is powered up: • Keyswitch Voltage > (Reset Volts Per Cell * the number of cells) • BDI percentage < BDI Reset Percent Specify a voltage that is higher than the Full Volts Per Cell voltage.
Full Volts Per Cell `0x33A401`	0.900–3.000V 2.040V	900–3000 16-bit	Specifies the battery cell voltage at or above which the battery is considered 100% charged. When the battery voltage drops below this voltage, the battery begins to lose charge.
Empty Volts Per Cell `0x33A301`	0.900–3.000V 1.730V	900–3000 16-bit	Specifies the battery cell voltage at which the battery cell is considered 0% charged.
Discharge Time `0x33A201`	0–600 minutes 600 minutes	0–600 16-bit	Specifies the minimum time for decrementing the BDI percentage from 100% to 0% if the battery cell voltage is lower than the Empty Volts Per Cell voltage.
BDI Reset Percent `0x33A601`	0%–100% 75%	0–100 16-bit	Specifies the percentage of battery voltage above which the BDI percentage will not reset when the keyswitch is turned on. 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.
Full Charge Voltage `0x339B01`	0.900–3.000V 2.350V	900–3000 16-bit	Specifies the voltage above which the controller considers the battery as finished charging.
Start Charge Voltage `0x339C01`	0.900–3.000V 2.100V	900–3000 16-bit	Specifies the voltage above which the controller considers the battery as starting to charge.

BATTERY MENU, cont'd

PARAMETER CAN INDEX	VALUES DEFAULT	RAW VALUES DATA SIZE	DESCRIPTION
Charge Time `0x339D01`	0–600 minutes 300 minutes	0–600 16-bit	Specifies how many minutes it takes for the BDI percentage to increase from 0% to 100% while the battery is being charged. When a charger is plugged in, the battery voltage gradually increases to the full level. To accurately reflect the state-of-charge, during charging the BDI percentage increases by 1% when the specified number of minutes elapses. **Note:** Higher battery amp/hour ratings require a larger Charge Time.
Lift Lockout Threshold `0x339E01`	0%–50% 20%	0–50 16-bit	Specifies the BDI percentage at or below which the controller disables the hydraulic lift to prevent battery damage.

Overvoltage and Undervoltage Protection

The following list describes the controller's overvoltage and undervoltage protection:

- The overvoltage controller cuts back regen current to prevent damage to batteries and other components. The User Overvoltage parameter specifies the overvoltage limit.
- The undervoltage controller is a closed loop PI (Proportional/Integral) controller that cuts back drive current to keep battery voltage from drooping. Undervoltage protection prevents systems from operating at voltages below minimum voltage requirements. The User Undervoltage parameter specifies the undervoltage limit.

Note: The controller's voltage ranges are listed in Specifications.

MOTOR MENU

The following table describes the Motor Menu's parameters.

MOTOR MENU

PARAMETER CAN INDEX	VALUES DEFAULT	RAW VALUES DATA SIZE	DESCRIPTION
Fault Stall Time 0x352101	1–32s 5s	250–8000 16-bit	Specifies how long it takes for the controller to generate the Stall Detected fault after the vehicle stalls.
Pole Pairs **[PCF]** 0x353A01	1–36 4	1–36 16-bit	Specifies the motor's number of pole pairs.
Swap Encoder Direction [PCF] 0x353B01	Off/On Off	0–1 16-bit	Changes the motor encoder's effective direction of rotation. The encoder provides data used to calculate motor position and speed. This parameter must be set so that when the motor is turning forward, the controller reports back a positive motor speed.
Swap Speed Direction 0x353C01	Off/On Off	0–1 16-bit	Indicates whether the controller adjusts the detected direction so that it matches the requested direction: Off = The controller does not adjust the detected direction. On = The controller adjusts the detected direction. In some configurations, by default the requested and detected directions do not match; the controller detects reverse when forward is requested, and vice versa. If that happens, the controller stops driving the motor and you should set Swap Speed Direction to On. **Note:** The Motor RPM variable indicates the detected direction.

EMERGENCY REVERSE MENU

Use the parameters in the following table to configure the emergency reverse feature.

Note: The MISC menu's EMR SRO Enable parameter specifies whether the vehicle can be driven if emergency reverse is active when the keyswitch is turned on.

EMERGENCY REVERSE MENU

PARAMETER CAN INDEX	VALUES DEFAULT	RAW VALUES DATA SIZE	DESCRIPTION
EMR Input Type **[PCF]** `0x349801`	0–2 0	0–2 16-bit	Specifies whether emergency reverse is activated from the normally open (NO) switch, normally closed (NC) switch, or a complementary usage of both NO and NC switches: 0 = NO switch 1 = NC switch 2 = Complementary NO and NC switches If an NC switch is used but the Digital/Analog Input 2 menu's Type parameter is non-zero, a Parameter Mismatch fault will occur.
EMR Fwd Only `0x349501`	Off/On On	0–1 8-bit	Specifies whether emergency reverse can be activated when driving in either direction: On = Activated only when driving forward. Off = Activated when driving in either direction.
EMR Dir Interlock `0x349401`	Off/On On	0–1 8-bit	Specifies whether the interlock must be cleared before the operator resumes driving after an emergency reverse operation: On = The interlock, direction switches, and throttle must be cleared. Off = Only the direction switches and throttle must be cleared.
EMR Time Limit `0x349701`	0–30s 5s	0–3750 16-bit	Indicates how long emergency reverse will be active after the vehicle starts moving in reverse.
EMR Speed `0x349601`	10%–100% 60%	3276–32767 16-bit	Specifies the maximum vehicle speed during emergency reverse. The value is a percentage of the maximum speed.
EMR Accel Rate `0x349201`	0.1–8.0s 0.8s	50–4000 16-bit	Specifies the rate at which the vehicle accelerates in the opposite direction after emergency reverse stops the vehicle.
EMR Decel Rate `0x349301`	0.1–8.0s 0.8s	50–4000 16-bit	Specifies the rate at which the vehicle brakes to a stop when emergency reverse is activated.

DIGITAL/ANALOG INPUTS MENU

The Digital/Analog Inputs menu lets you enable and configure the analog/digital inputs (pins J3-4 and J3-6). The menu consists of the Digital/Analog Input 1 and Digital/Analog Input 2 menus, which are described in the following topics.

Digital/Analog Input 1 Menu

The following table describes the Digital/Analog Input 1 parameters.

Note: To monitor the analog input voltage and the digital switch state, use the Inputs menu.

DIGITAL/ANALOG INPUTS MENU

PARAMETER CAN INDEX	VALUES DEFAULT	RAW VALUES DATA SIZE	DESCRIPTION
Type **[PCF]** `0x332D01`	0–3 0	0–3 16-bit	Specifies how the input will be used: 0 = Disable 1 = Lower Valve Input 2 = Lift Inhibit High Active 3 = Lift Inhibit Low Active If the value is 1 but the External Status LED Enable parameter is on, a Parameter Mismatch fault will occur.
Digital Input Low Threshold `0x332F01`	0.00–10.00V 3.00V	0–1000 16-bit	Specifies the analog input voltage below which the digital switch state changes to off (low).
Digital Input High Threshold `0x333001`	0.00–10.00V 5.00V	0–1000 16-bit	Specifies the analog input voltage above which the digital switch state changes to on (high).

Digital/Analog Input 2 Menu

The following table describes the Digital/Analog Input 2 parameters.

Note: To monitor the analog input voltage and the digital switch state, use the Inputs menu.

DIGITAL/ANALOG INPUTS MENU

PARAMETER CAN INDEX	VALUES DEFAULT	RAW VALUES DATA SIZE	DESCRIPTION
Type **[PCF]** `0x333101`	0–3 0	0–3 16-bit	Specifies how the input will be used: 0 = Disable 1 = Lower Valve Input 2 = Lift Inhibit High Active 3 = Lift Inhibit Low Active The value can conflict with other parameter values and cause a Parameter Mismatch fault. The following list describes these conflicts: • The value is non-zero but the EMR Input Type parameter indicates an NC switch is used. • The value is 1 but the External Status LED Enable parameter is on.
Digital Input Low Threshold `0x333301`	0.00–10.00V 3.00V	0–1000 16-bit	Specifies the analog input voltage below which the digital switch state changes to off (low).
Digital Input High Threshold `0x333401`	0.00–10.00V 5.00V	0–1000 16-bit	Specifies the analog input voltage above which the digital switch state changes to on (high).

CAN INTERFACE MENU

The CAN Interface parameters configure the controller for CANopen. The CAN Interface menu also contains the PDO Setups menu, which in turn contains parameters for PDO maps.

The following table describes the parameters contained by the CAN Interface menu, and RPDO and TPDO Byte Map Menus describes the menus contained by the PDO Setups sub-menu.

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

CAN INTERFACE MENU

PARAMETER CAN INDEX	VALUES DEFAULT	RAW VALUES DATA SIZE	DESCRIPTION
CAN Inputs Configuration `0x32C200`	0–65535 0	0–65535 16-bit	Indicates whether various switches are commanded by the controller's inputs or the CAN Switches object. Each switch is configured by a bit in the parameter value. For details, see CAN Inputs Configuration Parameter.
Baud Rate `0x200101`	125K–1M 125K	0–4 16-bit	Specifies the CAN baud rate: 0 = 125 KB/s 1 = 250 KB/s 2 = 500 KB/s 3 = 800 KB/s 4 = 1 MB/s
Heartbeat Rate `0x101700`	100–1000ms 100ms	100–1000 16-bit	Specifies the cyclic rate of the controller's heartbeat messages.
CAN NMT State `0x32A401`	0–127 *N/A*	0–127 16-bit	Displays the NMT state. This is a read-only parameter. The following values identify the NMT states: 4 = Stopped 5 = Operational 127 = Pre-operational
CAN Node ID `0x200001`	0–0xFFFFh 0x2Ah	0h–0xFFFFh 16-bit	Indicates the controller's Node ID. The Node ID can be changed when the CANbus is in the Pre-Operational or Operational state. However, the updated Node ID will not be active until the system is reset by cycling the keyswitch or sending an NMT reset message. **Note:** Node ID 0 is reserved by CANopen, and Node ID 127 is reserved for Curtis programming devices.

CAN Inputs Configuration Parameter

The 10 least significant bits of the CAN Inputs Configuration parameter indicate whether various switches are commanded by the controller's inputs or the CAN Switches object. 0 indicates the switch is controlled by the controller's input, 1 by CAN.

The following table lists the bits and corresponding switches.

Note: The parameter's 6 most significant bits are always 0.

Bit	Switch
9	Digital 2
8	Digital 1
7	Lift
6	Mode
5	Reverse
4	Forward
3	EMR NO
2	Charger Inhibit
1	EMR NC
0	Interlock

For example, if the CAN Inputs Configuration value is 110001b, the interlock, forward, and reverse switches are commanded by CAN, and the other switches are commanded by the controller's inputs.

RPDO and TPDO Byte Map Menus

The PDO setup menus contains the RPDO 1-4 Byte Map and TPDO 1-4 Byte Map menus. These menus let you use CIT or a Curtis programming device to create and edit PDO maps for the predefined PDOs.

Note: You must be familiar with PDOs and PDO mapping in order to use the PDO Byte Map parameters. See PDOs and Mapping a PDO.

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 and default values. For simplicity's sake, the following table describes the RPDO 1-4 Byte Map and TPDO 1-4 Byte menus' parameters, and Table 4 lists the parameters' CAN indexes and defaults.

