CURTIS

Manual

Model **1226**

Brushed Permanent Magnet Controller

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

⚠ Read Instructions Carefully!

53229, RevC 6/21

TABLE OF CONTENTS

CHAPTERS

TABLE OF CONTENTS cont'd

TABLE OF CONTENTS cont'd

TABLE OF CONTENTS cont'd

The Curtis Difference

You feel it when you drive it

TABLE OF CONTENTS cont'd

FIGURES

TABLE OF CONTENTS cont'd

TABLES

TABLE OF CONTENTS cont'd

1 — OVERVIEW

The Curtis Model 1226 motor speed controller provides efficient, optimal control of permanent magnet drive motors for battery powered vehicles. The 1226 controller is optimized for use on light duty Class III pallet trucks and sweeper scrubber floorcare machines. Highly flexible programmability allows the controller to be used on any low power permanent magnet motor application.

Figure 1
Curtis 1226 Controller

Like all Curtis motor controllers, the 1226 offers superior operator control of the vehicle's motor drive speed.

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

Easy Installation and Set-up

- Easily programmed with the Model 1313 handheld programmer or 1314 PC programming station, or can be supplied pre-programmed.
- Compatible with industrial tiller handle wigwag throttles such as the Curtis Model ET-190E.
- Simplified troubleshooting and diagnostics.
- Industry standard Molex Mini-fit Jr. logic connectors and heavier duty M5 threaded busbars for battery and motor wiring.

Smooth and Secure Control

- Advanced speed regulation maintains precise speed over varied terrain, obstacles, curbs and ramps.
- Linear cutback of current ensures smooth control with no sudden loss of power during undervoltage or overtemperature.
- Proprietary algorithms help prevent gearbox wear while providing smooth starts and reversals.
- The vehicle is brought to a complete halt before the electromagnetic brake is applied, ensuring safe and secure stopping under all conditions.
- Charger inhibit input prevents driving while the charger is connected.
- Emergency Stop Decel function ensures a smooth "brake to stop" when the key is turned off or a fault that requires the vehicle to stop occurs.
- Emergency reverse with belly button switch input.
- Anti-roll back/roll-forward function provides smooth and safe vehicle control on hills and ramps.
- Temporary "Boost Current" feature provides greatly improved performance with transient loads such as starting on a hill, crossing thresholds, climbing obstacles, etc.
- Hydraulic Lift Lockout functionality to protect the vehicle's batteries from damaging level of discharge.
- Dynamic pot fault detection (open/short wiring fault detection).
- Push input and a Push-too-Fast function which 'loads' the motor to prevent excessive motor speeds when the EM brake is off.

Highly Flexible I/O

All I/O pins are multi-function and can be configured to provide up to:

- 13 digital inputs
- 6 analog inputs
- 1 potentiometer source
- 1 speed limit input
- 2 active low 2A drivers
- 1 active high or low 2A driver

- Programmable momentary switching options
- +5V and +14V external power (120mA)

Valuable Additional Features

- Automatically compensates for changes in motor condition to ensure optimum drive performance at all times.
- Multi-mode provides for two distinct and programmable control modes (indoor/outdoor modes).
- Power Saver function prevents the controller from draining the battery when the vehicle is inactive.
- Battery Discharge Indicator output.
- Single channel speed sensor input for limiting the maximum speed.
- Adjustable brake hold voltage reduces heating of the Brake Coil.
- Output driver for connecting an external status LED.
- Horn driver output.
- Integrated LED status indicator.
- Brake light driver output option.
- Speed limit pot input.

Meets or Complies with Relevant US and International Regulations

- EMC: Designed to the requirements of EN 12895:2015+A1:2019.
- Safety: Designed to the requirements of EN1175-1:1998+A1:2010, EN ISO 13849-1:2015.
- UL 583.
- Electronics sealed to IP54 per IEC 60529.

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

GETTING THE MOST OUT OF YOUR CONTROLLER

Read and apply the information in this manual. While you need to be familiar with the entire manual, the following chapters are particularly critical to the proper operation of the 1226 controller:

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

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

2 — INSTALLATION AND WIRING

This chapter explains how to mount and wire the controller.

MOUNTING THE CONTROLLER

The 1226 controller can be oriented in any position, but the location should be carefully chosen to 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 outline and mounting hole dimensions are shown in Figure 2. The controller should be mounted by means of the two mounting holes at the opposing corners of the heatsink, using M5 screws.

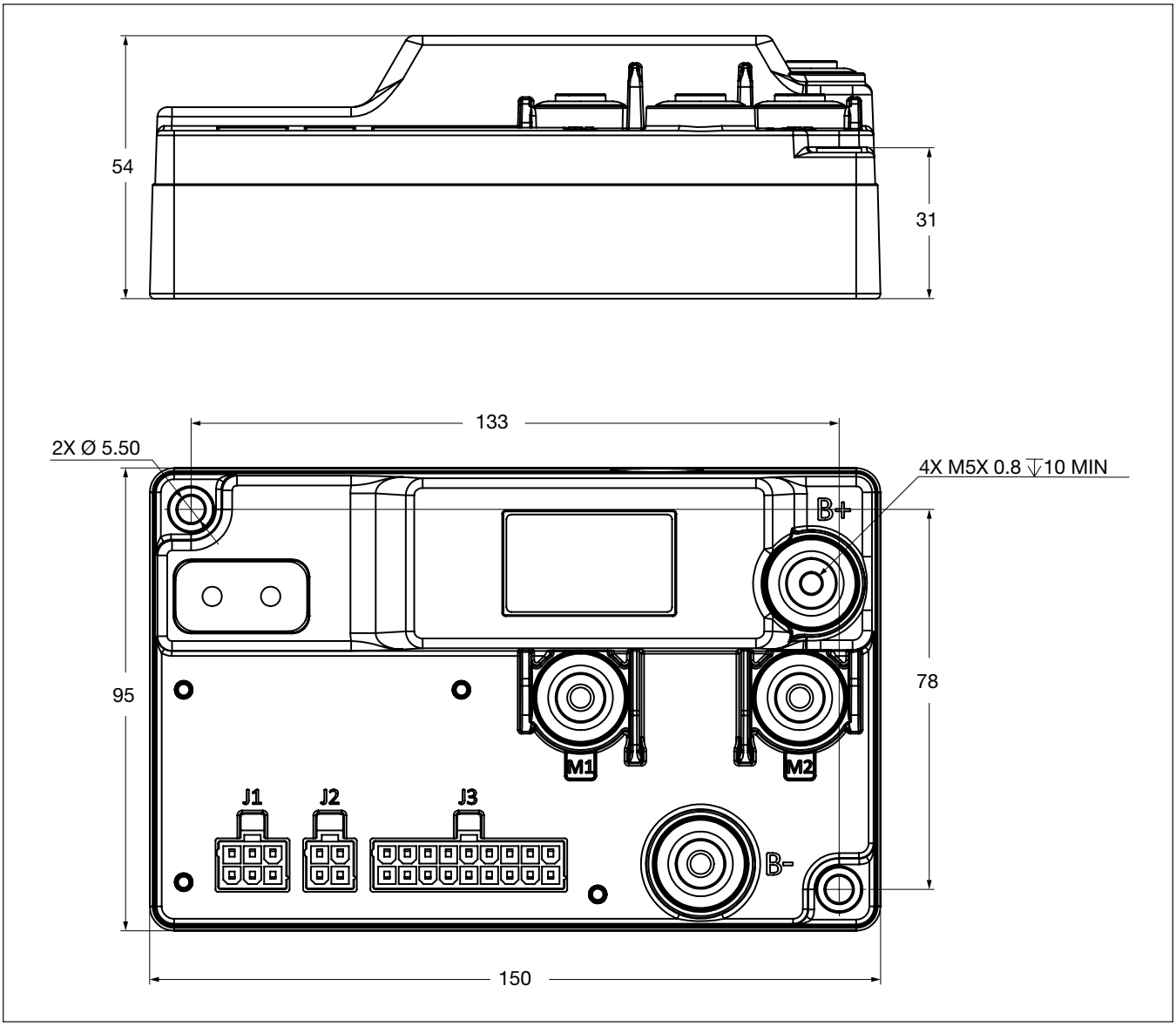


Figure 2

Mounting Dimensions, Curtis 1226 Controller

⚠ CAUTION

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. See installation suggestions in Appendix A for protecting the controller from ESD damage.

HIGH CURRENT CONNECTIONS

Four M5 bolt-on terminals are provided for the high current connections. Table 1 describes the terminals.

Table 1 High Current Terminals

Connector	Description
B+	Positive battery input
B–	Negative battery input
M1	Motor phase M1
M2	Motor phase M2

Note: Positive current flows from phase M1 to phase M2, and negative current flows from phase M2 to phase M1.

LOW CURRENT CONNECTIONS

The low current connections are provided by 3 connectors, which are listed in Table 2.

Table 2 Low Current Connectors

Connector	Description
J1	Motor connector
J2	Communication port
J3	Logic connector

The connectors' current ratings are 8A per pin.

The following topics describe the low current connectors.

Motor Connector (J1)

The 6-pin motor connector (J1) handles all low power connections to the motor. Use a Molex #39-28-8060, mating connector: Molex #39-01-2065 with appropriate 45750 series crimp terminals.

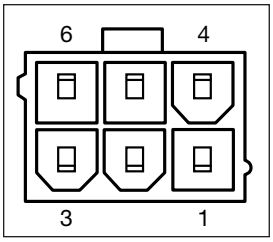


Figure 3
Motor Connector Pins (J1)

Table 3 describes the connector's pins and their typically used functions. The table also shows the switch number or analog input number, if any, that is associated with each pin.

Table 3 J1 Connector

Pin Number	Function	Switch Input	Analog Input
J1-1	External +5V power supply		
J1-2	Speed sensor input	6	6
J1-3	Generic driver 1		
J1-4	Brake+		
J1-5	I/O ground		
J1-6	Motor temperature sensor input	5	5

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 4-pin communication connector handles serial communications and the external +14V power supply. Use a Molex #39-28-8040, mating connector: Molex #39-01-2045 with appropriate 45750 series crimp terminals.

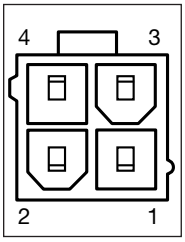


Figure 4

Communication Connector Pins (J2)

Table 4 describes the connector's pins.