RPDO AND TPDO BYTE MAP MENUS

PARAMETER	VALUES	RAW VALUES DATA SIZE	DESCRIPTION
RPDO *n* Event Time and TPDO *n* Event Time	0–65535ms	0–65535 16-bit	Specifies an RPDO timeout or TPDO transmission interval. The parameter's purpose depends upon whether the PDO is an RPDO or a TPDO: • RPDO: If the controller doesn't receive the RPDO's data before the timeout elapses, a PDO Timeout fault will occur. To disable the timeout, specify 0. • TPDO: The rate at which the controller transmits the TPDO's data.
RPDO *n* COB ID and TPDO *n* COB ID	0–FFFFFFFFh	0–FFFFFFFFh 32-bit	Specifies the PDO's COB-ID. See PDO Value Object.
Length	0–8	0–8 8-bit	Specifies the number of objects contained by the PDO map.
1-8	0–FFFFFFFFh	0–FFFFFFFFh 32-bit	Specifies the index, sub-index, and size of PDO mapped object *n*, where *n* represents the parameter name. For example, the 2 parameter specifies the PDO's second mapped object. For information on how to specify values for the parameters, see PDO Mapping Objects.

PDO Byte Map CAN Indexes and Defaults

The following table lists the CAN indexes and defaults of the RPDO Byte Map and TPDO Byte Map parameters:

Table 4 PDO Mapping Objects — CAN Indexes and Defaults

Parameter	PDO	CAN Index	Default
RPDO 1 Event Time	RPDO1	0x140005	100ms
RPDO 1 COB ID	RPDO1	0x140001	22Ah
Length	RPDO1	0x160000	1
1	RPDO1	0x160001	32B50110h
2	RPDO1	0x160002	50008h
3	RPDO1	0x160003	50008h
4	RPDO1	0x160004	50008h
5	RPDO1	0x160005	50008h
6	RPDO1	0x160006	50008h
7	RPDO1	0x160007	50008h
8	RPDO1	0x160008	50008h
RPDO 2 Event Time	RPDO2	0x140105	40ms
RPDO 2 COB ID	RPDO2	0x140101	8000032Ah
Length	RPDO2	0x160100	0
1	RPDO2	0x160101	50008h
2	RPDO2	0x160102	50008h
3	RPDO2	0x160103	50008h
4	RPDO2	0x160104	50008h
5	RPDO2	0x160105	50008h
6	RPDO2	0x160106	50008h
7	RPDO2	0x160107	50008h
8	RPDO2	0x160108	50008h
RPDO 3 Event Time	RPDO3	0x140205	40ms
RPDO 3 COB ID	RPDO3	0x140201	8000042Ah
Length	RPDO3	0x160200	0
1	RPDO3	0x160201	50008h
2	RPDO3	0x160202	50008h
3	RPDO3	0x160203	50008h
4	RPDO3	0x160204	50008h
5	RPDO3	0x160205	50008h
6	RPDO3	0x160206	50008h
7	RPDO3	0x160207	50008h
8	RPDO3	0x160208	50008h
RPDO 4 Event Time	RPDO4	0x140305	40ms
RPDO 4 COB ID	RPDO4	0x140301	8000052Ah
Length	RPDO4	0x160300	0
1	RPDO4	0x160301	50008h
2	RPDO4	0x160302	50008h

Table 4 PDO Mapping Objects — CAN Indexes and Defaults, cont'd

Parameter	PDO	CAN Index	Default
3	RPDO4	0x160303	50008h
4	RPDO4	0x160304	50008h
5	RPDO4	0x160305	50008h
6	RPDO4	0x160306	50008h
7	RPDO4	0x160307	50008h
8	RPDO4	0x160308	50008h
TPDO 1 Event Time	TPDO1	0x180005	40ms
TPDO 1 COB ID	TPDO1	0x180001	400001AAh
Length	TPDO1	0x1A0000	4
1	TPDO1	0x1A0001	10010010h
2	TPDO1	0x1A0002	34560110h
3	TPDO1	0x1A0003	35380110h
4	TPDO1	0x1A0004	35370110h
5	TPDO1	0x1A0005	50008h
6	TPDO1	0x1A0006	50008h
7	TPDO1	0x1A0007	50008h
8	TPDO1	0x1A0008	50008h
TPDO 2 Event Time	TPDO2	0x180105	40ms
TPDO 2 COB ID	TPDO2	0x180101	400002AAh
Length	TPDO2	0x1A0100	2
1	TPDO2	0x1A0101	30000110h
2	TPDO2	0x1A0102	30040110h
3	TPDO2	0x1A0103	50008h
4	TPDO2	0x1A0104	50008h
5	TPDO2	0x1A0105	50008h
6	TPDO2	0x1A0106	50008h
7	TPDO2	0x1A0107	50008h
8	TPDO2	0x1A0108	50008h
TPDO 3 Event Time	TPDO3	0x180205	40ms
TPDO 3 COB ID	TPDO3	0x180201	C00003AAh
Length	TPDO3	0x1A0200	0
1	TPDO3	0x1A0201	50008h
2	TPDO3	0x1A0202	50008h
3	TPDO3	0x1A0203	50008h
4	TPDO3	0x1A0204	50008h
5	TPDO3	0x1A0205	50008h
6	TPDO3	0x1A0206	50008h
7	TPDO3	0x1A0207	50008h
8	TPDO3	0x1A0208	50008h

Table 4 PDO Mapping Objects — CAN Indexes and Defaults, cont'd

Parameter	PDO	CAN Index	Default
TPDO 4 Event Time	TPDO4	0x180305	40ms
TPDO 4 COB ID	TPDO4	0x180301	C00004AAh
Length	TPDO4	0x1A0300	0
1	TPDO4	0x1A0301	50008h
2	TPDO4	0x1A0302	50008h
3	TPDO4	0x1A0303	50008h
4	TPDO4	0x1A0304	50008h
5	TPDO4	0x1A0305	50008h
6	TPDO4	0x1A0306	50008h
7	TPDO4	0x1A0307	50008h
8	TPDO4	0x1A0308	50008h

STEERING SPEED LIMIT MENU (CAN MODELS ONLY)

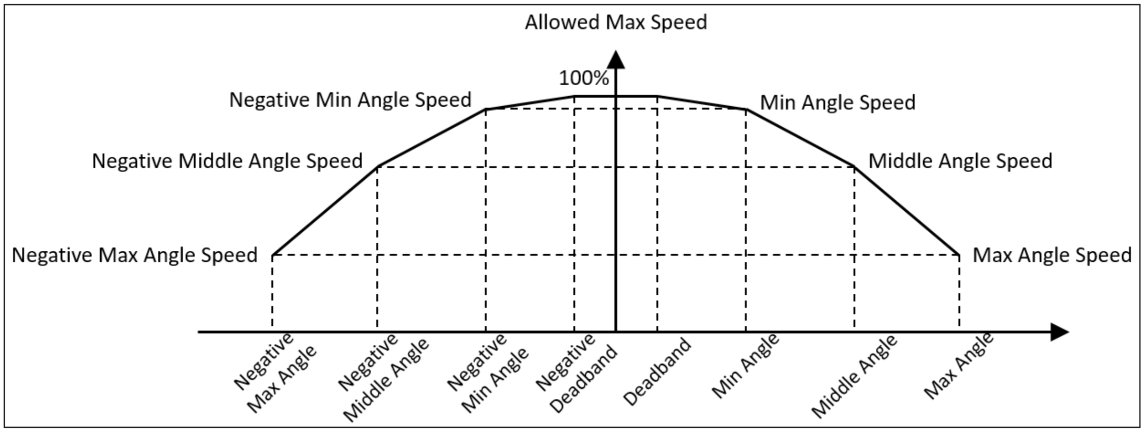
Models 1226BL-2251 and 1226BL-4151 include a steering speed limit function for vehicles equipped with the Curtis 1220E electric steering controller.

If the steering speed limit function is enabled, the 1226BL adjusts the maximum speed based on the drive wheel angle or steering command angle transmitted by the 1220E over the CANbus. The Steering Angle Enable parameter specifies whether the drive wheel angle or steering command angle is used.

Note: For information on connecting the 1226BL and 1220E and configuring the controllers to interact, see the 1220E manual.

The Speed Limitation menu parameters specify the maximum speeds for various angles. The menu includes parameters for the forward and reverse directions. Typically the parameters are configured so that the maximum speeds are slowest for the largest angles.

The following diagram shows the correspondences between the various angles and maximum speeds:



The following table describes the parameters on the Steering Speed Limit menu:

STEERING SPEED LIMIT MENU

PARAMETER CAN INDEX	VALUES DEFAULT	RAW VALUES DATA SIZE	DESCRIPTION
Steering Speed Limit Enable [PCF] 0xA13300	Off/On Off	0–1 8-bit	Indicates whether the steering speed limit feature is enabled.
Steering Controller Node ID 0xA13000	1h–7Fh 14h	1h–7Fh 8-bit	Indicates the 1220E controller's CAN Node Id.
Steering Angle Enable [PCF] 0xA12F00	Off/On On	0–1 8-bit	Indicates whether the 1226BL uses the drive wheel or steering command angle to adjust the maximum speed: Off = Drive wheel angle On = Steering command angle
TPDO 1 Event Time 0xA13100	40–65535ms 40ms	40–65535 16-bit	Indicates the rate at which the 1226BL transmits its TPDO1 data to the 1220E's RPDO1. **Note:** If the 1220E's RPDO1 does not receive the data within the interval specified by the **1220E's** RPDO1 Event Time parameter, the 1220E will generate a PDO1 Timeout fault.
RPDO1 Event Time 0xA13200	0–65535ms 100ms	0–65535 16-bit	Indicates the timeout interval for the 1226BL's RPDO1. If RPDO1 does not receive the data transmitted by the 1220E's TPDO1 data before the timeout elapses, a PDO Timeout fault will occur. To disable the timeout, specify 0.

Speed Limitation Menu

The Speed Limitation parameters define the angles and corresponding maximum speeds for the steering speed limit function.

Most of the parameters are pairs, with one parameter defining the angle and the corresponding parameter defining the maximum speed for that angle. Additional parameters specify the angles for deadband thresholds.

The following table describes the parameters on the Speed Limitation menu.

Note: The Steering Angle Enable parameter specifies whether the angle parameters are for the drive wheel angle or steering command angle. The menu's maximum speed parameters are percentages of the vehicle's maximum speed.

SPEED LIMITATION MENU

PARAMETER CAN INDEX	VALUES DEFAULT	RAW VALUES DATA SIZE	DESCRIPTION
Forward Max Angle **[PCF]** `0xA11300`	0.0–120.0° 120.0°	0–21844 16-bit	Indicates the angle at which the Forward Max Angle Speed is used.
Forward Max Angle Speed **[PCF]** `0xA11400`	0–100% 50%	0–8192 16-bit	Indicates the maximum speed for the Forward Max Angle.
Forward Middle Angle **[PCF]** `0xA11500`	0.0–120.0° 60.0°	0–21844 16-bit	Indicates the angle at which the Forward Middle Angle Speed is used.
Forward Middle Angle Speed **[PCF]** `0xA11600`	0–100% 60%	0–8192 16-bit	Indicates the maximum speed for the Forward Middle Angle.
Forward Min Angle **[PCF]** `0xA11700`	0.0–120.0° 30.0°	0–21844 16-bit	Indicates the angle at which the Forward Min Angle Speed is used.
Forward Min Angle Speed **[PCF]** `0xA11800`	0–100% 80%	0–8192 16-bit	Indicates the maximum speed for the Forward Min Angle.
Forward Deadband **[PCF]** `0xA11900`	0.0–120.0° 10.0°	0–21844 16-bit	Indicates the angle that defines the forward deadband threshold.
Forward Negative Max Angle `0xA11A00`	–120.0–0.0° –120.0°	–21843–0 16-bit	Indicates the angle at which the Forward Negative Max Angle Speed is used.
Forward Negative Max Angle Speed `0xA11B00`	0–100% 50%	0–8192 16-bit	Indicates the maximum speed for the Forward Negative Max Angle.
Forward Negative Middle Angle `0xA11C00`	–120.0–0.0° –60.0°	–21843–0 16-bit	Indicates the angle at which the Forward Negative Middle Angle Speed is used.
Forward Negative Middle Angle Speed `0xA11D00`	0–100% 60%	0–8192 16-bit	Indicates the maximum speed for the Forward Negative Middle Angle.
Forward Negative Min Angle `0xA11E00`	–120.0–0.0° –30.0°	–21843–0 16-bit	Indicates the angle at which the Forward Negative Min Angle Speed is used.
Forward Negative Min Angle Speed `0xA11F00`	0–100% 80%	0–8192 16-bit	Indicates the maximum speed for the Forward Negative Min Angle.

SPEED LIMITATION MENU, cont'd

PARAMETER CAN INDEX	VALUES DEFAULT	RAW VALUES DATA SIZE	DESCRIPTION
Forward Negative Deadband `0xA12000`	–120.0–0.0° –10.0°	–21843–0 16-bit	Indicates the angle that defines the forward negative deadband threshold.
Reverse Max Angle **[PCF]** `0xA12100`	0.0–120.0° 120.0°	0–21844 16-bit	Indicates the angle at which the Reverse Max Angle Speed is used.
Reverse Max Angle Speed **[PCF]** `0xA12200`	0–100% 50%	0–8192 16-bit	Indicates the maximum speed for the Reverse Max Angle.
Reverse Middle Angle **[PCF]** `0xA12300`	0.0–120.0° 60.0°	0–21844 16-bit	Indicates the angle at which the Reverse Middle Angle Speed is used.
Reverse Middle Angle Speed **[PCF]** `0xA12400`	0–100% 60%	0–8192 16-bit	Indicates the maximum speed for the Reverse Middle Angle.
Reverse Min Angle **[PCF]** `0xA12500`	0.0–120.0° 30.0°	0–21844 16-bit	Indicates the angle at which the Reverse Min Angle Speed is used.
Reverse Min Angle Speed **[PCF]** `0xA12600`	0–100% 80%	0–8192 16-bit	Indicates the maximum speed for the Reverse Min Angle.
Reverse Deadband **[PCF]** `0xA12700`	0.0–120.0° 10.0°	0–21844 16-bit	Indicates the angle that defines the reverse deadband threshold.
Reverse Negative Max Angle `0xA12800`	–120.0–0.0° –120.0°	–21843–0 16-bit	Indicates the angle at which the Reverse Negative Max Angle Speed is used.
Reverse Negative Max Angle Speed `0xA12900`	0–100% 50%	0–8192 16-bit	Indicates the maximum speed for the Reverse Negative Max Angle.
Reverse Negative Middle Angle `0xA12A00`	–120.0–0.0° –60.0°	–21843–0 16-bit	Indicates the angle at which the Reverse Negative Middle Angle Speed is used.
Reverse Negative Middle Angle Speed `0xA12B00`	0–100% 60%	0–8192 16-bit	Indicates the maximum speed for the Reverse Negative Middle Angle.
Reverse Negative Min Angle `0xA12C00`	–120.0–0.0° –30.0°	–21843–0 16-bit	Indicates the angle at which the Reverse Negative Min Angle Speed is used.
Reverse Negative Min Angle Speed `0xA12D00`	0–100% 80%	0–8192 16-bit	Indicates the maximum speed for the Reverse Negative Min Angle.
Reverse Negative Deadband `0xA12E00`	–120.0–0.0° –10.0°	–21843–0 16-bit	Indicates the angle that defines the reverse negative deadband threshold.

MISC MENU

Use the MISC menu to configure the following:

- Whether the controller generates faults for open coil conditions for the EM brake, pump, and valve drivers.

  Note: The controller provides short circuit protection for the drivers regardless of whether a driver is configured to check for the open condition.

- The PWM mode for the pump and valve drivers.
- SRO (Static Return to Off) detection for the pump driver, valve driver, and emergency reverse inputs.

MISC MENU

PARAMETER CAN INDEX	VALUES DEFAULT	RAW VALUES DATA SIZE	DESCRIPTION
EM Brake Driver Checks Enable `0x341B01`	Off/On Off	0–1 8-bit	Specifies whether the controller checks the driver for the open condition: On = If the open condition occurs, the controller opens the driver and generates the EM Brake Driver Fault. Off = The controller does not check for the open condition.
Pump Contactor Driver Checks Enable `0x341C01`	Off/On Off	0–1 8-bit	Specifies whether the controller checks the driver for the open condition: On = If the open condition occurs, the controller opens the driver and generates the Pump Driver Fault. Off = The controller does not check for the open condition.
Valve Driver Checks Enable `0x341D01`	Off/On Off	0–1 8-bit	Specifies whether the controller checks the driver for the open condition: On = If the open condition occurs, the controller opens the driver and generates the Valve Driver Fault. Off = The controller does not check for the open condition.
Pump Contactor Driver Compensation `0x341F01`	Off/On Off	0–1 8-bit	Specifies the driver PWM mode. On = Voltage Compensated PWM mode Off = Direct PWM mode For descriptions of the PWM modes, see Driver Outputs.
Valve Driver Compensation `0x342001`	Off/On Off	0–1 8-bit	
EMR SRO Enable `0x335E01`	Off/On Off	0–1 16-bit	Specifies whether the controller generates an EMR SRO fault if an emergency reverse switch is active when the keyswitch is turned on.
Pump SRO Enable `0x335D01`	Off/On Off	0–1 16-bit	Specifies whether the controller generates a Pump SRO fault if the lift switch is on when the keyswitch is turned on.
Valve SRO Enable `0x335F01`	Off/On Off	0–1 16-bit	Specifies whether the controller generates a Valve SRO fault if the valve switch is on when the keyswitch is turned on.
Pump Driver Pull In Voltage `0x342201`	0–100% 100%	0–32767 16-bit	Specifies the pump contactor's initial voltage when the system is first turned on, to ensure that the contactor is engaged. After 1 second, the peak voltage drops to the Pump Driver Holding Voltage.
Pump Driver Holding Voltage `0x342301`	0–100% 80%	0–32767 16-bit	Specifies the reduced voltage the controller applies to the pump contactor coil once the contactor has been engaged. Set the holding voltage so that it is high enough to keep the contactor engaged under all shock and vibration conditions that the vehicle is expected to encounter.

MISC MENU, cont'd

PARAMETER CAN INDEX	VALUES DEFAULT	RAW VALUES DATA SIZE	DESCRIPTION
Valve Driver Pull In Voltage `0x342401`	0–100% 100%	0–32767 16-bit	Specifies the contactor's initial voltage when the system is first turned on, to ensure that the valve contactor is engaged. After 1 second, the peak voltage drops to the Valve Driver Holding Voltage.
Valve Driver Holding Voltage `0x342501`	0–100% 80%	0–32767 16-bit	Specifies the reduced voltage the controller applies to the valve contactor coil once the contactor has been engaged. Set the holding voltage so that it is high enough to keep the contactor engaged under all shock and vibration conditions that the vehicle is expected to encounter.
External Status LED Enable `0x342901`	Off/On Off	0–1 8-bit	Indicates whether pin J3-2 is used to drive an external status LED or a valve contactor: On = External status LED Off = Valve contactor If the value is On but the Type parameter of the Digital/Analog Input 1 or the Digital/Analog Input 2 menu is 1 (Lower Valve Input), a Parameter Mismatch fault will occur.
Hourmeter Source (1226BL-4151 model) `0x32C800`	0–1 0	0–1 8-bit	Indicates the hour meter source: 0= Keyswitch 1= Interlock
Parameter Interlock `0x507601`	0–65535 0	0–65535 16-bit	Resets all parameters to their factory default values. To reset the parameters, specify any value except 1, then cycle the keyswitch.

4 — MONITOR MENU VARIABLES

The Monitor menu contains variables that display real-time data. You can use this data when you are configuring or troubleshooting the system.

The Monitor menu contains the following menus:

- Controller Menu
- Battery Menu
- Outputs Menu
- Motor Menu
- Inputs Menu

CONTROLLER MENU

The following table describes the variables on the Controller menu.

CONTROLLER MENU

VARIABLE NAME CAN INDEX	VALUES	RAW VALUES DATA SIZE	DESCRIPTION
Armature PWM `0x353801`	–100% – +100%	–8191 – +8191 16-bit	Indicates the controller output's duty cycle.
Armature Current `0x345601`	–150A – +150A	–150 – +150 16-bit	Indicates the controller's phase current.
Current Limit `0x345701`	–150A – +150A	–150 – +150 16-bit	Indicates the armature current limit.
Controller Temp Cutback `0x343701`	0–100%	0–4096 16-bit	Indicates the current available as a result of the temperature cutback function. The value is a percentage of the Drive Current Limit parameter. 100% indicates no cutback.
Overvoltage Cutback `0x343A01`	0–100%	0–4096 16-bit	Indicates the current available due to overvoltage cutback. 100% indicates no cutback.
Undervoltage Cutback `0x343B01`	0–100%	0–4096 16-bit	Indicates the current available due to undervoltage cutback. 100% indicates no cutback.
Motor Temp Cutback `0x343901`	0–100%	0–4096 16-bit	Indicates the current available due to motor temperature control cutback. 100% indicates no cutback.
Temperature `0x300001`	–40 – +120°C	–400 – +1200 16-bit	Indicates the controller's internal temperature.
Internal Timer `0x4E1401`	0–429496729.5s	0–4294967295 32-bit	Indicates the total time that the controller has been powered on during its lifetime.
Mode `0x333701`	1–2	1–2 8-bit	Indicates the active speed mode.
Interlock `0x34B801`	Off/On	0–1 8-bit	Indicates the interlock state.
Charger Inhibit `0x333901`	Off/On	0–1 8-bit	Indicates whether the charger inhibit function is active.
Lift Lockout `0x333A01`	Off/On	0–1 8-bit	Indicates whether the hydraulic lift lockout function is active. **Note:** The Lift Lockout Threshold parameter specifies the battery level that activates lift lockout.

CONTROLLER MENU, cont'd

VARIABLE NAME CAN INDEX	VALUES	RAW VALUES DATA SIZE	DESCRIPTION
Emer Rev `0x333B01`	Off/On	0–1 8-bit	Indicates whether the emergency reverse function is active.
Lift Input `0x331001`	Off/On	0–1 16-bit	Indicates whether the lift function is active.
Valve Input `0x331101`	Off/On	0–1 16-bit	Indicates whether the valve function is active.
Supervision Error `0x3AF301`	0–65535	*N/A*	Indicates the fault type for the Supervision fault. Values are described in Table 8.

BATTERY MENU

The following table describes the variables on the Battery menu.

BATTERY MENU

VARIABLE NAME CAN INDEX	VALUES	RAW VALUES DATA SIZE	DESCRIPTION
BDI `0x33B101`	0–100%	0–100 16-bit	Indicates the battery's state of charge.
Keyswitch Voltage `0x339801`	0.00–105.00V	0–10500 16-bit	Indicates the keyswitch voltage.
Capacitor Voltage `0x34C101`	0.00–200.00V	0–20000 16-bit	Indicates the voltage of the controller's internal capacitor bank.

OUTPUTS MENU

The following table describes the variables on the Outputs menu.

OUTPUTS MENU

VARIABLE NAME CAN INDEX	VALUES	RAW VALUES DATA SIZE	DESCRIPTION
Main Relay/Contactor Driver PWM `0x34D201`	0–100%	0–8192 16-bit	Indicates the main relay or contactor driver's PWM output.
EM Brake Driver PWM `0x340201`	0–100%	0–32767 16-bit	Indicates the electromagnetic brake driver's PWM output.
Pump Contactor Driver PWM `0x340601`	0–100%	0–32767 16-bit	Indicates the hydraulic contactor driver's PWM output.
Valve Driver PWM `0x340501`	0–100%	0–32767 16-bit	Indicates the lower valve contactor driver's PWM output.
External 5 Volts `0x36AA01`	0.00–6.00V	0–600 16-bit	Indicates the voltage of the external +5V power supply.
External 14 Volts `0x36AB01`	0.00–16.00V	0–1600 16-bit	Indicates the voltage of the external +14V power supply.

MOTOR MENU

The following table describes the variables on the Motor menu.