Table 4 J2 Connector

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

Logic Connector (J3)

The 18-pin logic connector is used for inputs, outputs, and low power drivers. Use a Molex #39-28-8180, mating connector: Molex #39-01-2185 with appropriate 45750 series crimp terminals.

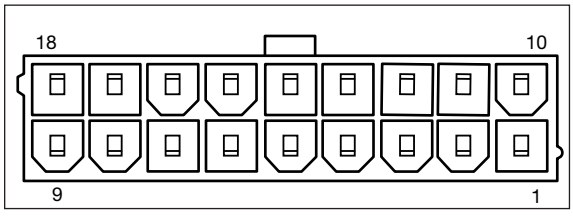


Figure 5

Logic Connector Pins (J3)

Table 5 describes the logic connector's pins and their typically used functions. The table also shows the switch number or analog input number, if any, that is associated with each pin.

Note: Pins J3-4, J3-8, and J3-18 each integrate an LED driver that shows the function's status when the input is set as a momentary switch. These pins can also be used for an external LED driver that shows the controller's status and fault codes.

Table 5 J3 Connector

Pin Number	Typical Function	Switch Input	Analog Input	LED Driver
J3-1	Keyswitch input			
J3-2	Horn driver			
J3-3	Interlock input	7		
J3-4	Emergency reverse NC input	3	3	3
J3-5	BDI output (low active)			
J3-6	Speed limit pot input	2	2	
J3-7	Throttle pot wiper	1	1	
J3-8	Reverse input	8		2
J3-9	Push input	9		
J3-10	Coil return			
J3-11	Generic driver 3			
J3-12	Generic driver 2			
J3-13	I/O ground			
J3-14	Emergency reverse NO input	10		
J3-15	Charger inhibit	11		
J3-16	Throttle pot high	4	4	
J3-17	Forward input	12		
J3-18	Mode input	13		1

Pin Protection

Table 6 describes the specifications for pin protection.

Table 6 Pin Protection Specifications

Specification	Pins	Model	Value	Referenced Pins
Maximum Forward Voltage	All pins other than the I/O Ground pins and the serial communication pins (J2-1 and J2-3). **Note:** Pins J2-1 and J2-3 can be protected when shorted to the +14V external power supply (pin J2-4)	1226-2201	+36 VDC	Referenced to the I/O Ground pins (J1-5, J2-2, and J3-13)
		1226-3101	+54 VDC	
		1226-5201	+72 VDC	
Maximum Reverse Voltage	J3-1	1226-2201	–36 VDC	Referenced to the I/O Ground pins (J1-5, J2-2, and J3-13)
		1226-3101	–54 VDC	
		1226-5201	–72 VDC	
	J1-1, J1-3, J1-4, J1-6, J2-1, J2-3, J2-4, J3-2, J3-5, J3-10, J3-11, J3-12	All models	–0.5 VDC	Referenced to the I/O Ground pins (J1-5, J2-2, and J3-13)
	All other pins	All models	–10 VDC	Referenced to the I/O Ground pins (J1-5, J2-2, and J3-13)
Short to B+	All pins other than the I/O Ground pins and the serial communication pins (J2-1 and J2-3). **Note:** Pins J2-1 and J2-3 can be protected when shorted to the +14V external power supply (pin J2-4)	All models	Protected	
Short to B–	All pins other than the Coil Return pin (J3-10)	All models	Protected	
ESD	All pins	All models	• Contact: ±8 kV • Air: ±15 kV	

I/O Ground Specifications

Table 7 describes the considerations for the I/O ground pins (J1-5, J2-2, and J3-13).

Table 7 I/O Ground Specifications

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 the Curtis 1226 models. The diagram is for a Class III vehicle that has the operator controls directly wired to the controller.

Note: The wiring diagram is designed for typical Class III vehicles and may not fully meet your application's requirements. However, the 1226 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.

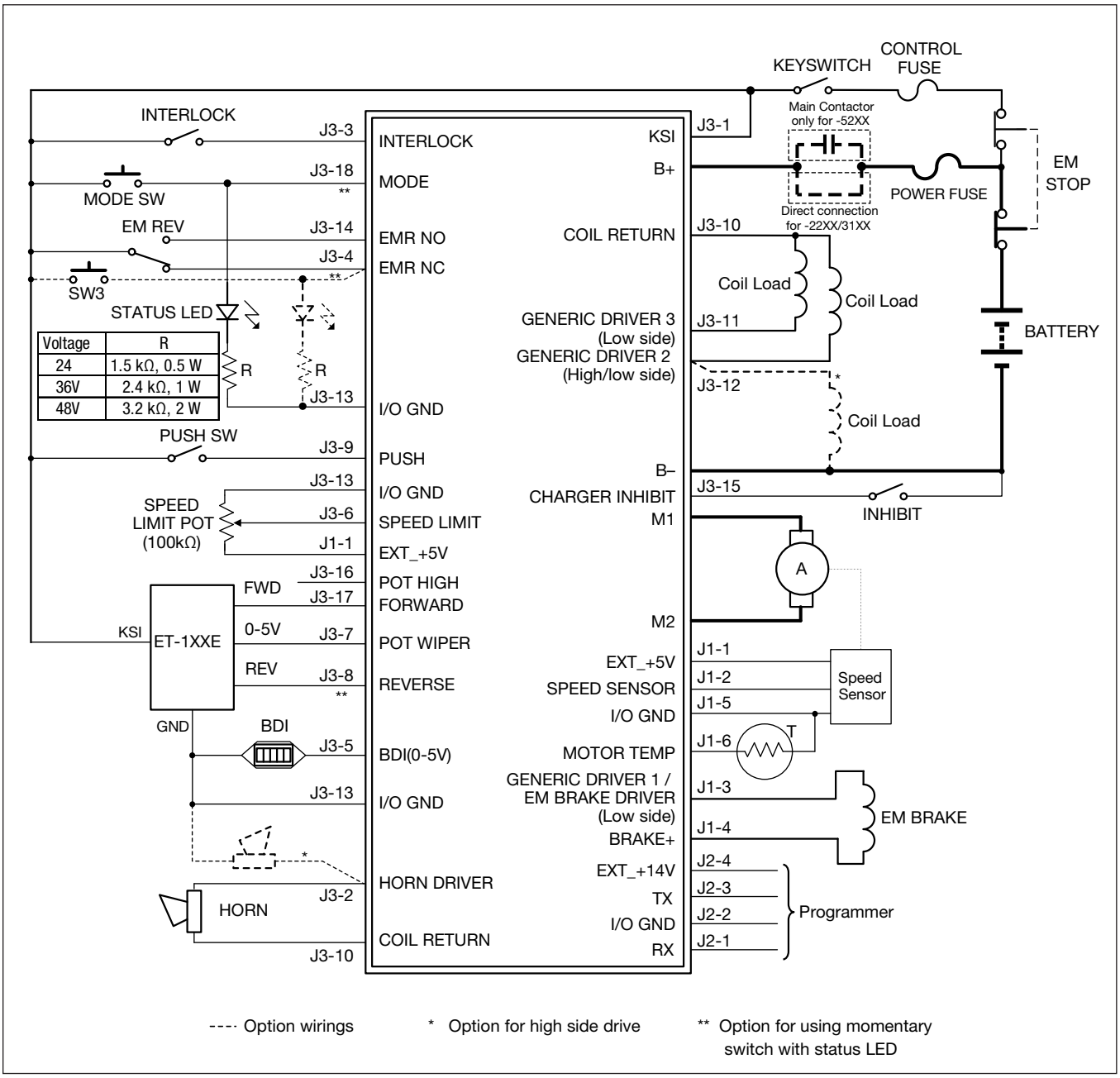


Figure 6

Wiring Diagram, Curtis 1226 Controllers

INPUTS AND OUTPUTS (I/Os)

Unlike many controllers that have preconfigured I/Os and fixed functions, the 1226 controller has flexible I/Os that can be used with any low power permanent magnet motor application.

The controller provides a set of predefined functions that are typically assigned to the I/Os. When your application requires one of these functions, you'll use a parameter to assign the function to its I/O. The parameter used depends upon whether the I/O is for a digital input, analog input, or output.

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

Analog Inputs

The controller provides 6 analog inputs that can be used for a variety of purposes. The inputs are designed for different primary functions and thus have different voltage ranges.

The analog inputs' signals are normalized to a signal scaled from 0 to 32767, which represent a range of 0-100%. You can observe an input's normalized value with the Analog n Percent field; see Analog Inputs Menu.

All digital inputs other than Digital 6 can be configured as analog inputs. In other words, you can configure a digital input so that the controller processes the input's signals as normalized analog signals instead of on/off switch states. The input's Enable property specifies how the input signal is processed.

The controller provides predefined functions for using the throttle and speed limit pot as analog inputs. Use the Controls menu to assign these functions to inputs.

Table 8 describes the specifications for analog inputs.

Table 8 Analog Input Specifications

Analog Input	Pin Number	Typical Function	Measurement Range	Input Impedance
Analog 1	J3-7	Throttle pot wiper input	0V – 9V	> 5kΩ
Analog 2	J3-6	Speed limit pot input	0V–10V for 1226-2201 0V–17V for 1226-3101/-5201	> 5kΩ
Analog 3	J3-4	Emergency reverse NC input	0V–10V for 1226-2201 0V–15V for 1226-3101/-5201	> 5kΩ
Analog 4	J3-16	Throttle pot high input	0V – 9V	> 5kΩ
Analog 5	J1-6	Motor temperature sensor input	0V – 3V	> 5kΩ
Analog 6	J1-2	Speed sensor input	0V – 3V	> 5kΩ

You can use the Analog 1-6 inputs for functions other than their typically used functions.

Note: The Analog 5 and Analog 6 inputs should not be used as voltage inputs because of the pull up load on their pins. However, Analog 5 and Analog 6 can be used as resistance analog inputs. For more information, contact your Curtis distributor or support engineer.

The following considerations apply to the voltage range specifications:

- To provide a sufficient response rate while also allowing for effective filtering, the controller reads the inputs' signals at least every 1ms.
- When an analog input's voltage is outside its voltage range, the controller generates an Analog Out of Range fault.
- An analog input's voltage range can be configured with the analog input's Low and High parameters.
- If you set an input's High parameter above the input's voltage range, the controller will not check whether the input's actual voltage exceeds the specified voltage.

Switch Inputs

The controller provides 13 digital switches. You use the Switch Assignment menu to assign functions to switches.

You can observe a digital input's state with the Switch *n* field; see Switches Menu.

Switches 3, 8, and 13 each provide an integrated LED driver that outputs the switch's status.

Table 9 describes the switch inputs.

Table 9 Switch Inputs

Switch Input	Pin Number	Analog Input	Typical Function	Switch Type
1	J3-7	1	Throttle pot wiper	High active
2	J3-6	2	Speed limit pot input	High active
3	J3-4	3	Emergency reverse NC input	• High active • LED driver 3
4	J3-16	4	Throttle pot high	High active
5	J1-6	5	Motor temperature sensor input	Low active
6	J1-2	6	Speed sensor input	Low active
7	J3-3		Interlock input	High active
8	J3-8		Reverse input	• High active • LED driver 2
9	J3-9		Push input	High active
10	J3-14		Emergency reverse NO input	High active
11	J3-15		Charger inhibit	• Charger inhibit • Low active
12	J3-17		Forward input	High active
13	J3-18		Mode input	• High active • LED driver 1

You can assign the switch inputs to functions other than their typically used functions. Use the Switch Assignment menu to assign switches.

Table 10 describes the specifications for switch inputs. Some values are model-dependent.

Table 10 Switch Input Specifications

Specification	Value
Low to High Threshold	Depends upon the model: • 1226-2201: 8.1V (8.7V for Switch 3) • 1226-3101 and 1226-5201: 13.9V (15.0V for Switch 3)
High to Low Threshold	Depends upon the model: • 1226-2201: 2.2V (2.3V for Switch 3) • 1226-3101 and 1226-5201: 3.7V (4.0V for Switch 3)
Open Pin Response	• Switches 5, 6, and 11: High or off • Other switches: Low or off
Maximum Voltage	150% of nominal battery voltage
Maximum Reverse Voltage	–10V (Except for Switch 5, which is –0.5V)

Switches with Integrated LED Drivers

Switches 3, 8, and 13 provide integrated LEDs that output the switch's status. If the switch state is on, the driver supplies power to light the external LED.

To enable a switch's integrated LED driver, you must use the Misc menu's parameters to configure the switch as a momentary switch.

The LED drivers are high side, and each external LED should be connected to the driver port with a resistor in series. The resistance depends upon the controller's nominal voltage. Table 11 shows the specifications for recommended resistors.

Table 11 External LED Resistor Specifications

Nominal Voltage	Resistance	Power Rating
24V	1.5kΩ	0.5W
36V	2.4kΩ	1W
48V	3.2kΩ	2W

The following specifications apply to the switches with integrated LED drivers:

- Drive current for each channel is 15mA.
- When the controller detects a short circuit, driver output will be disabled within 20ms.

Driver Outputs

The 1226 controller supports output through 3 generic drivers. Drivers 1 and 3 are low side drivers that provide PWM. Driver 2 can be configured as either a low side driver with PWM or a high side driver without PWM. The following table describes the PWM modes you can assign to the drivers (excepting Driver 2 when it is high side):

Table 12 Driver 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. This mode maintains a near-constant average voltage at the pin.

Use the Driver *n* Compensation parameter to define a driver's PWM mode. See page 51.

The following list describes considerations for the drivers:

- Driver 1 is a special purpose driver that provides a 2A current for electromagnetic braking.
- Driver 1 can also be assigned to the other supported functions only when the main contactor is engaged.
- Drivers 2 and 3 can be assigned to any of the supported output functions.
- You use the Coil Drivers menu to assign functions to the generic drivers; see page 50.
- The Brake+ pin (J1-4) supplies power to Driver 1.
- The Coil Return pin (J3-10) supplies power to Drivers 2 and 3 and provides reverse polarity protection.
- The Coil Return and Brake+ pins have a maximum current of 8A (maximum pin rating).
- You can use the Driver *n* Compensate parameter to configure the drivers to compensate for differences between the nominal and actual voltages.
- The drivers provide diagnostic faults for open and shorted coils.
- You can use the Outputs menu to monitor the outputs' values; see page 58.

Note: For electromagnetic brake considerations, see page 21.

Table 13 describes the generic driver specifications.

Table 13 Generic Driver Specifications

Specification	Value
Active level	The active level depends upon the driver: • Drivers 1 and 3: Low side driver • Driver 2: Can be configured as either a high side or low side driver. If Driver 2 is configured as a high side driver, it will not provide PWM.
Max Current	2A continuous
Frequency	16KHz
Pulse Width Resolution	0.5% minimum over a 2% to 100% duty cycle range (8 bit resolution)
Maximum Voltage	150% of nominal battery voltage
Maximum Reverse Voltage	–0.5V
Logic High Threshold	The threshold depends upon the model: • 1226-2201: 8.1V • 1226-3101 and 1226-5201: 13.9V
Logic Low Threshold	The threshold depends upon the model: • 1226-2201: 2.2V • 1226-3101 and 1226-5201: 3.7V
Input Impedance	>50kΩ

Throttle Pot

The Analog 1 and Analog 4 inputs provide a potentiometer circuit that includes full pot fault protection against open or shorted wires anywhere in the throttle assembly.

Both Analog 1 and 4 are used for 3-wire pots. For 2-wire pots, only Analog 1 is used. Table 14 describes how to connect 2-wire and 3-wire pots.

Table 14 Throttle Pot Connections

Pot Type	Pins
3-wire pot	• J3-7 for the pot wiper (Analog 1) • J3-16 for pot high (Analog 4)
2-wire pot	J3-7 (Analog 1) You can use Analog 4 as a normal voltage input.

Use the Analog 1 Type parameter value to specify the vehicle's pot type. See page 47.

Figure 7 and Figure 8 show how to wire 2-wire and 3-wire throttle pots.

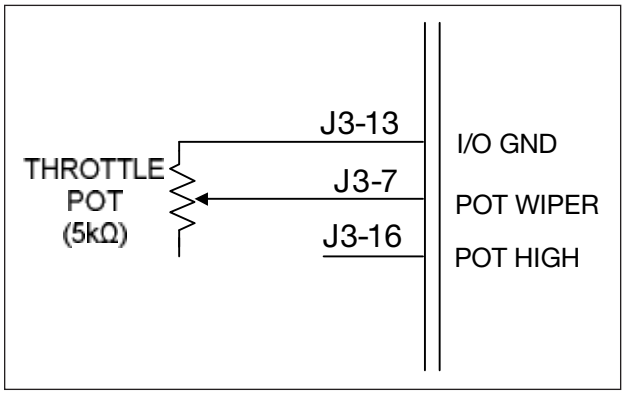


Figure 7
Wiring a 2-Wire Throttle Pot

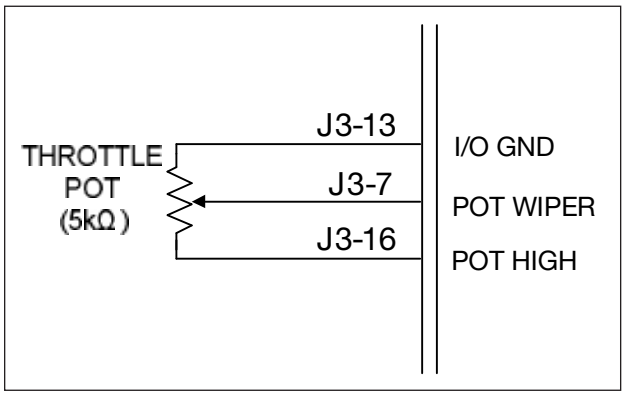


Figure 8
Wiring a 3-Wire Throttle Pot

Table 15 and Table 16 describe specifications for throttle pots.

Table 15 Potentiometer Resistance Specifications

Specification	Value
2 or 3 Wire Pot Resistance Range	0kΩ – 14kΩ (full resistance)
Measured Resistance Tolerance	+/– 20%

Table 16 Pot Wiper and Pot High Analog Specifications

Specification	Value
Input Voltage Range	0~8.2V
Input Impedance	>20 kΩ
Output Voltage Range	<16V

Speed Limit Pot

A speed limit pot allows the operator to adjust the vehicle speed. A 100kΩ pot is recommended.

If you are using a speed limit pot, perform the following steps.

1. Wire the speed limit pot to the following pins. See Figure 6 on page 10.
   – J3-6 (Speed limit pot input)
   – J1-1 (External +5V power supply)
   – J3-13 (I/O ground)
2. Set the Speed Limit Pot parameter to on. See page 34.

Note: If you are not using a speed limit pot, set this parameter to off.

3. Specify the Analog port with the Speed Limit Source parameter; see page 49.

Note: The Analog 2 port is typically used for the speed limit pot.

The following considerations apply to the speed limit pot:

- When the speed limit pot is in its maximum speed position, the vehicle's speed at full throttle corresponds to the speed mode's maximum speed settings.
- When the speed limit pot is in its minimum speed position, the vehicle's speed at full throttle corresponds to the speed mode's minimum speed settings.
- The speed limit pot changes the vehicle speed linearly over the range between the minimum and maximum speed settings for the active speed mode.

Keyswitch

The keyswitch input is connected to pin J3-1. Table 17 describes the specifications for the keyswitch input.

Table 17 Keyswitch Input Specifications

Specification	Value
Maximum Input Current	8A (maximum pin rating)
Maximum Voltage	150% of nominal battery voltage
Maximum Reverse Voltage	–(150% of nominal battery voltage)
Quiescent Current	75mA maximum **Note:** This is at nominal voltage and does not include current draw from coil loads or external power supplies.

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 the keyswitch as shown in Figure 6.

Interlock Input

To ensure operator safety, the 1226 controller does not allow vehicles to start from rest on level ground until the operator specifies the driving direction and applies throttle.

The interlock input indicates whether the operator intends to power up and drive the system, as described below:

- When the interlock goes on, it signals that the operator intends to drive the vehicle.
- When the interlock is off, the vehicle is considered to be at rest and the controller does not allow the vehicle to start driving.

Note: For the 1226 controller, the interlock input is typically connected to the tiller handle. The interlock is on when the tiller handle is pulled down.

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; see page 80.

You can use either the keyswitch or an interlock switch for the interlock. Use the Interlock Type parameter to indicate which is used; see page 36.

If the vehicle uses an interlock switch, connect it to pin J3-3. The input is typically assigned to Switch 7.

Push Switch

The push feature allows the electromagnetic brake to be released electrically when the push switch is active, thus allowing the vehicle to be pushed. For example, the push feature allows an attendant to manually push a mobility aid scooter.

The push feature prevents driving until the push switch is turned off. This ensures that the operator can drive the vehicle only when the electromagnetic brake is in a state where it can be engaged.