MOTOR MENU

VARIABLE NAME CAN INDEX	VALUES	RAW VALUES DATA SIZE	DESCRIPTION
Hall Sensor State `0x353201`	0–7	0–7 16-bit	Indicates the Hall sensor status.
Driver Step `0x353301`	0–7	0–7 16-bit	Indicates the active output step.
Motor Temperature `0x300401`	–40 – +120°C	–400 – +1200 16-bit	Indicates the temperature measured by the temperature sensor.
Electric RPM `0x353001`	–32767 – +32767 RPM	–32767 – +32767 16-bit	Indicates the motor's electrical speed.
Motor RPM `0x353701`	–6000 – +6000 RPM	–6000 – +6000 16-bit	Indicates the motor speed and direction detected by the controller. A positive number indicates the forward direction and a negative number indicates reverse. **Note:** If the value is negative even though forward was requested, or vice versa, you probably need to set the Swap Speed Direction parameter to On.

INPUTS MENU

The following table describes the variables on the Inputs menu.

INPUTS MENU

VARIABLE NAME CAN INDEX	VALUES	RAW VALUES DATA SIZE	DESCRIPTION
Throttle Pot Percent `0x335C01`	0–100%	0–1000 16-bit	Indicates the throttle request as a percentage of full throttle.
Throttle Command `0x335401`	0–100%	0–32767 16-bit	Indicates the controller output for the throttle request. The controller uses the following factors to calculate the throttle command: • The throttle request (which is indicated by the Throttle Pot Percent variable). • The Throttle menu's Deadband and Map parameters. See Throttle Menu and Throttle Response Parameters. • The status of the direction and interlock commands.
Interlock Switch `0x332401`	Off/On	0–1 8-bit	Indicates whether the switch is on.
Mode Switch `0x332A01`	Off/On	0–1 8-bit	Indicates whether the switch is on.
Forward Switch `0x332801`	Off/On	0–1 8-bit	Indicates whether the switch is on.
Reverse Switch `0x332901`	Off/On	0–1 8-bit	Indicates whether the switch is on.
EMR NC Switch `0x332501`	Off/On	0–1 8-bit	Indicates whether the switch is on.
EMR NO Switch `0x332701`	Off/On	0–1 8-bit	Indicates whether the switch is on.

INPUTS MENU, cont'd

VARIABLE NAME CAN INDEX	VALUES	RAW VALUES DATA SIZE	DESCRIPTION
Inhibit Switch `0x332601`	Off/On	0–1 8-bit	Indicates whether the switch is on. **Note:** The Charger Inhibit input is an active low input. The On value indicates the input is high level, not that the charger inhibit function is in effect.
Lift Switch `0x332B01`	Off/On	0–1 8-bit	Indicates whether the switch is on.
Digital Switch 1 `0x333501`	Off/On	0–1 8-bit	Indicates whether the switch is on.
Digital Switch 2 `0x333601`	Off/On	0–1 8-bit	Indicates whether the switch is on.
Analog Input 1 Voltage `0x32EC01`	0.00–10.00V	0–1000 16-bit	Indicates the input's voltage.
Analog Input 2 Voltage `0x32ED01`	0.00–10.00V	0–1000 16-bit	Indicates the input's voltage.

STEERING SPEED LIMIT MENU (CAN MODELS ONLY)

Models 1226BL-2251 and 1226BL-4151 contain the Steering Speed Limit menu, which provides variables for monitoring the steering speed limit function:

STEERING SPEED LIMIT MENU

VARIABLE NAME CAN INDEX	VALUES	RAW VALUES DATA SIZE	DESCRIPTION
Steering Controller Handshake Status `0xA10100`	0–255	0–255 8-bit	Indicates the status of the handshake between the 1226BL and 1220E controllers. The following list describes the values: • 0–5: *Internal status* • 6: Handshake failed • 7: Handshake succeeded • 8–255: *Reserved*
Wheel Angle `0xA10400`	–120.0 – +120.0°	–21845 – +21844 16-bit	Indicates the drive wheel angle transmitted by the 1220E.
Steering Angle `0xA10200`	–120.0 – +120.0°	–21845 – +21844 16-bit	Indicates the steering angle transmitted by the 1220E.
Used Angle `0xA10600`	–120.0 – +120.0°	–21845 – +21844 16-bit	Indicates the angle value that determines the maximum speed. Note: The Steering Angle Enable parameter indicates whether the drive wheel angle or steering command angle is used.
Allowed Max Speed `0xA10000`	–100 – +100%	–8192 – +8192 16-bit	Indicates the maximum speed for the Used Angle.

5 — CANOPEN COMMUNICATIONS

The 1226BL controller complies with the CAN in Automation (CiA) CANopen DS 301 specification.

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/

This chapter describes the controller's CANopen features. For information on the CANopen object dictionary, see CANopen Object Dictionary.

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.

The following example shows how an SDO 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 “1226BL-”:

0	1	2	3	4	5	6	7
Control Byte	Data						
00h	31h = “1”	32h = “2”	32h = “2”	36h = “6”	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

PROGRAMMING CANOPEN MODELS

To program CANopen models, use the Curtis 1313 handheld programmer or Curtis Integrated Toolkit™. For more information, see Curtis Programming Devices.

The following considerations apply when programming CANbus models:

- 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.

MESSAGE CAN-IDS

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

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, and is not resent while the fault remains active.

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: Byte 0 indicates the fault code, which is in the following format: • The four most significant bits contains the fault code's first digit. • The four least significant bits contains the fault code's second digit. For example, if the fault code is 3,2, the byte's value would be 32h. Byte 1 indicates one of the following error categories: • FFh = Active fault • 62h = Active fault from VCL • 00h = Cleared fault
2	Error Register	Indicates whether any faults are active on the transmitting device: • 00h = No active faults • 01h = At least one active fault **Note:** The value equals the value of the least significant bit in the CANopen Error Register object.
3–4	Fault Record Object Index	Identifies the fault's Fault Record object. Fault Record objects provide details on faults; see Fault Record Objects.
5–7	Fault Type	Indicates the fault's fault type.

Note: For information on emergency message COB-IDs, see the description of the Emergency COB ID object.

Emergency Message Example

The following example is an emergency message that indicates an HPD Sequencing fault has occurred:

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

The least significant byte indicates that the fault code is 2,1, and byte 1 indicates the fault is active. Bytes 3-4 indicate that the Fault Record object's index is 2211h.

SDO COMMUNICATION OBJECT

The controller's SDO communication object contains the COB-IDs for transmitted and received SDOs. The following table describes the object, which is read-only:

Index	Sub-Index	Name	Description	Values Data Size
1200h	01h	Receive SDO COB-ID	The value is the sum of 0600h and the device's Node ID.	0–0xFFFFFF 32-bit
	02h	Transmit SDO COB-ID	The value is the sum of 0580h and the device's Node ID.	0–0xFFFFFF 32-bit

EXPEDITED SDOS

The control byte of expedited SDOs must include a command specifier that defines the transfer type. Expedited SDOs that contain data always consist of 8 data bytes, and the data size must be specified in the *n* field of the control byte.

Note: The control byte is the least significant byte.

The following table shows 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, as 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 the fields in bits 0–3 depend upon whether the SDO transfers data. If the SDO does **not** contain data, these bits are always 0b. If the SDO contains data, the bit values are as follows:
- *n* indicates the number of data bytes that are not used.
- *e* = 1b, which indicates the message is an expedited SDO.
- *s* = 1b, which indicates that the *n* field specifies the number of data bytes that are not used.

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: • 1 byte = 2Fh • 2 bytes = 2Bh • 3 bytes = 27h • 4 bytes = 23h
Confirm a write	60h
Request data from a device	40h
Device responds with requested data	Depends upon the data size: • 1 byte = 4Fh • 2 bytes = 4Bh • 3 bytes = 47h • 4 bytes = 43h
Abort SDO	80h

PDOS

The 1226BL provides four predefined RPDOs and four predefined TPDOs. The controller supports dynamic mapping, which allows you to specify the CAN objects that are processed by PDOs. To map an object, you use mapping parameters to specify the object's index, sub-index, and size.

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.
- An RPDO will timeout if it does not receive an incoming message before the specified timeout interval.

Note: A TPDO also transmits data when the value of a mapped object changes.

PDO Objects

A PDO consists of the following objects:

Object	Description
PDO communication object	Specifies the PDO's CAN-ID, number of mapped CAN objects, and timing-related parameters.
PDO mapping object	Specifies the CAN objects that will be processed by the PDO.

The following topics describe these objects.

PDO Communication Object

The following table lists the predefined PDO Communication objects' indexes:

Communication Object Index	Index
RPDO1	1400h
RPDO2	1401h
RPDO3	1402h
RPDO4	1403h
TPDO1	1800h
TPDO2	1801h
TPDO3	1802h
TPDO4	1803h

The following table describes the PDO communication objects' sub-indexes:

Note: Sub-indexes 01h and 05h are also exposed as the Event Time and COB-ID parameters on the RPDO and TPDO Byte Map menus.

Sub-Index	Name	Description	Read / Write	Values Data Size
01h	PDO Value	Indicates the PDO's COB-ID, type, and whether the PDO is enabled. For details, see PDO Value Object.	RW	0–4294967295 32-bit
02h	Transmission Type	The controller supports event-driven asynchronous PDOs, so the value is always FEh.	R	FEh 8-bit
03h	Inhibit Time	*Reserved.*	RW	40 16-bit
04h	*N/A*	*Reserved.*	*N/A*	*N/A*
05h	Event Time	Depends upon the type of PDO: • TPDO: The maximum time between transmissions. • RPDO: The timeout interval. If the RPDO does not receive data before the timeout elapses, a PDO Timeout fault will occur. To disable the RPDO's timeout, specify 0.	RW	0–65535ms 16-bit

PDO Value Object

The following table describes the PDO Value object, which is sub-index 01 of PDO Communication objects. The object consists of 32 bits and is described in the following table:

Note: The 11 least significant bits define the PDO's COB-ID.

Bit(s)	Description
31	Indicates whether the PDO is enabled. 0b indicates enabled.
30	Indicates the type of PDO: • 0 = RPDO • 1 = TPDO
29	Indicates whether the COB-ID is 11 or 29 bits. The controller supports only 11-bit COB-IDs, so the value is always 0.
11-28	29-bit COB-IDs are not supported, so these bits always have a value of 0.
7-10	The function code for the PDO. See Table 5.
0-6	The device's Node ID.

Table 5 PDO Function Codes

PDO ID	Function Code
TPDO1	0011b
RPDO1	0100b
TPDO2	0101b
RPDO2	0110b
TPDO3	0111b
RPDO3	1000b
TPDO4	1001b
RPDO4	1010b

For example, if TPDO1 is enabled and the Node ID is 2Ah, the value of sub-index 01h is 400001AAh.

Note: The predefined connections avoid CAN-ID clashes. However, the predefined connections are not configured to allow PDO messages between devices. You must configure the PDO CAN-IDs to enable the PDO messaging that your system requires.

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 contains an entry that specifies an object's index, sub-index, and size.

You can map objects by using either SDOs or the RPDO and TPDO byte map parameters. For information on the parameters, see RPDO and TPDO Byte Map Menus.

The indexes of the PDO Mapping objects are described in PDO Byte Map CAN Indexes and Defaults.

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

Sub-Index	Description
00h	The number of objects that the PDO maps.
01h–08h	Each sub-index contains a mapping object entry. The entry's bytes identify a mapped CAN object's index, sub-index, and length.

Mapping object entries consist of 4 bytes, which are described in the following table:

Byte(s)	Description
3-4	The object's index.
2	The object's sub-index.
1	The size of the object's data, in bits. The allowed values are: • 08h (8 bits) • 10h (16 bits) • 18h (24 bits) • 20h (32 bits) **Note:** The controller does not support mapping of individual bits.

The following example shows an SDO that maps a 16-bit object with an index and sub-index of 3824-01h to RPDO1's first mapped object:

```
23 00 16 01 10 01 24 38
```

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 maps four 16-bit objects:

Name			Device Value
TPDO 1 Event Time	⊖	⊕	1000
TPDO 1 COB ID	⊖	⊕	400001AAh
Length	⊖	⊕	4
1	⊖	⊕	33450110h
2	⊖	⊕	33440110h
3	⊖	⊕	33430110h
4	⊖	⊕	33420110h

Suppose the PDO transmits the following data:

```
64 00 00 40 02 00 84 03
```

Since the mapped objects are all 16-bit, the two least significant bytes (64h 00h) contain the data for the first mapped object (33450110h), the next two bytes contain the data for the second mapped object, and so on.

Mapping a PDO

To add entries to a PDO's mapping object, take the following steps.

You can perform these steps using either SDOs or the RPDO and TPDO Byte Map menus. For information on the parameters, see RPDO and TPDO Byte Map.

Note: The screen shots used in examples are from the CIT programming software.

1. Send an NMT message that changes the device to the pre-operational state.
2. Disable the PDO by changing its COB-ID's most significant bit to 1.
3. Disable mapping for the PDO by changing the PDO communication object's length to 0.

   The following example shows the disabled TPDO1, which has one mapped object:

Name			Device Value
TPDO 1 Event Time			1000
TPDO 1 COB ID			C00001AAh
Length			0
1			33450110h
2			50008h
3			50008h
4			50008h
5			50008h
6			50008h
7			50008h
8			50008h

4. In the PDO's mapping object, add entries for the CAN objects that the PDO will process.
5. Set the PDO communication object's length to the number of mapping object entries that the PDO will process.
6. Enable the PDO by changing its COB-ID's most significant bit to 0.

   The following example shows TPDO1 enabled and with the following objects added to the map:

   - A 16-bit object with an index and sub-index of 3348-01h
   - An 8-bit object with an index and sub-index of 3475-01h.

Name			Device Value
TPDO 1 Event Time			1000
TPDO 1 COB ID			400001AAh
Length			3
1			33450110h
2			33480110h
3			34750108h
4			50008h
5			50008h
6			50008h
7			50008h
8			50008h

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

6 — CANOPEN OBJECT DICTIONARY

The following topics describe objects in the controller's CANopen object dictionary.

Note: This chapter does not describe the objects for parameters, Monitor menu variables, and faults. For descriptions and CAN indexes of these objects, see Chapter 3, Chapter 4, and Table 6, respectively.

STANDARD COMMUNICATION OBJECTS

The following table describes communication objects that are defined by the CANopen standard.

Name	Index	Sub-Index	Description	Read / Write	Values Data Size
Device Type	1000h	00h	Indicates whether a device follows a standard CiA device profile.	RO	0 32-bit
Error Register	1001h	00h	Indicates if a fault is active: 0 = No active fault 1 = One or more active faults	RO	0–1 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 8-bit
		01h–04h	Provide data on the most recent faults. For details, see Error History Object (1003h).	RO	0–2147483647 32-bit
Manufacturer Device Name	1008h	00h	Initiates a segmented SDO that uploads the model name and number as an ASCII string.	RO	String
Manufacturer Hardware Version	1009h	00h	Indicates the controller's hardware version as an ASCII string.	RO	String
Manufacturer Software Version	100Ah	00h	Indicates the controller's software version as an ASCII string. **Note:** The Controller Information object provides the controller's device name, hardware version, and software version. See Miscellaneous Objects.	RO	String
Store Parameters	1010h	Saves changed parameter values to NVM.			
		00h	Indicates the size of the object	RO	0–127 8-bit
		01h	Saves the current parameter values to NVM. The data bytes must represent the string "save".	RW	0–2147483647 32-bit

Name	Index	Sub-Index	Description	Read / Write	Values Data Size
Restore Default Parameters	1011h	Resets parameters to their default values.			
		00h	Indicates the size of the object.	RO	0–127 8-bit
		01h	Restores parameters to their default values. The data bytes must represent the string “load”.	RW	0–2147483647 32-bit
Emergency COB ID	1014h	00h	Indicates the Emergency Message COB-ID: • 0: The COB-ID consists of the emergency message function code (0001b) and the node ID. • Non-zero: The COB-ID consists of the emergency message function code (0001b) and the specified value. **Note:** The COB-ID’s four most significant bits represent the emergency message function code.	RO	0–16777215 32-bit
Heartbeat Rate	1017h	00h	This object is contained by the CAN Interface menu. See the Heartbeat Rate parameter description.	RW	100–1000 16-bit
Identity Object	1018h	Provides information on the controller			
		00h	Indicates the size of the object.	RO	0–127 8-bit
		01h	Indicates the CiA-assigned identifier of Curtis Instruments. **Note:** The identifier is 4349h.	RO	0–2147483647 32-bit
		02h	Indicates the controller’s product code.	RO	0–2147483647 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 32-bit
		04h	Indicates the controller’s serial number.	RO	0–2147483647 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 controller uses the ZIP compressed 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.

Note: The controller provides fault objects that contain more detail than the Error History object. See Active Fault Array and Fault History Array Objects.

The fault data consists of four bytes and is described in the following table:

Byte(s)	Description
0–1	Contains an error category and the fault code: Byte 0 indicates the fault code, which is in the following format: • The 4 most significant bits indicate the fault code's first digit. • The 4 least significant bits indicate the fault code's second digit. For example, if the fault code is 3,2, the byte's value would be 32h. Byte 1 indicates the error category, which will be one of the following: • FFh = Active fault • 62h = Active fault from VCL • 00h = Cleared fault
2–3	A timestamp indicating when the fault occurred. The timestamp measures the running hours since the controller was first powered up. After the controller's internal hour meter passes 65,335 hours, the timestamp counter resets to 0. For example, if a fault occurs after 65,340 hours of running time, the timestamp would be 5 hours.

VEHICLE CONTROL OBJECTS

The following table describes objects that control the throttle and switches:

⚠ CAUTION

It is recommended that vehicles use PDOs, not SDOs, to control the throttle and switches. PDOs are recommended because if the CANbus is unexpectedly disconnected, the PDO Timeout fault protects against uncontrolled movement.

Name	Index	Sub-Index	Description	Read-Write	Values Data Size
CAN Throttle	32B5h	01h	Commands the throttle if the Throttle Type parameter specifies a CAN throttle. The values are scaled from –100% – +100%. The absolute value specifies the throttle command. The Direction Type parameter specifies whether the CAN Throttle object also commands direction. When Direction Type is 0, the CAN Throttle value's sign indicates the direction: positive indicates forward, negative indicates reverse. For example, the value –32767 applies maximum throttle. If the Direction Type parameter is 0, the value also specifies the reverse direction.	RW	–32767 – +32767 16-bit
CAN Switches	32BEh	01h	Indicates whether various switches are on or off. The object applies to switches that the CAN Inputs Configuration parameter indicates are controlled by CAN. The object's bits indicate the switches' on/off states. For details, see CAN Switches Object.	RW	0–65535 16-bit

CAN Switches Object

The CAN Switches object commands the on/off states of the switches controlled by CAN. These switches are specified with the CAN Inputs Configuration parameter.

The 10 least significant bits of the CAN Switches object indicate the switches' on/off states. The following table lists the bits and corresponding switches. 1 indicates the switch is on.

Bit	Switch
9	Digital 2
8	Digital 1
7	Lift
6	Mode
5	Reverse
4	Forward
3	EMR NO
2	Charger Inhibit
1	EMR NC
0	Interlock

For example, if the CAN Inputs Configuration parameter indicates all the switches are controlled by CAN, a CAN Switches value of 10001b turns the interlock and forward switches on and the other switches off.

Example: Driving with the CAN Throttle and CAN Switches Objects

Suppose you are configuring a vehicle that commands throttle and direction with the CAN Throttle and CAN Switches objects.

To configure the controller, you would set the following parameters:

- Throttle Type = 7 (CAN)
- Direction Type = 1
- CAN Inputs Configuration: Bits 4 and 5 must be set to 1. In this example, only the direction switches are commanded by CAN, so the CAN Inputs Configuration value would be 110000b.

The following table describes a trace of a TPDO that transmits throttle and direction commands. The TPDO's 1 and 2 parameters map the following 16-bit mapped objects:

- 1 parameter: CAN Switches object (32BE01h).
- 2 parameter: CAN Throttle object (32B501h).

TPDO Data	Direction	Throttle
10 00 00 00	Forward	0%
10 00 33 33	Forward	40%
10 00 FF 7F	Forward	100%
10 00 00 00	Forward	0%
20 00 00 00	Reverse	0%
20 00 33 33	Reverse	40%

FAULT OBJECTS

The following table describes objects for getting information on active faults and the fault history and for clearing the fault history.

Name	Index	Sub-Index	Description	Read-Write	Values Data Size
Active Fault Array	20FFh	Contains an array of Fault Record objects that represent active faults. **Note:** For more information on the Fault Array objects, see Active Fault Array and Fault History Array Objects.			
		00h	Indicates how many Fault Records the object contains and the highest available sub-index.	RO	16-bit
		01h–20h	Contains Fault Records for active faults.	RO	16-bit
Fault History Array	20FEh	Contains an array of Fault Record objects that represent the fault history.			
		00h	Indicates how many Fault Records the object contains and the highest available sub-index.	RO	16-bit
		01h–20h	Contains Fault Records for the fault history.	RO	16-bit
Clear Fault History Function	20F0h	01h	Clears the Fault History Array object. If a fault is active, the function does not remove the record for the active fault. To clear the fault history, specify 01h.	RW	16-bit

Active Fault Array and Fault History Array Objects

The Active Fault Array and Fault History Array objects store data for the 20 most recent active faults and the 32 most recent faults in the fault history. Each fault's data is contained by a Fault Record object. The Fault Records are accessed using sub-indexes of the Fault Array objects.

Note: The Fault Array objects provide more detailed information than that provided by CANopen's Error History object.

The sub-indexes of the Fault Array objects are ordered in the sequence in which the faults were first detected. Sub-index 01h represents the first detected fault, sub-index 02h represents the second fault, etc.

Fault Record Objects

Fault Record objects include data on whether a given fault is active, how many times a fault has occurred, and the times at which a fault first and most recently occurred.

Fault Record objects are identified by a 2-byte index. When a fault occurs, the index is specified by bytes 3-4 of the emergency message. For example, if an emergency message's third and fourth bytes are 1122h, the Fault Record object's index is 2211h.

Fault Record indexes are listed in Table 6.

The following table describes the Fault Record object sub-indexes. Each sub-index contains 4 bytes of data.

Note: The time values in sub-indexes 04h and 05 are scaled. To calculate the number of seconds, divide the value by 10.

Sub-Index	Description	Read-Write	Values Data Size

01h	The two least significant bits indicate whether the fault is in the fault history and is active:
	• Bit 0: Indicates whether the fault is in the fault history:
	  • 0 = Not in the history
	  • 1 = In the history
	• Bit 1: Indicates whether the fault is active:
	  • 0 = Not active
	  • 1 = Active
		RO	0–255
			32-bit

02h	*Internal use.*	*N/A*	*N/A*
03h	The number of times the fault has occurred after the fault history was last cleared.	RO	0–4294967295 32-bit
04h	The time, in seconds, of the fault's most recent occurrence after the fault history was last cleared.	RO	0–4294967295 32-bit
05h	The time, in seconds, of the fault's first occurrence since the fault history was last cleared.	RO	0–4294967295 32-bit
06h	The fault's fault type.	RO	0–4294967295 32-bit
07h	*Reserved.*	*N/A*	*N/A*
08h	*Reserved.*	*N/A*	*N/A*
09h	*Reserved.*	*N/A*	*N/A*

MISCELLANEOUS OBJECTS

The following table describes various objects provided by the controller:

<table>
<tr><th>Name</th><th>Index</th><th>Sub-Index</th><th>Description</th><th>Read-Write</th><th>Values
Data Size</th></tr>
<tr><td>Segment Inhibit Time</td><td>2002h</td><td>01h</td><td>Reserved.</td><td>N/A</td><td>N/A
N/A</td></tr>
<tr><td rowspan="4">Controller Information</td><td rowspan="4">2003h</td><td colspan="4">Provides information such as the controller's model name and serial number.</td></tr>
<tr><td>01h</td><td>Indicates the model name.</td><td>RO</td><td>String</td></tr>
<tr><td>06h</td><td>Indicates the controller’s hardware version.</td><td>RO</td><td>0–32767
32-bit</td></tr>
<tr><td>07h</td><td>Indicates the controller’s software version.</td><td>RO</td><td>0–32767
32-bit</td></tr>
</table>

7 — FAULTS, DIAGNOSTICS, AND TROUBLESHOOTING

The 1226BL controller provides diagnostic information to help technicians troubleshoot drive system problems. You can view the diagnostic information using Curtis programming devices and the controller's status LEDs.