The push switch is typically connected to pin J3-9. You must also specify that the Push Enable parameter is on; see page 29.

To use the push feature, the following conditions must apply:

- The batteries must be wired to the controller.
- The keyswitch must be enabled.
- The vehicle must be stopped.
- The electromagnetic brake must be engaged.

If the vehicle is pushed too fast, indicating a runaway or other abnormal condition, the controller will automatically turn on and limit the vehicle speed. The controller will limit the speed even if the vehicle was not powered on or connected to the battery.

Note: The Push Max Speed parameter defines the maximum speed at which the vehicle can be pushed before the controller limits the vehicle's speed. See page 29.

Emergency Reverse Input

Emergency reverse is typically used in Class III material handling vehicles. When emergency reverse is activated, the controller produces a rapid braking force to quickly stop the vehicle, then 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 which switch(es) is being used; see page 43.

When complementary switches are used for emergency reverse, the controller continually checks both switches. Table 18 lists which combinations of switches result in valid actions and which result in faults.

Table 18 Complementary Emergency Reverse States

NO State	NC State	Valid or Fault?	Comments
Off	Off	Fault	This occurs if the NC connection is broken or the NO switch is defective. An EMR Switch Redundancy fault occurs.
Off	On	Valid	Emergency reverse is off.
On	Off	Valid	Emergency reverse is on.
On	On	Fault	This occurs if the NO switch is shorted or the NC switch is defective. An EMR Switch Redundancy fault occurs.

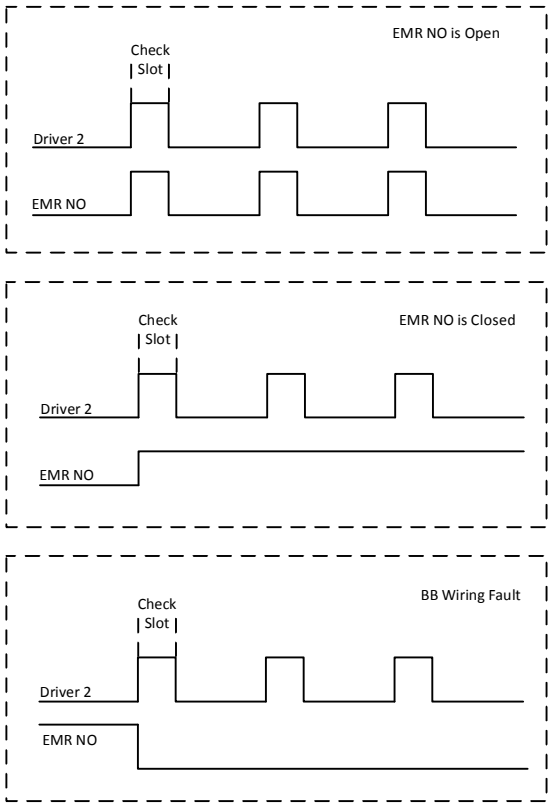
You can use the EMR SRO Enable parameter to specify that the vehicle cannot be driven if emergency reverse is active when the operator turns on the keyswitch. For information on configuring the emergency reverse feature, see page 42.

Belly Button Check

You can use the Generic Driver 2 output (pin J3-12) to perform a belly button check (BB check). The belly button check tests whether the emergency reverse wiring is broken. If the controller detects the wiring is broken, the controller generates a BB Wiring Fault.

Figure 9 shows how the belly button check works. The controller periodically activates Driver 2 in order to detect whether the wiring between the tiller head's emergency reverse switch and the controller's emergency reverse NO input is broken. If the controller detects that the NO input's status is low after activating the driver 3 times, the controller generates a BB Wiring Fault.

Figure 9
Belly Button Wiring Check



To use the Driver 2 output for the belly button check, configure parameters as described in Table 19.

Table 19 Belly Button Check Configuration

Action	Parameter	More Information
Specify that emergency reverse uses a normally open switch.	EMR Input Type	See page 43.
Assign Driver 2 as an Aux driver.	Aux 1 Contactor Driver or Aux 2 Contactor Driver	See Coil Drivers Menu on page 50.
Specify that the Aux driver is for the belly button check.	Aux 1 Type or Aux 2 Type	See Aux 1 and Aux 2 Contactor Driver Menus on page 45.
Specify Driver 2 as a high side driver.	Driver 2 Type **Note:** If the driver is not configured as a high side driver, the controller will generate a Parameter Mismatch fault.	See page 51.
Specify how the controller will handle the BB Wiring Fault.	BB Wiring Fault LOS Enable	See page 43.

Electromagnetic Braking

Driver 1 is a special purpose driver for electromagnetic (EM) braking. For information on the driver, see page 14.

Pin J1-3 supplies the Driver 1 output, and pin J1-4 (Brake+) supplies power to the electromagnetic brake. See Figure 6.

Note: The controller provides a brake holding voltage feature that reduces brake coil heating. Use the EM Brake menu to configure the holding voltage and other electromagnetic braking parameters; see page 38.

Mode Switch

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

Typically, you would connect the mode switch to pin J3-18. That pin is associated with Switch 13, which provides an integrated LED driver that can be used to display the mode switch's status when the switch is configured as a momentary switch.

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 on page 27.

Battery Discharge Indicator (BDI)

The 1226 controller can drive a 0V-5V BDI panel meter that displays the battery's state-of-charge. The battery must be put through a full charge cycle with the controller installed before the BDI will begin operation.

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 BDI Setup Menu on page 41 and Calibrating the Battery Discharge Indicator (BDI) Output on page 71.

Charger Inhibit

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

To configure charger inhibit for your vehicle system, you must 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 to pin J3-15.
- Otherwise, connect the charger's B- to pin J3-15.

For an example, see Figure 6.

Circuitry Protection Devices

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.

External Status LED

The 1226 controller supports using an external status LED that allows the operator to see the controller's status. This LED always indicates whether the controller is powered on or off. The LED will also provide fault information via the flash codes described in Table 33.

To configure the controller for an external status LED, do the following:

- Connect the LED to the pin for the driver you will use.
- Set the External Status LED Enable parameter to 1. See page 46.
- Set the External Status LED Driver to the number of the LED driver. See page 50.

If the vehicle system requires an external status LED, install the LED with the proper resistor in series. The LED drivers are capable of a maximum current of 15mA. The recommended resistor—designed to limit driver current to 15mA when active—is dependent upon the battery's nominal voltage, as described in Table 11.

Alternatively, an LED with a built-in resistor can be used; it should be rated for the battery's nominal voltage operation.

Horn

The 1226 controller has a dedicated horn driver that drives with either the low side or high side method. The driver's maximum current is 30mA.

To use a horn driver, do the following:

- Connect the horn to pin J3-2.
- If you are using a low side driver, it should take feed from the Coil Return pin (J3-10). For an example, see Figure 6.
- Specify the driver type with the Horn menu's Type parameter. See page 44.

Note: You can use the Horn menu to configure the horn to sound when the vehicle is traveling in reverse. You can also configure the horn to sound audible fault codes.

External Power Supply

The controller provides two output pins for external power supply, as described in Table 20.

Table 20 External Power Supply Pins

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

Table 21 describes the specifications for the external power supply outputs.

Table 21 +5V and +14V External Power Supply Specifications

Specification	Value (+5V Supply)	Value (+14V Supply)
Nominal Output	5.2V +/–5%	14V +/–15%
Maximum Current	50mA	70mA
Maximum Voltage	150% nominal battery voltage	
Maximum Reverse Voltage	–0.5V	

Load Hold Contactor

If the vehicle includes a load hold valve, use one of the generic drivers for the load hold contactor. Driver 1 is typically used for electromagnetic braking, so most likely you will assign the contactor to Driver 2 (pin J3-12) or Driver 3 (pin J3-11).

To configure the load hold contactor and assign it to a generic driver, see the following topics:

Load Hold Contactor Driver Menu (page 45)

Driver 1, Driver 2, and Driver 3 Menus (page 51)

Hydraulic Pump Contactor

If the vehicle includes a hydraulic pump, use one of the generic drivers for the hydraulic pump contactor. Driver 1 is typically used for electromagnetic braking, so most likely you will assign the contactor to Driver 2 (pin J3-12) or Driver 3 (pin J3-11).

To configure the hydraulic pump contactor and assign it to a generic driver, see the following topics:

Hydraulic Contactor Driver Menu (page 44)

Driver 1, Driver 2, and Driver 3 Menus (page 51)

Reverse Switch

If the vehicle uses a single switch or dual switch throttle, connect the switches as described in Table 22.

Table 22 Single and Dual Switch Throttle Connections

Throttle Type	Description
Single switch	Connect the reverse switch to pin J3-8.
Dual switch	Connect the reverse switch to pin J3-8 and the forward switch to pin J3-17.

Switch 8 is associated with pin J3-8 and provides an integrated LED driver that can be used to output the switch's status when it is configured as a momentary switch.

Speed Sensor

The 1226 controller provides an input for a single wire motor speed sensor. If the vehicle uses a speed sensor, you can configure the controller to strictly limit vehicle speed.

When a vehicle includes a speed sensor, the controller measures the pulses per revolution every 4ms. The controller then calculates the vehicle speed based on the number of pulses specified with the Pulses/Rev parameter. When measuring the pulses, the controller uses a low pass filter to block motor-generated noise and smooth speed changes.

To connect a speed sensor input, use pin J1-2, which is associated with the Analog 6 and Switch 6 inputs. You enable and configure the speed sensor with the parameters described in Speed Sensor Menu on page 53.

Table 23 describes the specifications for the speed sensor.

Table 23 Speed Sensor Specifications

Specification	Value
Max Speed Sensor Frequency	200Hz
Speed Sensor PPR	1-32 pulses per revolution
Speed Measurement Accuracy	Depends on the speed sensor's resolution
Max Glitch rejection	50 µs

The following list describes speed sensor considerations:

- The input is pulled high. If a switch configuration is required, the input must be configured as a switch to B– (low active).
- The input should not be used as a voltage input due to the pull up load on the pin.
- You can power the speed sensor with the +5.0V external power supply.

Motor Temperature Sensor

The 1226 controller provides an input for a motor temperature sensor and can apply a limited operating strategy (LOS) to prevent damage caused by overheating. The input measures the sensor's resistance, then uses the measured resistance to calculate the temperature.

The controller's motor temperature function linearly cuts back the current from 100% to 0% when the motor reaches the specified temperatures.

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

To connect a motor temperature sensor input, use pin J1-6, which is associated with the Analog 5 and Switch 5 inputs.