PROGRAMMING DEVICE DIAGNOSTICS

The programming devices display diagnostic information in two menus:

- Real-time data such as the statuses of inputs and outputs are displayed in the Monitor menu. See Monitor Menu Variables.
- Active faults and a history of faults are displayed in the Diagnostics menu or Fault History menu. (The menu name depends upon the programming device).

Note: Checking and clearing the fault history is recommended each time the vehicle is brought in for maintenance.

STATUS LEDS

The 1226BL controller has red and yellow LEDs that indicate the controller's status.

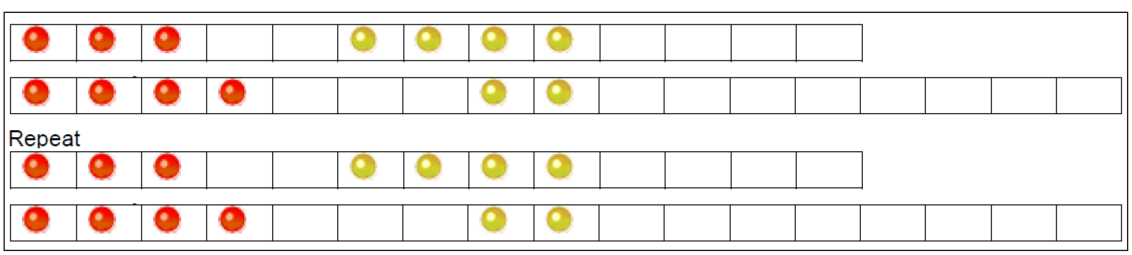
When the controller is operating correctly, the yellow light steadily flashes.

When one or more faults are active, the red and yellow lights indicate the faults in the following flash sequence:

1. The red light indicates the fault code's first digit by flashing *n* times, where *n* is the digit.
2. The yellow light indicates the fault code's second digit by flashing *n* times, where *n* is the digit.

   For example, if the fault code is 3,4, the red light flashes 3 times, then the yellow light flashes 4 times.
3. A delay occurs.
4. If more than one fault is active, the previous steps occur for each fault.
5. A delay occurs.
6. This sequence repeats as long as there are active faults.

The following example shows how the status LEDs would flash if both the 3,4 and 4,2 faults are active.



CANbus models transmit an emergency message when a fault is generated or cleared. See Emergency Messages and Faults and Fault Objects.

Note: Some faults share the same fault code. For example, the fault code 1,3 is used for the Severe Overvoltage and Overvoltage Cutback faults.

Status LEDs and Software Status

The status LEDs also indicate statuses related to the controller's software, as described in the following table:

Condition	LEDs
No software is installed.	The red light is on.
The primary processor is waiting for software to be downloaded.	The red light rapidly flashes.
Software is downloading.	The yellow light rapidly flashes.
Download is complete and the controller is waiting to be reset.	The yellow light is on.

FAULT CODES

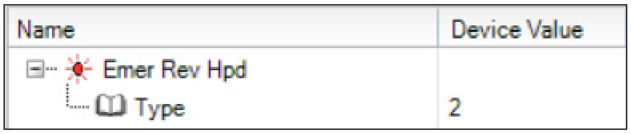
When the controller detects a fault, the controller operates in a manner that is safe in the presence of that fault. Depending on the severity of the fault, the response can range from reduction of current to complete shutdown of drive.

For example, when an EMR SRO fault occurs, the controller prevents the vehicle from unexpectedly driving in emergency reverse if the emergency reverse switch is active when the keyswitch is turned on.

Some faults have multiple causes. 1226BL CANbus models use *fault types* to distinguish these causes. All faults have a fault type of 1; faults with multiple causes have additional fault types.

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

If you are using CIT, you can view fault types in the CIT Programmer application by expanding the fault. Fault types are listed in the Device Value column. In the following example, the Emer Rev Hpd fault has a fault type of 2:



The following table describes the fault codes. The first column contains the fault codes and CAN indexes. The CAN indexes identify Fault Record objects; see Fault Record Objects. The second column contains the fault names and the actions the controller takes when faults occur.

Note: If a fault has multiple fault types, the Recovery column lists the fault types.

Table 6 Fault Codes

Fault Code CAN Index	Fault Fault Effects	Description	Recovery
1,2 0x2120	Severe Undervoltage *Current limit decreases to 0*	The capacitor bank voltage is below the Severe Undervoltage threshold. Possible causes include: • A system other than the controller is draining the battery. • The battery is disconnected. • The B+ fuse is blown. • The main contactor did not close. • The User Undervoltage parameter is incorrectly configured.	Address the possible causes.
1,2 0x2121	Undervoltage Cutback *Reduced drive current limit*	The capacitor bank voltage dropped below the Undervoltage threshold. • The batteries need recharging. • The User Undervoltage parameter is incorrectly configured. • A system other than the controller is draining the battery. • The battery is disconnected. • The B+ fuse is blown. • The main contactor did not close.	Address the possible causes.
1,3 0x2130	Severe Overvoltage *Shutdown Motor Bridge* *Shutdown Main Contactor Driver* *Shutdown EM Brake Driver* *Shutdown Throttle Command* *Shutdown Interlock Status*	The capacitor bank voltage is above the Severe Overvoltage threshold. Possible causes include: • The User Overvoltage parameter is incorrectly configured. • The battery resistance is too high for the regen current. • The battery disconnected during regen braking.	Address the possible causes.
1,3 0x2131	Overvoltage Cutback *Reduced regen current limit*	The capacitor bank voltage exceeded the Overvoltage threshold. Possible causes include: • The regen braking current elevated the battery voltage. • The User Overvoltage parameter is incorrectly configured. • The battery disconnected during regen braking.	Address the possible causes.
1,4 0x2140	Controller Overtemp Cutback *Reduced drive current limit* *Reduced regen current limit*	The heatsink temperature exceeded 75°C. Possible causes include: • The controller is operating in an extremely hot environment. • There is excessive load on the vehicle. • The controller is incorrectly mounted, which is preventing the controller from cooling.	Address the possible causes.
1,4 0x2141	Controller Severe Undertemp *Shutdown Motor Bridge* *Shutdown Main Contactor Driver* *Shutdown EM Brake Driver* *Shutdown Throttle Command* *Shutdown Interlock Status*	The heatsink temperature is below –40°C. This can occur if the controller is operating in an extremely cold environment.	Raise the heatsink temperature to above –40°C.

Quick Link:
User Overvoltage p.40
User Undervoltage p.40

Table 6 Fault Codes, cont'd

Fault Code CAN Index	Fault Fault Effects	Description	Recovery
1,4 0x2142	Controller Severe Overtemp *Shutdown Motor Bridge* *Shutdown Main Contactor Driver* *Shutdown EM Brake Driver* *Shutdown Throttle Command* *Shutdown Interlock Status*	The heatsink temperature is above 85°C. This can occur if the controller is operating in an extremely hot environment.	Decrease the heatsink temperature to below 85°C.
1,5 0x2150	Motor Temp Sensor *MaxSpeed reduced (Limited Operating Strategy)* *Motor temperature cutback disabled*	The resistance of the motor thermistor is above 10kΩ or below 100Ω. Possible causes include: • The motor thermistor is incorrectly connected. • The sensor polarity is incorrect. • The motor temperature and sensor parameters are incorrectly configured. See Motor Temperature Control Menu.	Address the possible causes, then cycle the keyswitch.
1,5 0x2151	Motor Temp Hot Cutback *Reduce drive current*	The motor temperature is at or above the Temperature Hot parameter's value. Possible causes include: • The motor temperature is at or above the temperature specified with the Temperature Hot parameter. • The Temperature Hot parameter is incorrectly configured.	Take one of the following steps: • Cool the motor until its temperature is below the Temperature Hot parameter value. • Adjust the Temperature Hot parameter.
2,1 0x2210	Throttle *Shutdown Throttle Command*	The throttle input is out of range. Possible causes include: • The throttle pot's resistance is outside the range of 0–6kΩ. • One or more of the throttle wires are open.	Make sure the throttle pot's resistance is in the range and that all wires are connected, then cycle the keyswitch.
2,1 0x2211	HPD Sequencing *Shutdown Throttle Command*	The keyswitch, interlock, direction, and throttle inputs were not cycled in the correct order after an HPD action.	Turn off the direction switches and set the throttle to less than 25% of its maximum voltage.
2,2 0x2220	Main Contactor Welded *Shutdown Motor Bridge* *Shutdown Main Contactor Driver* *Shutdown EM Brake Driver* *Shutdown Throttle Command* *Shutdown Interlock Status*	Prior to the main contactor closing, the capacitor bank voltage was loaded for a short time, but the voltage did not discharge. Possible causes include: • The main contactor tips are welded closed. • An alternate voltage path, such as an external circuit to B+, is providing current to the capacitor bank.	Address the possible causes, then cycle the keyswitch.
2,2 0x2221	Main Contactor Did Not Close *Shutdown Motor Bridge* *Shutdown Main Contactor Driver* *Shutdown EM Brake Driver* *Shutdown Throttle Command* *Shutdown Interlock Status*	The capacitor bank voltage did not charge to B+ when the controller commanded the main contactor to close. Possible causes include: • The main contactor tips are oxidized, burnt, or not making good contact. • An external load on the capacitor bank is preventing the capacitor bank from charging. • Blown B+ fuse. • The Pull In Voltage and Holding Voltage parameters are incorrectly configured. See Main Relay (Contactor) Menu. • The main contactor opened even though the controller commanded the contactor to close. • The wiring to the contactor's coil was removed. • The coil is defective.	Address the possible causes, then cycle the keyswitch.

Table 6 Fault Codes, cont'd

Fault Code CAN Index	Fault Fault Effects	Description	Recovery
2,2 0x2222	Main Driver Fault *Shutdown Motor Bridge* *Shutdown Main Contactor Driver* *Shutdown EM Brake Driver* *Shutdown Throttle Command* *Shutdown Interlock Status*	The Main Contactor driver is either open or shorted. Possible causes include: • The main driver is open or shorted. • The connector pins for the controller or contactor coil are dirty. • Bad connector crimps or faulty wiring. • The controller is defective.	Repair the wiring and connections, then cycle the keyswitch. If the controller still doesn't work, the controller is defective.
2,2 0x2223	Precharge Failed *Shutdown Motor Bridge* *Shutdown Main Contactor Driver* *Shutdown EM Brake Driver* *Shutdown Throttle Command* *Shutdown Interlock Status*	The precharge circuit failed to charge the capacitor bank. Possible causes include: • An external load on the capacitor bank prevents the capacitor bank from charging. • The controller is defective.	Address the possible causes, then cycle the keyswitch.
2,3 0x2230	Encoder *Shutdown Motor Bridge* *Shutdown Main Contactor Driver* *Shutdown EM Brake Driver* *Shutdown Throttle Command* *Shutdown Interlock Status*	The controller detected a motor encoder phase failure. An Encoder fault can be caused by connector crimps, faulty wiring, or if the encoder mounted to the motor is defective.	Check the crimps and wiring, then cycle the keyswitch.
2,3 0x2231	Stall Detected *Shutdown Motor Bridge* *Shutdown Main Contactor Driver* *Shutdown EM Brake Driver* *Shutdown Throttle Command* *Shutdown Interlock Status*	The controller did not detect motor movement.	Cycle the keyswitch.
2,4 0x2240	Motor Open *Shutdown Motor Bridge* *Shutdown Main Contactor Driver* *Shutdown EM Brake Driver* *Shutdown Throttle Command* *Shutdown Interlock Status*	The controller detected that motor phase U,V, or W is open. This can be caused by bad crimps or faulty wiring.	Make sure the motor is connected to the UVW bus bars, then cycle the keyswitch.
2,5 0x2241	Overcurrent *Shutdown Motor Bridge* *Shutdown Main Contactor Driver* *Shutdown EM Brake Driver* *Shutdown Throttle Command* *Shutdown Interlock Status*	The current detected by the controller exceeds the maximum current limit. Possible causes include a damaged controller or motor.	Check for damage, then cycle the keyswitch.
2,6 0x2832	Current Sense *Shutdown Motor Bridge* *Shutdown Main Contactor Driver* *Shutdown EM Brake Driver* *Shutdown Throttle Command* *Shutdown Interlock Status*	The zero current point is out of range for 64ms. The range is 827±32 for 41*XX* and 61*XX* models, 685±32 for 22*XX* models.	Cycle the keyswitch.

Table 6 Fault Codes, cont'd

Fault Code CAN Index	Fault Fault Effects	Description	Recovery
3,1 0x2320	EM Brake Driver Fault *Shutdown EM Brake Driver* *Shutdown Throttle Command*	The electromagnetic brake driver is either open or shorted. Possible causes include: • The connector pins for the controller coil or electromagnetic brake coil are dirty. • Bad connector crimps or faulty wiring. • The brake coil is shorted. • The controller is defective.	Repair the wiring and connections, then cycle the keyswitch.
3,1 0x2321	EM Brake Failed to Set *None*	The vehicle is moving even though the controller commanded the EM brake to engage and the number of subsequent motor revolutions has exceeded the EM Brake Fault Motor Revs parameter value. This fault can occur if there isn't enough brake torque.	Repair the EM brake, then cycle the keyswitch.
3,1 0x2330	Emer Rev Timeout *Shutdown EM Brake Driver* *Shutdown Throttle Command*	An emergency reverse operation stopped because the operation exceeded the time limit specified with the EMR Time Limit parameter.	Turn off the emergency reverse switch.
3,2 0x2331	Emer Rev HPD *Shutdown EM Brake Driver* *Shutdown Throttle Command*	The throttle, direction, and interlock inputs were not turned off after an emergency reverse operation.	If the EMR Dir Interlock parameter's value is On, clear the interlock, throttle, and direction inputs. Otherwise, clear the throttle and direction inputs. **Fault Types:** 1 = Throttle or direction switches were not turned off. 2 = Interlock switch was not turned off.
3,2 0x2332	EMR SRO *Shutdown EM Brake Driver* *Shutdown Throttle Command*	The emergency reverse switch was on when the keyswitch was powered on.	Turn off the emergency reverse switch.
3,3 0x2410	Pump Driver Fault *Shutdown Pump*	The driver for the pump contactor is either open or shorted. Possible causes include: • The connector pins for the controller or contactor coil are dirty. • Bad connector crimps or faulty wiring. • The contactor coil is shorted. • The controller is defective.	Repair the wiring and connections, then cycle the keyswitch.
3,4 0x2420	Pump SRO *Shutdown Pump*	The hydraulic lift switch was on when the keyswitch was powered on.	Turn off the hydraulic lift switch.
3,5 0x2510	Valve Driver Fault *Shutdown Valve*	The valve driver is either open or shorted. Possible causes include: • The connector pins are dirty. • Bad connector crimps or faulty wiring. • The valve coil is shorted. • The controller is defective.	Repair the wiring and connections, then cycle the keyswitch.
3,6 0x2520	Valve SRO *Shutdown Valve*	The valve switch was on when the keyswitch was powered on.	Turn off the valve switch.
4,1 0x2531	5V Supply Failure *None*	The internal +5V power supply's voltage is higher or lower than the threshold voltage.	Cycle the keyswitch. If the controller still doesn't work, the controller is defective.

Table 6 Fault Codes, cont'd

Fault Code CAN Index	Fault Fault Effects	Description	Recovery
4,1 0x2532	15V Supply Failure *None*	The internal +15V power supply's voltage is higher or lower than the threshold voltage.	Cycle the keyswitch. If the controller still doesn't work, the controller is defective.
4,1 0x2533	External Supply Out of Range *None*	The load on the external +5V or +14V supply is outside the range of the threshold voltages listed in External Power Supply. This fault can occur if the load is heavy or a high voltage wire is connected to one of the external power supplies.	Try the following, then cycle the keyswitch: • Make sure the external load is under the specified maximum current (so that the voltage is within the range of the threshold voltages). • Check the wiring.
4,2 0x2541	PDO Timeout *Shutdown Throttle Command*	The time between PDO messages exceeded the time specified by the PDO's Event Time parameter. This can occur if the interval between TPDO transmissions exceeds the Event Time of an RPDO.	Adjust the RPDO's Event Time parameter, then cycle the keyswitch. **Fault Types:** 1 = RPDO1 timeout 2 = RPDO2 timeout 3 = RPDO3 timeout 4 = RPDO4 timeout 201 = RPDO timeout for the electronic power steering controller.
4,2 0x2542	PDO Mapping Error *None*	A PDO is mapped to an invalid object or the total size of its mapped objects exceeds 8 bytes.	Adjust the mapping parameters, then cycle the keyswitch.
4,3 0x2610	HW Failsafe *Shutdown Motor Bridge* *Shutdown Main Contactor Driver* *Shutdown EM Brake Driver* *Shutdown Throttle Command* *Shutdown Interlock Status* *Shutdown Pump Driver* *Shutdown Valve Driver*	An internal controller fault occurred.	Cycle the keyswitch. If the controller still doesn't work, the controller is defective.
4,4 0x2620	SW Fault *Shutdown Motor Bridge* *Shutdown Main Contactor Driver* *Shutdown EM Brake Driver* *Shutdown Throttle Command* *Shutdown Interlock Status* *Shutdown Pump Driver* *Shutdown Valve Driver*	The controller did not power up correctly. • Defective controller. • A CAN NMT reset command is received when the motor driver is in the driving state.	Download the correct firmware, then cycle the keyswitch. If the controller still doesn't work, the controller is defective.
4,5 0x2854	Interlock SRO *Shutdown Throttle Command*	The interlock was on when the keyswitch was turned on. Note: The controller checks for this condition if the Interlock SRO Enable parameter is on.	Turn the interlock off.
4,8 0x2858	Steering Controller Handshake Fault *Shutdown Throttle Command*	The handshake with the Curtis 1220E electric steering controller failed. Possible causes include: • The Steering Controller Node ID parameter does not specify the correct node. • The baud rate is incorrect. • The 1220E controller is not powered on. • The 1220E controller is not connected to the CANbus.	Address the possible causes, then cycle the keyswitch.

Table 6 Fault Codes, cont'd

Fault Code CAN Index	Fault Fault Effects	Description	Recovery
8,1 0x2812	*Parameter Mismatch* *Shutdown Motor Bridge* *Shutdown Main Contactor Driver* *Shutdown EM Brake Driver* *Shutdown Throttle Command* *Shutdown Interlock Status*		Adjust the parameters, then cycle the keyswitch. **Fault Types:** See Table 7.
8,1 0x2813	Parameter Change *Shutdown Motor Bridge* *Shutdown Main Contactor Driver* *Shutdown EM Brake Driver* *Shutdown Throttle Command* *Shutdown Interlock Status* *Shutdown Pump Driver* *Shutdown Valve Driver*	A parameter that requires the keyswitch to be cycled was changed. **Note:** Parameters that require the keyswitch to be cycles are marked as [PCF] in the Programmable Parameters chapter.	Cycle the keyswitch.
8,3 0x2830	NV Failure *Shutdown Motor Bridge* *Shutdown Main Contactor Driver* *Shutdown EM Brake Driver* *Shutdown Throttle Command* *Shutdown Interlock Status* *Shutdown Pump Driver* *Shutdown Valve Driver*	The controller's operating system was not able to read or write to EEPROM memory.	Set the Parameter Interlock parameter to any value except 1, clear the fault history, then cycle the keyswitch
8,4 0x2840	Supervision *Shutdown Motor Bridge* *Shutdown Main Contactor Driver* *Shutdown EM Brake Driver* *Shutdown Throttle Command* *Shutdown Interlock Status*	Possible causes include: • The controller's Supervisor module is damaged. • The Supervisor module detects discrepancies in data read by the primary and secondary microprocessors. • The voltage of the inputs does not match the required voltage.	Check the voltage of the inputs, then cycle the keyswitch. **Fault Types:** See Table 8.

Table 7 Parameter Mismatch Fault Types

Fault Type	Description
1	The External Status LED Enable parameter is on but the Type parameter on the Digital/Analog Input 1 or Digital/Analog Input 2 menu is set to 1 (Lower Valve Input).
2	The EMR Input Type parameter indicates an NC switch is being used, but the Analog/Digital 2 menu's Type parameter has a non-zero value.
51	The forward angle or forward negative angle parameters on the Speed Limitation menu conflict. The angles must meet the following requirements: • Forward Deadband < Forward Min Angle < Forward Middle Angle < Forward Max Angle • Forward Negative Deadband > Forward Negative Min Angle > Forward Negative Middle Angle > Forward Negative Max Angle
52	The reverse angle parameters on the Speed Limitation menu conflict. The angles must meet the following requirements: • Reverse Deadband < Reverse Min Angle < Reverse Middle Angle < Reverse Max Angle • Reverse Negative Deadband > Reverse Negative Min Angle > Reverse Negative Middle Angle > Reverse Negative Max Angle

Table 8 Supervision Fault Types

Fault Type	Description
400	Interlock switch mismatch.
401	Forward switch mismatch.
402	Reverse switch mismatch
403	Mode switch mismatch.
404	Lift switch mismatch.
405	EMR NC mismatch.
406	EMR NO mismatch.
407	Analog 1 input mismatch.
408	Analog 2 input mismatch.

Note: For serial port models, the Supervision Error variable displays the fault type.

8 — INITIAL SETUP

To configure the 1226BL controller so that it is compatible with your vehicle's characteristics and requirements, perform the following procedures:

Step 1. Characterize the Hall Sensors and UVW Output

Step 2. Prepare the Vehicle

Step 3. Configure the Throttle

Step 4. Verify the Vehicle's Configuration

Step 1 Characterize the Hall Sensors and UVW Output

The Hall sensors provide the controller with the position of the motor rotor. The controller uses the Hall sensor status to output current to the correct motor phases.

The following procedure shows how to match the Hall sensor signals to the controller's UVW output steps. The procedure determines the correct way to wire the motor's high current connections to the UVW bus bar and the correct value for the Swap Speed Direction parameter.

1. Set the following parameters on the Current Limits menu to 20%:
   - Drive Current Limit
   - Regen Current Limit
2. Set **all** of the parameters on the following menus to 100%:
   - Drive Limiting Map menu
   - Regen Limiting Map menu
3. Connect the Hall sensors to the Hall A, B, and C pins (pins J1-2, J1-3, and J1-4) as shown in Figure 6. The sequence in which you connect the wires doesn't matter.
4. Connect the motor's high current connections to the UVW bus bar, starting with the first phase wiring sequence listed in the following table:

Phase Wiring	Swap Speed Direction	Armature Current	Motor Behavior Notes
UVW to UVW	Off		
	On		
UWV to UVW	Off		
	On		
VUW to UVW	Off		
	On		
VWU to UVW	Off		
	On		
WUV to UVW	Off		
	On		
WVU to UVW	Off		
	On		

Note: You can use this table to record your observations until you determine the correct high current wiring sequence and Swap Speed Direction parameter.

5. Set the Swap Speed Direction parameter to Off.
6. Cycle the keyswitch.
7. Turn on the interlock.
8. Slowly apply the throttle and observe the motor and the Armature Current variable.

   If the motor runs smoothly and the current is lower than 5A without a load, the configuration is correct. Skip ahead to step 12.
9. Set the Swap Speed Direction parameter to On.
10. Slowly apply the throttle and observe the motor and the Armature Current variable.

If the motor runs smoothly and the current is lower than 5A without a load, the configuration is correct. Skip ahead to step 12.