Note: Analog 5 provides a circuit that supports an external temperature sensor input. Analog 5 is typically used as the motor temperature sensor, but the input can be used for any external resistive temperature sensor.

You enable and configure the motor temperature sensor with the parameters described in Motor Temperature Control Menu on page 54.

Table 24 describes specifications for the motor temperature sensor.

Table 24 Motor Temperature Sensor Specifications

Specification	Value
Temperature Range	–40°C to + 200°C
Analog Filter	~1 kHz
Resistance Measurement Range	250Ω – 5kΩ
Resistance Measurement Accuracy	• ± 20Ω @ 2kΩ and below • ± 100Ω @ above 2kΩ
Maximum sensor current	2.5mA

The following list describes temperature sensor considerations:

- The input is pulled high. If a switch configuration is required, the input must be configured as a switch to B– (low active).
- The input should not be used as a voltage input due to the pull up load on the pin. The input can be used as a resistance analog input.

3 — PROGRAMMABLE PARAMETERS

The 1226 controller has numerous parameters that you can program using a Curtis handheld programmer or Curtis PC Programming Station. Use these parameters to customize a vehicle's performance and functionality.

Note: For information on Curtis programming devices, see page 90.

The parameters are grouped hierarchically into menus and are described in the following topics.

You must cycle the keyswitch after you change a parameter marked as [PCF]. If you do not cycle the keyswitch, the controller generates a Parameter Change Fault. To clear a Parameter Change Fault, cycle the keyswitch.

APPLICATION SETUP MENU

The Application Setup menu contains the following menus:

APPLICATION SETUP MENU

Speed Mode Menu

The controller provides two speed modes. The modes are useful in cases where the vehicle will be driven under different driving conditions. A typical usage is to configure one speed mode for outdoor driving and the other speed 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.

The following sections describe the submenus of the Speed Mode menu:

Mode 1 and Mode 2 Menus on page 28

Other Menu on page 29

Fine Tuning Menu on page 30

Mode 1 and Mode 2 Menus

Use the Mode 1 and Mode 2 menus to configure the speed modes. The following table describes the Mode 1 and Mode 2 menus' parameters.

Note: All parameters ending in "HS" or "LS" depend upon the HS(High Speed) and LS(Low Speed) parameter values. See Fine Tuning Menu on page 30.

SPEED MODE MENU — MODE 1 AND MODE 2 MENUS

PARAMETER	VALUES	DEFAULT	DESCRIPTION
Max Speed	0%-100%	100%	Sets the vehicle speed under the following conditions: • Full throttle is applied. • The speed limit pot is at its maximum position. • The vehicle is moving forward.
Min Speed	0%-100%	80%	Sets the vehicle speed under the following conditions: • Full throttle is applied. • The speed limit pot is at its minimum position. • The vehicle is moving forward. If Min Speed is greater than Max Speed, a Parameter Mismatch fault occurs. **Note:** Min Speed is used only if a speed limit pot is installed and the Speed Limit Pot parameter is on. See Throttle Menu on pages 33-34.
Rev Max Speed	0%-100%	100%	Sets the vehicle speed under the following conditions: • Full throttle is applied. • The speed limit pot is at its maximum position. • The vehicle is moving in reverse.
Rev Min Speed	0%-100%	80%	Sets the vehicle speed under the following conditions: • Full throttle is applied. • The speed limit pot is at its minimum position. • The vehicle is moving in reverse. If Rev Min Speed is greater than Rev Max Speed, a Parameter Mismatch fault occurs. **Note:** This parameter is used only if a speed limit pot is installed and the Speed Limit Pot parameter is on; see page 34.
Full Accel Rate HS	0.1s-8.0s	3.0s	Sets the rate, in seconds, at which the vehicle accelerates when full throttle is applied at high vehicle speeds. Larger values represent slower response. See Understanding Low and High Speed Acceleration on page 31.
Full Accel Rate LS	0.1s-8.0s	3.0s	Sets the rate, in seconds, at which the vehicle accelerates when full throttle is applied at low vehicle speeds. Larger values represent slower response.
Low Accel Rate	0.1s-8.0s	3.0s	Sets the rate, in seconds, 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	0.1s-8.0s	3.0s	Sets the rate, in seconds, at which the vehicle decelerates when the throttle is released to neutral while the vehicle is moving forward at high speed.
Neutral Decel Rate LS	0.1s-8.0s	3.0s	Sets the rate, in seconds, at which the vehicle decelerates when the throttle is released to neutral while the vehicle is moving forward at low speed.

SPEED MODE MENU — MODE 1 AND MODE 2 MENUS, cont'd

PARAMETER	VALUES	DEFAULT	DESCRIPTION
Rev Neutral Decel Rate HS	0.1s-8.0s	3.0s	Sets the rate, in seconds, at which the vehicle decelerates when the throttle is released to neutral while the vehicle is moving in reverse at high speed.
Rev Neutral Decel Rate LS	0.1s-8.0s	3.0s	Sets the rate, in seconds, at which the vehicle decelerates when the throttle is released to neutral while the vehicle is moving in reverse at low speed.
Full Brake Rate HS	0.1s-8.0s	3.0s	Sets the rate, in seconds, at which the vehicle decelerates from high speeds when full throttle is applied in the opposite direction. See Understanding Low and High Speed Brake Deceleration on page 32.
Full Brake Rate LS	0.1s-8.0s	3.0s	Sets the rate, in seconds, at which the vehicle decelerates from low speeds when full throttle is applied in the opposite direction.
Low Brake Rate	0.1s-8.0s	3.0s	Sets the rate, in seconds, at which the vehicle decelerates when a small amount of throttle is applied in the opposite direction.
Partial Decel Rate	0.1s-8.0s	3.0s	Sets the rate, in seconds, at which the vehicle decelerates when the throttle is reduced without being released to neutral. Larger values provide a slower response.
Rev Partial Decel Rate	0.1s-8.0s	3.0s	Sets the rate, in seconds, at which the vehicle decelerates while driving in reverse when the throttle is reduced without being released to neutral. Larger values provide a slower response.

Other Menu

Use the Other menu's parameters to smooth vehicle response, configure the vehicle's push function, and set the deceleration rate when the user switches the key off or a major fault occurs.

For steps on using Soft Start and Gear Soften parameters, see Fine-tune the Vehicle's Response Smoothness on page 69.

SPEED MODE MENU — OTHER MENU

PARAMETER	VALUES	DEFAULT	DESCRIPTION
Soft Start	0-100%	0%	Softens the bump caused by gear train slack when the vehicle starts from neutral. Larger values provide a softer start.
Gear Soften	0-100%	0%	Softens the bump associated with gear slack in the transaxle when the throttle is released and then reapplied while the vehicle is still moving. Larger values provide a softer slack take-up.
Push Enable [PCF]	On/Off	Off	Sets whether the push function is enabled.
Push Max Speed	0%-50%	25%	Sets the maximum speed at which the vehicle can be pushed. The value is a percentage of the Speed Scaler parameter's value. **Note:** The controller uses Push Max Speed only if Push Enable is on.
Key Off Decel	0.1-4.0s	3.0s	Sets the rate, in seconds, at which the vehicle decelerates when the user switches the key off or a major fault occurs. See Configure the Key Off Deceleration Rate on page 67.

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:

Understanding Low and High Speed Acceleration

Understanding Low and High Speed Brake Deceleration (page 32)

SPEED MODE MENU — FINE TUNING MENU

PARAMETER	VALUES	DEFAULT	DESCRIPTION
HS(High Speed)	0%-100%	90%	Sets the percentage of the Speed Scaler parameter voltage above which the high speed (HS) parameters are used.
LS(Low Speed)	0%-100%	10%	Sets the percentage of the Speed Scaler parameter voltage below which the low speed (LS) parameters are used.

Understanding 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 on page 30.

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

Figure 10 shows the acceleration rate when full throttle is applied.

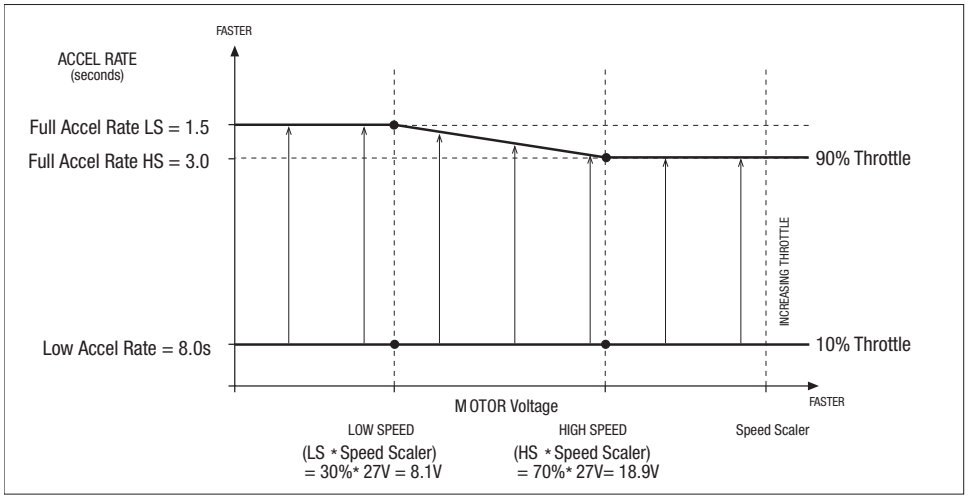


Figure 10

Low Speed and High Speed Acceleration Rates

For steps on configuring acceleration rates, see Set the Acceleration and Deceleration Rates on page 66.

Understanding 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 on page 30.

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: These deceleration rates apply to forward and reverse.

Example

Suppose you set the following parameters to the following values:

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

Figure 11 shows the deceleration rates when full throttle is applied in the opposite direction.

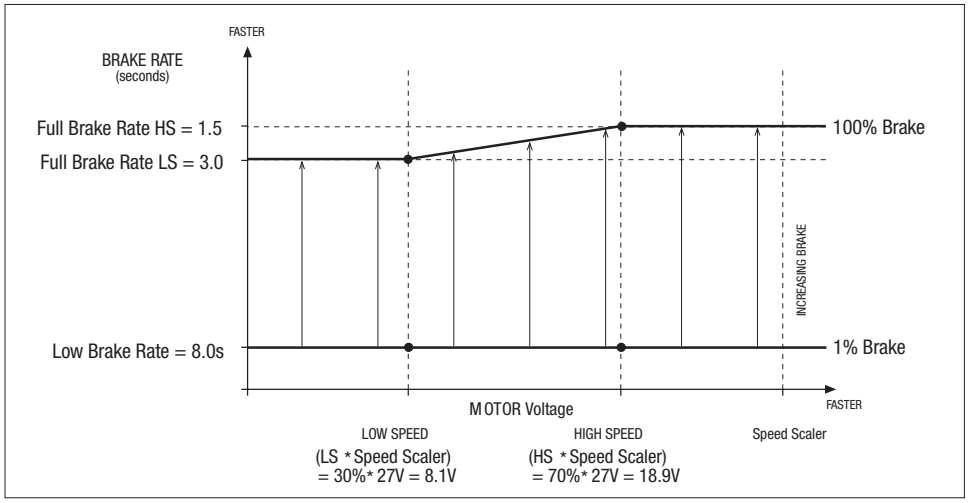


Figure 11

Low Speed and High Speed Brake Deceleration Rates

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 configure the HPD/SRO function.

Note: The Forward and Reverse Deadband, Max, Offset, and Map parameter values are percentages of the throttle's maximum output voltage or resistance. The throttle's maximum output voltage and maximum resistance are specified with the Analog 1 input's High and Nominal Resistance parameters. See Analog Inputs Menu on page 47.

THROTTLE MENU

PARAMETER	VALUES	DEFAULT	DESCRIPTION
Direction Source [PCF]	0-2	0	Specifies the throttle type: 0 = Dual switch 1 = Wigwag 2 = Single switch For descriptions of the throttle types, see Table 25.
Forward Deadband [PCF]	0%-100%	10%	Defines the wiper voltage at the deadband threshold while the vehicle is moving forward. Increasing Forward Deadband increases the neutral range.
Forward Max [PCF]	0%-100%	90%	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 Understanding the Throttle Response Parameters on page 35.
Forward Offset	0%-100%	0%	Defines the controller output 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	0%-100%	50%	Sets 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.
Reverse Deadband [PCF]	0%-100%	10%	These parameters work just like the corresponding Forward parameters, except that they apply when the vehicle is moving in reverse.
Reverse Max [PCF]	0%-100%	90%	
Reverse Offset	0%-100%	0%	
Reverse Map	0%-100%	50%	
Throttle Filter	0.5-125Hz	50Hz	Sets the low pass filter cutoff frequency for the throttle pot wiper input. Lower values provide a slower response.

THROTTLE MENU, cont'd

PARAMETER	VALUES	DEFAULT	DESCRIPTION
HPD/SRO Type [PCF]	0-2	1	Indicates whether the HPD/SRO function is enabled. If HPD/SRO is enabled, the controller generates the HPD/Sequencing fault when it detects an HPD condition. Whether the controller generates the fault for SRO conditions depends upon the parameter value and the throttle type specified with the Direction Source parameter: 0 = Disabled. 1 = HPD/SRO enabled for material handling vehicles. For dual switch throttles, the controller detects SRO if the forward or reverse direction is selected before the interlock input is turned on, and ignores SRO for the other throttle types. 2 = HPD/SRO forward only. For single switch and dual switch throttles, the controller detects SRO if the forward direction is selected when the interlock input is turned on, and ignores SRO for wigwag throttles. **Note:** For single switch throttles, the forward direction is selected when the reverse switch is inactive. See Understanding the HPD/SRO Function on page 36.
Sequencing Delay	0.1-5.0s	0.5s	Sets 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.
Speed Limit Pot [PCF]	On/Off	Off	Specifies whether the vehicle uses a speed limit pot. On = Uses a speed limit pot Off = No speed limit pot

Table 25 Throttle Types and Driving Direction

Throttle Type	Description
Dual switch	The controller uses forward and reverse switches to determine the driving direction. **Note:** If both switches are active, the controller considers it an error and clears the throttle command.
Single switch	The controller uses the status of the reverse switch to determine the driving direction. If the reverse switch is inactive, the controller drives the motor forward. Otherwise the controller drives the motor in reverse.
Wigwag	The driving direction is based on the throttle input: • If the throttle input is between the values of the Forward Max and Forward Deadband parameters, the controller drives the motor forward. • If the throttle input is between the values of the Reverse Max and Reverse Deadband parameters, the controller drives the motor in reverse. • If the throttle input is between the values of the Forward Deadband and Reverse Deadband parameters, the controller considers the vehicle to be in neutral.

Understanding the Throttle Response Parameters

The Forward and Reverse Deadband, Max, and Map parameters set the controller output that is generated at various throttle wiper 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.

Figure 12 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.

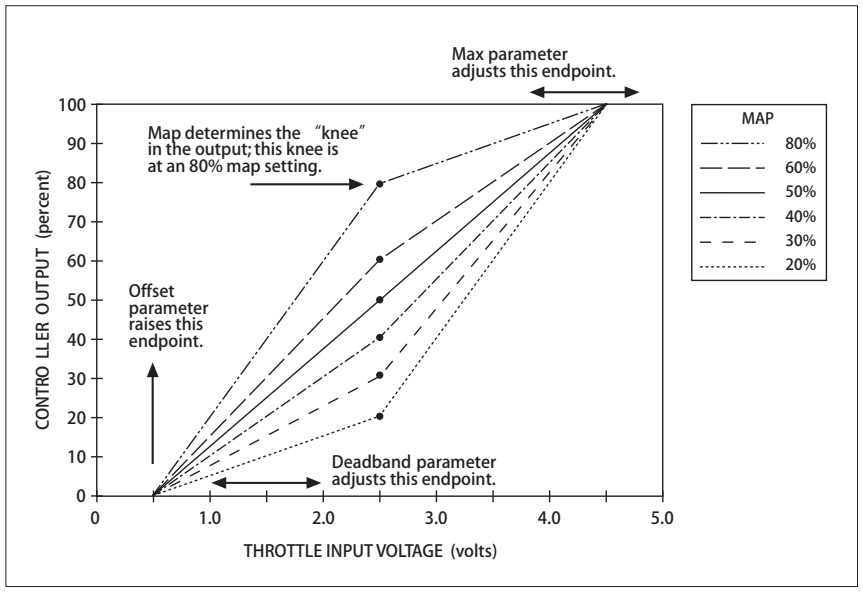


Figure 12

Throttle Response Parameters

The following list describes the parameters in this diagram.

- Deadband = 10%. The vehicle is in neutral until the throttle's wiper voltage is 0.5 volts (10% of 5.0V).
- Offset = 0%. A 0% value means there is no controller output when the throttle's wiper 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 wiper voltage equals 2.5V (50% of 5.0V).

Note: You can use the Throttle Pot Percent and Mapped Throttle Percent fields to monitor the throttle wiper voltage and the throttle request. See Analog Inputs Menu on page 61.

Understanding the HPD/SRO Function

The HPD/SRO safety function protects users from unexpected starts when the interlock input changes from off to on. If the HPD/SRO parameter is enabled and one of the conditions described in Table 26 occurs, the controller generates an HPD/Sequencing Fault.

Table 26 HPD and SRO

Abbreviation	Name	Condition
HPD	High Pedal Disable	The throttle input is greater than 25% when the interlock input changes to on.
SRO	Static Return to Off	A direction input is on when the interlock input changes to on

To clear an HPD/Sequencing Fault, perform the following steps:

1. Turn off the direction switches.
2. Set the throttle so that it is under 25% of its maximum voltage.

Interlock Braking Menu

The following table describes the interlock braking parameters.

INTERLOCK BRAKING MENU

PARAMETER	VALUES	DEFAULT	DESCRIPTION
Interlock Type [PCF]	0-1	0	Specifies whether interlock braking is turned on with the keyswitch or the interlock input: 0 = Interlock input 1 = Keyswitch
Decel Rate	0.1-8.0s	1.0s	Sets the rate, in seconds, at which the vehicle decelerates when the interlock is released. Larger values represent slower response times.
Interlock Brake Timeout	0.2-8.0s	2.0s	Sets the maximum allowable duration of an interlock braking event. The timer starts when the interlock input's 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.

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

MAIN RELAY (CONTACTOR) MENU

PARAMETER	VALUES	DEFAULT	DESCRIPTION
Pull In Voltage	0%-100%	100%	Sets the main contactor's initial voltage when the relay or contactor 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, the controller generates a Main Contactor Did Not Close fault.
Holding Voltage	0%-100%	80%	Sets the voltage the controller applies to the relay or contactor coil after the relay closes. Set 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 Contactor Driver PWM field to monitor the pull-in and holding voltages. See page 58.
Battery Voltage Compensated	On/Off	On	Specifies whether the controller adjusts pull-in and holding voltages to compensate for differences between the nominal and actual voltages.
Open Delay	0-40s	0s	Specifies how long the main relay should remain closed after the interlock input has opened. A delay prevents unnecessary cycling of the relay and maintains power for other functions that the operator may need to briefly use after the interlock input opens.

EM Brake Menu

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

Note: For information on the electromagnetic braking feature, see page 38.

EM BRAKE MENU

PARAMETER	VALUES	DEFAULT	DESCRIPTION
Pull In Voltage	20%-100%	100%	Sets the electromagnetic braking system's initial voltage when the system 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	20%-100%	80%	Sets the reduced voltage the controller applies to the brake coil once the brake has been released. Set 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 field to monitor the pull-in and holding voltages. See page 58.
EM Brake Delay	0-2.0s	1.0s	Sets how long it takes for the controller to engage the electromagnetic brake when the controller output decreases to 0%.

Understanding Electromagnetic Braking

The electromagnetic braking feature works as follows:

- The controller releases the electromagnetic brake when all the following conditions occur:
  - The interlock input is closed.
  - Either the forward or reverse direction is selected.
  - The throttle is above the deadband threshold.
- The controller engages the electromagnetic brake when the controller output is 0%. Output goes to 0% when either of the following conditions occurs:
  - The controller detects that the vehicle has stopped and the EM Brake Delay timer has expired.
  - The vehicle is moving in a direction that does not comply with the throttle's direction.

Battery Menu

The battery menu contains the following menus:

Undervoltage Controller Menu (page 40)

Overvoltage Controller Menu (page 40)

BDI Setup Menu (page 41)

In addition, for 36V/48V models, the Battery menu contains the following parameter:

BATTERY MENU

PARAMETER	VALUES	DEFAULT	DESCRIPTION
Nominal Voltage (36V/48V model only)	36V-48V	48V	Sets the battery's nominal voltage.