11. If the motor is not running smoothly and with a low current, try the other combinations of UVW wiring and the Swap Speed Direction parameter. There are six possible combinations of UVW wiring. Repeat steps 4–10 until you find the correct combination.
12. Restore the parameters you changed in steps 1 and 2.

Note: For instructions on troubleshooting the sensors, see Troubleshooting Hall Sensors.

Step 2 Prepare the Vehicle

Perform the following steps before programming the controller.

⚠ WARNING **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 and Wiring.
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.
8. Connect the programming device to the controller.

Note: If you are using the handheld programmer, it should power up with an initial display, and the status LED should light steadily. If neither happens, check for continuity in the keyswitch circuit and controller ground.

Step 3 Configure the Throttle

It is important to configure the throttle so that it operates over the throttle's full range. To do so, you specify the throttle type, then tune the deadband and the wiper voltage until the throttle performs satisfactorily.

Note: 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.

To configure the throttle, perform the following steps.

1. Select Program » Throttle to access the throttle-related parameters. See Throttle Menu.
2. Set the Throttle Type parameter to match the vehicle's throttle type.
3. Tune the deadband by performing the steps in Configure the Deadband.
4. Configure the wiper voltage required to produce 100% controller output by performing the steps in Configure the Wiper Voltage.
5. Verify that the throttle is correctly configured. See Confirm Throttle Operation.

Configure 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.

Configure the Wiper Voltage

The wiper voltage parameters should be set so that the controller produces 100% controller output. To configure the wiper voltage, take the following steps.

1. In the Monitor menu, select Monitor » Inputs.
2. Apply full throttle and observe the Throttle Command value. This value should be 100% at full throttle. If the Throttle Command value is less than 100%, perform the following steps:
   a. Select Program » Throttle.
   b. Decrease the Forward Max value.
   c. Apply full throttle and observe the Throttle Command value.
   d. If the value is less than 100%, repeat these steps until the value is 100%.
3. Slowly reduce the throttle until the Throttle Command 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.

   a. Select Program » Throttle.
   b. Increase the Forward Max value.
   c. Return to the Monitor menu and repeat this step until an appropriate amount of extra range is attained.

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.

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; see Throttle Menu.

Step 4 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 Pot Percent variable 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.

9 — TUNING VEHICLE PERFORMANCE

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

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

To adjust vehicle performance, perform the following procedures in the following order:

Step 1. Set the Maximum and Minimum Speeds

Step 2. Set the Acceleration and Deceleration Rates

Note: 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 1226BL controller's acceleration and deceleration features provide smooth throttle response when maneuvering at low speeds, and snappy throttle response when traveling at high speeds.

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

Note: For more information, see Low and High Speed Acceleration Rates.

1. Select Program » Speed Mode » Fine Tuning.
2. Set the LS (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 HS (High Speed) parameter to the percentage of motor speed at or above which the controller should apply the high speed acceleration rate.
4. Select Program » Speed Mode, then perform the flowing steps for each speed mode.
   a. Select Mode 1 or Mode 2.
   b. 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.
   c. Drive the vehicle at a low speed, then apply full throttle. Adjust the parameter until you are satisfied with the vehicle's low speed acceleration.

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

d. 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.

e. Drive the vehicle at a low speed, then release the throttle to neutral. Adjust the parameter until you are satisfied with the vehicle's low speed deceleration.

f. 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.

g. Drive the vehicle at a high speed, then apply full throttle. Adjust the parameter until you are satisfied with the vehicle's high speed acceleration.

h. 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.

i. Drive the vehicle at a high speed, then release the throttle to neutral. Adjust the parameter until you are satisfied with the vehicle's high speed deceleration.

If you need to further tune the acceleration and deceleration, you can do the following:

- 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.
- 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 — CALIBRATING THE BATTERY DISCHARGE INDICATOR (BDI) OUTPUT

If your vehicle system includes a Battery Discharge Indicator (BDI) gauge, you must calibrate the controller for the battery's size, the charger's type and size, and the expected driving conditions.

To configure the BDI for your vehicle, perform the following procedures:

Step 1. Set 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 Discharge Time

Step 7. Set Charge Time and Start Charge Voltage

Step 8. Test and Tune

Note: For more information on the parameters you'll use, see Battery Menu.

Step 1 Set Parameters to Initial Values

To start, take the following steps to set parameters to initial values:

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

Parameter	Value
Reset Volts Per Cell	2.09V
Full Volts Per Cell	2.04V
Empty Volts Per Cell	1.73V
Discharge Time	600 minutes
Full Charge Voltage	2.35V
Start Charge Voltage	2.10V
Charge Time	300 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. Select a medium speed mode and drive the vehicle on a level surface for 10–15 minutes.
2. Select Monitor » Battery.
3. Note the voltage displayed in the Keyswitch Voltage variable.
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 Discharge Time

Set the 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 Discharge Time parameter. Use the following formula to calculate the new Discharge Time value:

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

Step 7 Set Charge Time and Start Charge Voltage

How you set the Charge Time and Start Charge Voltage parameters depends upon whether the vehicle's BDI gauge 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 1226BL controller can be configured to allow the operator to stop charging in mid-cycle and then view a partial charge reading.

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

- To require full charging:
  1. Set Charge Time to 600 minutes.
  2. Set Start Charge Voltage equal to the Full Charge Voltage parameter's value.
- To allow partial charging:
  1. Set 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 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 BDI as described in this chapter, you'll have a good initial BDI configuration. However, for optimal BDI accuracy you should 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 procedures in this chapter.

11 — TROUBLESHOOTING HALL SENSORS

The controller relies on Hall sensors to provide the position of the motor rotor. If any of the sensors are damaged or inaccurately mounted, the controller cannot drive the motor correctly. To determine whether the Hall sensors are working correctly, take the following steps:

1. Make sure the wires between the motor, controller, and battery are connected.
2. Set the Interlock Type parameter to 0.
3. Cycle the keyswitch.
4. Make sure the main relay or main contactor is not activated.
5. Rotate the motor slowly with a tool such as a wrench while observing the Hall Sensor State variable. The status values should occur in one of the following sequences:
    - 3 5 4 1 2 6
    - 6 2 1 4 5 3

If the status numbers do not occur in either sequence, there are a few possible causes:

- One or more sensors are damaged.
- Unsupported sensors are being used, such as 60° Hall sensors.
- Power is not being supplied to the Hall sensors.

This procedure does not determine whether the sensors are mounted in the correct position. Inaccurate positioning can cause noise and inefficient driving. If the vehicle is experiencing these conditions, the sensors may need to be repositioned.

12 — MAINTENANCE

There are no user serviceable parts in the Curtis 1226BL controller. Do not attempt to open, repair, or otherwise modify the controller. Doing so may damage the controller and will void the warranty. However, it is recommended that the controller's fault history file 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 file. The programming device will read out all the faults that have occurred since the history file 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 history file is recommended. This allows the controller to accumulate a new file of faults. By checking the new history file at a later date, you can readily determine whether the problem was indeed completely 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, CURTIS 1226BL CONTROLLER

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 EN13849. EN13849 supersedes the EN954 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 (MTTFd), 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 EN13849-1 provide guidelines that must be followed in order to achieve compliance. Some industries have developed further standards (called type-C standards) that refer to EN13849 and specifically outline the path to regulatory compliance. EN1175-1 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 1226BL controllers comply with these directives using advanced active supervisory techniques.

To mitigate the hazards typically found in machine operations, EN13849 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. Three safety functions are defined for the Curtis 1226BL controller:

1. Crushing by unintended or uncontrolled movement.
2. Crushing through loss of STO/braking.
3. Loss of stability from excessive speed.

Curtis has analyzed each safety function and calculated its Mean Time To Dangerous Failure (MTTFd) and Diagnostic Coverage (DC), and designed them against Common Cause Faults (CCF). The safety-related performance of the Curtis 1226BL is summarized in the following table:

Table 9 Safety-Related Performance

Safety Function	Designated Architecture	MTTFd	Diagnostic Coverage	CCF	Performance Level
Uncommanded Powered Movement	Category 2	> 40 years	> 90%	Pass	D
Motor Braking Torque	Category 2	> 16 years	> 90%	Pass	C

EN1175 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 (MTTFd) 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.

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. EN13849 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 EN13849 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 controllers. Three programming devices are available:

- 1314 PC Programming Station for serial models
- 1313 handheld programmer
- Curtis Integrated Toolkit™ (CIT) for CANbus models

All programming devices include the following features:

- Parameter adjustment: provides access to the programmable parameters.
- Monitoring: presents real-time values during vehicle operation; these include all inputs and outputs.
- Diagnostics and troubleshooting: presents diagnostic information, and also a means to clear the fault history file.
- Programming: allows you to save/restore custom parameter settings files and also to update the system software.

The PC Programming Station and Curtis Integrated Toolkit™ both have the advantage of a large, easy-to-read screen. On the other hand, the 1313 handheld programmer is more portable, making it convenient for adjusting in the field.

The programmers are available in User, Service, Dealer, and OEM versions. Each programmer can perform the actions available at its own level and the levels below that—a User-access programmer can operate at only the User level, whereas an OEM programmer has full access.

PC PROGRAMMING STATION (1314)

The Programming Station is an MS-Windows 32-bit application that runs on a standard Windows PC.

HANDHELD PROGRAMMER (1313)

The 1313 handheld programmer is functionally equivalent to the PC Programming Station.

CURTIS INTEGRATED TOOLKIT™ (CIT)

Curtis Integrated Toolkit™ (CIT) is a Microsoft Windows application that programs CANbus models. In addition to the features it shares with other Curtis programming devices, CIT allows you to perform the following tasks:

- Package and flash firmware.
- Edit menus.
- Perform oscilloscope-style traces of a controller's operations.

APPENDIX D — SPECIFICATIONS

Voltage Ranges	see table below

Model	Nominal Voltage	Brownout Voltage	Minimum Voltage	Maximum Voltage	Severe Over-voltage
1226BL-22*XX*	24V	12V	14V	30V	34V
1226BL-41*XX*	36V/48V	20V	25.2V	60V	63V
1226BL-61*XX*	72V	30V	50.4V	95V	105V

PWM operating frequency	14.7 kHz
Electrical isolation to heatsink	Depends upon the model: • 500 VAC (minimum) for models 1226BL-22*XX* and 1226BL-41*XX* • 1200 VAC (minimum) for model 1226BL-61*XX*
Weight	0.7 kg
Dimensions (W × L × H)	95 × 150 × 54 mm
Mounting	2x ø5.5 mm
I/O connections	4 pin, 6 pin, 18 pin Molex Mini Fit
Power connections	5x M5x0.8
Storage ambient temperature range	−40 – +85°C
Operating ambient temperature range	−40 – +50°C
Package environmental rating	Electronics sealed to IP54 per IEC 60529
EMC	Designed to the requirements of EN12895:2015
Safety	Designed to the requirements of EN1175-1:1998+A1:2010 and EN (ISO) 13849-1
UL	Recognized Component as per UL 583
Communications	Serial port or CANbus

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

Table 10 Model Chart

Model Number	Part Number	Nominal Battery Voltage	Current Rating (S2-1 minute)[1]	Current Rating (S2-60 minutes)[2]	Boost Current 10 seconds	CANbus or Serial Port	Internal Main Relay
1226BL-2201	17751700	24V	130A	50A	150A	Serial port	Yes
1226BL-2251	17751703					CANbus	Yes
1226BL-4101	17751701	36/48V	90A	35A	120A	Serial port	Yes
1226BL-4151	17751704					CANbus	Yes
1226BL-6151	17751702	72V	70A	30A	80A	CANbus	No

[1] *1 minute current ratings are based on operating the controller on a non-thermally conductive bench, starting at an ambient temperature of 25°C with no airflow. The controller must operate for at least 1 minute before reaching thermal cutback at 75°C.*

[2] *The S2-60 current ratings are based on mounting the controller on a 1/8 m² 8 mm thick aluminum plate with 6 km/hour airflow perpendicular to the back side of the plate. The controller starts from an ambient temperature of 25°C for 1 hour.*