Overvoltage and Undervoltage Protection

The 1226 controller's overvoltage protection cuts back regen current to prevent damage to batteries and other electrical system components. The controller's undervoltage protection prevents systems from operating at voltages below minimum voltage requirements.

Table 27 describes the controller's overvoltage and undervoltage thresholds. These are hardware limits.

Table 27 1226 Controller Voltage Limits

Voltage Range	Percentage of Nominal Battery Rating
Severe Overvoltage	150%
Overvoltage	125%
Undervoltage	50%
Severe Undervoltage	40%
Brownout	33%

You can use the Overvoltage Controller and Undervoltage Controller menus to customize the controller's overvoltage and undervoltage thresholds.

Note: If you set an overvoltage or undervoltage parameter to a value outside the range of the controller's voltage limits, the controller will ignore the parameter and instead use the corresponding controller voltage limit.

Undervoltage Controller Menu

The Undervoltage Controller parameters allow you to configure how the controller handles undervoltage conditions.

Note: To configure these parameters, you must be familiar with the controller's system voltage ranges. See Table 27.

The undervoltage controller is a closed loop PI (Proportional/Integral) controller that attempts to keep battery voltage from drooping by cutting back the drive current.

The following table describes the Undervoltage Controller parameters.

BATTERY MENU — UNDERVOLTAGE CONTROLLER MENU

PARAMETER	VALUES	DEFAULT	DESCRIPTION
User Undervoltage	0%-95%	80%	Sets the undervoltage threshold. The value is a percentage of the battery's nominal voltage.
Kp UV	0-100%	20%	Sets the undervoltage controller's proportional gain. The value is the desired percentage of cutback per volt. For example, a setting of 25% provides full cutback with 4V of droop.
Ki UV	0-100%	0%	Sets the integral gain for the undervoltage controller. The integral gain 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 controllers is preferred, set Ki UV to 0%.

Overvoltage Controller Menu

The following table describes the parameter on the Overvoltage Controller menu.

Note: To configure the User Overvoltage parameter, you must be familiar with the controller's system voltage ranges. See Table 27.

BATTERY MENU — OVERVOLTAGE CONTROLLER MENU

PARAMETER	VALUES	DEFAULT	DESCRIPTION
User Overvoltage	105%-200%	120%	Sets the overvoltage threshold, which is the voltage at or above which the controller cuts back regenerative braking to prevent electrical damage. The value is a percentage of the battery's nominal voltage.

BDI Setup Menu

The BDI Setup parameters allow you to configure the Battery Discharge Indicator (BDI) output for the system's battery, charger, and expected drive cycle.

The following list defines terms used in the parameter descriptions:

- **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.

The controller sets the BDI percentage to 0% when its voltage decreases to the Empty Volts Per Cell voltage, and to 100% when its voltage increases to the Full Charge Voltage. BDI percentage changes occur gradually, with the duration defined by the Discharge Time and Charge Time parameters.

- **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.
- **Moving threshold:** The battery voltage below which the BDI percentage is decremented. The moving threshold is calculated using the Full Volts Per Cell and Empty Volts Per Cell parameters:

```
BDI% * (Full Volts Per Cell - Empty Volts Per Cell) * the Number of Cells
```

See the following topics for more information:

- The Battery menu of the Monitor menu contains fields you can watch when working with the BDI parameters; see page 58.
- For steps on calibrating the BDI for your vehicle system, see page 71.

The following table describes the BDI Setup parameters.

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

BATTERY MENU — BDI SETUP MENU

PARAMETER	VALUES	DEFAULT	DESCRIPTION
Reset Volts Per Cell	0.90V-3.00V	2.09V	Sets 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 You must set Reset Volts Per Cell to a voltage greater than that of Full Volts Per Cell. **Note:** The controller only checks the reset voltage once, when the main contactor first closes.
Full Volts Per Cell	0.90V-3.00V	2.04V	Sets 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	0.90V-3.00V	1.73V	Sets the battery cell voltage at which the battery cell is considered 0% charged.
Discharge Time	0-600 minutes	600	Sets the minimum time, in minutes, for decrementing the BDI percentage from 100% to 0% if the battery cell voltage is lower than the Empty Volts Per Cell voltage. When the battery voltage is below the moving threshold for a duration of `Discharge Time/100`, the BDI percentage is decremented by one percentage point.

BATTERY MENU — BDI SETUP MENU, cont'd

PARAMETER	VALUES	DEFAULT	DESCRIPTION
BDI Reset Percent	0%-100%	75%	Sets 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	0.90-3.00V	2.35V	Sets the voltage above which the controller considers the battery as finished charging.
Start Charge Voltage	0.90-3.00V	2.10V	Sets the voltage at which the controller considers the battery as starting to charge.
Charge Time	0-600 minutes	300	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	0-%50%	20%	Sets the BDI percentage at or below which the controller activates the hydraulic lift lockout function. **Note:** When hydraulic lift lockout is active, the controller disables the hydraulic lift to prevent battery damage.

Emergency Reverse Menu

You can configure many aspects of the emergency reverse feature, including the following:

- Whether emergency reverse is activated by a normally open switch, normally closed switch, or both normally open and normally closed switches.
- 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.
- How the controller handles belly button wiring (BB Wiring) faults.

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

EMERGENCY REVERSE MENU

PARAMETER	VALUES	DEFAULT	DESCRIPTION
EMR Input Type [PCF]	0-2	0	Sets 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 For information on how the controller handles complementary NO and NC switches, see Table 18.
EMR Fwd Only	On/Off	On	Sets whether emergency reverse can be activated when driving in either direction: On = Emergency reverse can be activated only when driving forward. Off = Emergency reverse can be activated while driving in either direction.
EMR Dir Interlock	On/Off	On	Specifies whether the interlock input must be cleared before the operator resumes driving after an emergency reverse operation: On = The operator must clear the interlock input, direction switches, and throttle. Off = The operator must clear the direction switches and throttle.
EMR Time Limit	0-30s	5s	Indicates how long emergency reverse will be active after the vehicle starts moving in reverse. **Note:** If the vehicle should not have a time limit, specify the maximum value of 30s.
EMR Speed	0%-100%	60%	Sets the maximum vehicle speed during emergency reverse. The value is a percentage of the Speed Scaler parameter; see page 52.
EMR Accel Rate	0.1-8.0s	0.8s	Sets the rate, in seconds, at which the vehicle accelerates in the opposite direction after emergency reverse stops the vehicle.
EMR Decel Rate	0.1-8.0s	0.8s	Sets the rate, in seconds, at which the vehicle brakes to a stop when emergency reverse is activated.
EMR SRO Enable	On/Off	On	Specifies whether the controller generates an EMR SRO fault if an emergency reverse switch is active when the keyswitch is turned on.
BB Wiring Fault LOS Enable	On/Off	On	Specifies how the controller will handle a BB Wiring fault: On = The controller limits the maximum speed to the value of the BB Wiring LOS Speed parameter. **Note:** This is known as the Limited Operating Strategy (LOS). Off = The controller stops the vehicle and generates a BB Wiring Fault. For more information, see Belly Button Check on page 20.
BB Wiring LOS Speed	0-100%	50%	Sets the maximum operating speed when a BB Wiring Fault occurs and BB Wiring Fault LOS Enable is on. The value is a percentage of the speed mode's Max Speed parameter.

Horn Menu

The following table describes the parameters on the Horn menu.

HORN MENU

PARAMETER	VALUES	DEFAULT	DESCRIPTION
Type [PCF]	0-2	0	Specifies the horn driver type, if any: 0 = Disable the horn 1 = High side driver 2 = Low side driver
Fault Beep	On/Off	Off	Specifies whether controller uses the horn to provide audible fault codes. When Fault Beep is on, the controller beeps the same fault codes that it displays on the status LED. **Note:** If both Fault Beep and Reverse Beep are on and a fault occurs while the vehicle is driving in reverse, the fault beep takes precedence over the reverse beep.
Reverse Beep	On/Off	Off	Specifies whether the horn sounds when the vehicle is driving in reverse.
Beep Constant	On/Off	Off	Specifies whether the reverse beep is a constant tone or a pulsing sound: Off = Pulsing sound with a 1Hz frequency. On = Constant tone

Drivers Menu

The Drivers menu contains the following menus:

- Hydraulic Contactor Driver Menu
- Load Hold Contactor Driver Menu (page 45)
- Aux 1 and Aux 2 Contactor Driver Menu (page 45)

Hydraulic Contactor Driver Menu

The following table describes the parameters on the Hydraulic Contactor Driver menu.

DRIVERS MENU — HYDRAULIC CONTACTOR DRIVER MENU

PARAMETER	VALUES	DEFAULT	DESCRIPTION
Hydraulic Contactor Pull In Voltage	20%-100%	100%	Specifies a high initial voltage to ensure the contactor engages when it turns on. After 1 second, the peak voltage drops to the holding voltage.
Hydraulic Contactor Holding Voltage	20%-100%	100%	Sets the average voltage the controller applies to the coil. Specify a voltage high enough to hold the contactor under all shock and vibration conditions to which the vehicle will be subjected.
Hydraulic SRO Enable	On/Off	Off	Specifies whether the controller detects the Hydraulic SRO fault. If this parameter is on, the controller generates a Hydraulic SRO fault if the lift switch is closed before the keyswitch is turned on.

Load Hold Contactor Driver Menu

The following table describes the parameters on the Load Hold Contactor Driver menu.

DRIVERS MENU — LOAD HOLD CONTACTOR DRIVER MENU

PARAMETER	VALUES	DEFAULT	DESCRIPTION
Load Hold Contactor Pull In Voltage	20%-100%	100%	Specifies a high initial voltage to ensure the contactor engages when it turns on. After 1 second, the peak voltage drops to the holding voltage.
Load Hold Contactor Holding Voltage	20%-100%	100%	Sets the average voltage the controller applies to the coil. Specify a voltage high enough to hold the contactor under all shock and vibration conditions to which the vehicle will be subjected.
Load Hold SRO Enable	On/Off	Off	Specifies whether the controller detects the Load Hold SRO fault. If this parameter is on, the controller generates a Load Hold SRO fault if the lift switch is closed before the keyswitch is turned on.

Aux 1 and Aux 2 Contactor Driver Menus

The following table describes the parameters on the Aux 1 Contactor Driver and Aux 2 Contactor Driver menus.

DRIVERS MENU — AUX 1 AND AUX 2 CONTACTOR DRIVER MENUS

PARAMETER	VALUES	DEFAULT	DESCRIPTION
Aux 1/2 Type [PCF]	0-8	0	Specifies the function that will use the Aux *n* contactor. For descriptions of the parameter's values, see Table 28.
Aux 1/2 Contactor Pull In Voltage	20%-100%	100%	Allows a high initial voltage when the contactor first turns on to ensure the contactor is engaged. After 1 second, this peak voltage drops to the holding voltage.
Aux 1/2 Contactor Holding Voltage	20%-100%	100%	Allows a reduced average voltage to be applied to the coil. Specify a voltage high enough to hold the contactor under all shock and vibration conditions to which the vehicle will be subjected.

The following table describes the values you can specify for the Aux 1 Type and Aux 2 Type parameters.

Table 28 Aux 1 Type and Aux 2 Type Parameter Values

Value	Usage	Comments
0	Disable the driver	
1	Brake light driver	Turns on when the controller is in braking mode. When braking stops, turns off after a 0.5s delay.
2	Contactor coil driver option 1	Turns on when the operator selects a direction. Turns off with no delay when the PWM output returns to zero.
3	Contactor coil driver option 2	Turns on when the operator selects a direction. Turns off after a 2s delay when the PWM output returns to zero.
4	Contactor coil driver option 3	Turns on only when the operator selects the forward direction. Turns off with no delay under any other condition.
5	Contactor coil driver option 4	Turns on only when the operator selects the forward direction. Turns off after a 2s delay under any other condition.
6	Hourmeter option 1	Turns on when the power is turned on. Turns off when the power is turned off. Hourmeter option 1 can only be used when the contactor is assigned to Driver 2 or Driver 3. If the contactor is assigned to Driver 1, a Precharge Failed fault will occur when the keyswitch is turned on.
7	Hourmeter option 2	Turns on when the electromagnetic brake is released, and the operator selects a direction.
8	Belly button check	Periodically checks the continuity of the wiring from the belly button switch to the controller's emergency reverse NO input. For more information, see Belly Button Check on page 20.

MISC Menu

The following table describes the parameters on the MISC menu.

MISC MENU

PARAMETER	VALUES	DEFAULT	DESCRIPTION
External Status LED Enable [PCF]	0-1	0	Sets whether the external status LED is enabled: 0 = Disabled 1 = Enabled If you enable the external status LED, you must also specify the LED's driver with the External Status LED Driver parameter. See page 50.
Sleep	0-60 min.	0 min.	Specifies how long it takes the controller to go into sleep mode after the last throttle request or input from a programming device. To disable sleep mode, specify 0.
Parameter interlock	–32767 – 32767	0	Resets all parameters to their default values. To reset the parameters, specify –1.

Controller Setup Menu

The Controller Setup menu contains the following menus:

Analog Inputs Menu

The Analog Inputs menu contains the Analog 1, Analog 2, Analog 3, Analog 4, and Analog 5 menus, which are described in the following topics.

Note: The Analog 6 menu is not displayed and is reserved for future use.

Analog 1 Menu

The following table describes the parameters on the Analog 1 menu.

CONTROLLER SETUP MENU — ANALOG INPUTS MENU — ANALOG 1 MENU

PARAMETER	VALUES	DEFAULT	DESCRIPTION
Enable [PCF]	On/Off	On	Specifies whether the input's signal is analog or digital: On = Analog. The controller normalizes the input's voltage, using the values in the input's High and Low parameters as the 0% and 100% points. Switch 1 is always considered off. Off = Digital. The controller only detects whether Switch 1 is on or off and does not normalize the input's voltage.
Analog 1 Type [PCF]	0-2	0	Specifies how the Analog 1 input will be used. The parameter also impacts how the Analog 4 input will be used: 0 = Analog 1 is a normal voltage input 1 = Analog 1 and 4 are the pot wiper and pot high inputs (3-wire pot). 2 = Analog 1 is the pot wiper input (2-wire pot).
Nominal Resistance	800Ω-10kΩ	5kΩ	Sets the input's resistance. When the Analog 1 Type value is 1 or 2, this is the resistance expected at the pot's maximum position.
Low	0-12V (24V model) 0-20V (36V or 36/48V model)	0V	Sets the input's minimum voltage. The value represents the 0% point for normalized analog signals. If the input's voltage goes below this threshold the controller generates an Analog 1 Out of Range fault.
High	0-12V (24V model) 0-20V (36V or 36/48V model)	12V	Sets the input's maximum voltage. The value represents the 100% point for normalized analog signals. If the input's voltage goes above this threshold, the controller generates an Analog 1 Out of Range fault.
Filter	1-250Hz	250Hz	Sets the input's low pass filter cutoff frequency. Higher frequencies make the throttle more responsive to quick changes. Lower frequencies make the throttle less responsive to electrical noise.

Analog 2, 3, 4, and 5 Menus

The following table describes the parameters on the Analog 2, Analog 3, Analog 4, and Analog 5 menus.

CONTROLLER SETUP MENU — ANALOG INPUTS MENU — ANALOG 2, 3, 4, AND 5 MENUS

PARAMETER	VALUES	DEFAULT	DESCRIPTION
Enable [PCF]	On/Off	On	Specifies whether the input's signal is analog or digital: On = Analog. The controller normalizes the input's voltage, using the values in the input's High and Low parameters as the 0% and 100% points. Switch n is always considered off. Off = Digital. The controller only detects whether Switch n is on or off and does not normalize the input's voltage.
Low	0-12V (24V model) 0-20V (36V or 36/48V model)	0V	Sets the input's minimum voltage. The value represents the 0% point for normalized analog signals. If the input's voltage goes below this threshold the controller generates an Analog *n* Out of Range fault.
High	0-12V (24V model) 0-20V (36V or 36/48V model)	12V	Sets the input's maximum voltage. The value represents the 100% point for normalized analog signals. If the input's voltage goes above this threshold, the controller generates an Analog *n* Out of Range fault.
Filter	1-250Hz	250Hz	Sets the input's low pass filter cutoff frequency. Higher frequencies make the throttle more responsive to quick changes. Lower frequencies make the input less responsive to electrical noise.

IO Assignment Menu

The IO Assignment menu contains the following menus:

- Controls Menu
- Switch Assignment Menu (page 49)
- Coil Drivers Menu (page 50)
- Misc Menu (page 50)

Controls Menu

Use the Controls parameters to specify the analog inputs for the throttle and speed limit pot. The following table describes these parameters.

CONTROLLER SETUP MENU — IO ASSIGNMENT MENU — CONTROLS MENU

PARAMETER	VALUES	DEFAULT	DESCRIPTION
Throttle Source [PCF]	0-4	1	Specifies the analog input used for the throttle: 0 = *Reserved for future use* 1 = Analog 1 2 = Analog 2 3 = Analog 3 4 = Analog 4
Speed Limit Source [PCF]	0-4	2	Specifies the analog input used for the speed limit pot: 0 = *Reserved for future use* 1 = Analog 1 2 = Analog 2 3 = Analog 3 4 = Analog 4

Switch Assignment Menu

The following table describes the parameters on the Switch Assignment menu.

Note: Table 9 describes the switches' types and primary functions.

CONTROLLER SETUP MENU — IO ASSIGNMENT MENU — SWITCH ASSIGNMENT MENU

PARAMETER	VALUES	DEFAULT	DESCRIPTION
Interlock Switch Source [PCF]	0-13	7	Assigns a function to a switch. Use the switch number as the value. For example, to assign the interlock input to Switch 7, specify 7. If a function is not being assigned to a switch, specify 0.
Forward Switch Source [PCF]		12	
Reverse Switch Source [PCF]		8	
EMR Switch Source NO [PCF]		10	
EMR Switch Source NC [PCF]		3	
Hydraulic Switch Source [PCF]		0	
Load Hold Switch Source [PCF]		0	
Mode Switch Source [PCF]		13	
Push Switch Source [PCF]		9	
Charger Inhibit Switch Source [PCF]		11	

Coil Drivers Menu

The following table describes the parameters on the Coil Drivers menu.

CONTROLLER SETUP MENU — IO ASSIGNMENT MENU — COIL DRIVERS MENU

PARAMETER	VALUES	DEFAULT	DESCRIPTION
Main Contactor Driver (1226-52xx models only) [PCF]	0-3	3	Sets the generic driver for the function: 0 = Do not use a driver for the function. 1 = Driver 1 2 = Driver 2 3 = Driver 3
EM Brake Driver [PCF]		1	
Hydraulic Contactor Driver [PCF]		0	
Load Hold Contactor Driver [PCF]		0	
Aux 1 Contactor Driver [PCF]		0	
Aux 2 Contactor Driver [PCF]		0	

Misc Menu

The following table describes the parameters on the Misc menu.

CONTROLLER SETUP MENU — IO ASSIGNMENT MENU — MISC MENU

PARAMETER	VALUES	DEFAULT	DESCRIPTION
External Status LED Driver [PCF]	0-3	0	Specify the LED driver for the external status LED: 0 = No external status LED 1 = LED 1 driver (Switch 13) 2 = LED 2 driver (Switch 8) 3 = LED 3 driver (Switch 3)
Switch 3 Type [PCF]	0-1	0	Specifies whether the switch is used as an on/off or momentary switch: 0 = On/off switch 1 = Momentary switch If the switch is set as momentary, the switch's integrated LED driver can indicate the current status of the switch, and you cannot use this pin for external status LED output.
Switch 8 Type [PCF]		0	
Switch 13 Type [PCF]		0	

CONTROLLER SETUP MENU — IO ASSIGNMENT MENU — REDUNDANCY INPUTS

PARAMETER	VALUES	DEFAULT	DESCRIPTION
Switch 1-13 Redundancy Checks Enable	On / Off	On	On = switch 1 checks with redundancy checks features; Off = redundancy checks feature is disabled.

Outputs Menu

The Outputs menu contains the Driver 1, Driver 2, and Driver 3 menus.

Driver 1, Driver 2, and Driver 3 Menus

The following table describes the parameters on the Driver 1, Driver 2, and Driver 3 menus.

CONTROLLER SETUP MENU — OUTPUTS MENU — DRIVER 1, DRIVER 2, AND DRIVER 3 MENUS

PARAMETER	VALUES	DEFAULT	DESCRIPTION
Driver 2 Type (Driver 2 only) [PCF]	0-2	2	Sets whether Driver 2 is disabled, high side, or low side: 0 = Disable 1 = High side 2 = Low side
Driver *n* Checks Enable	On/Off	Off	Sets whether the controller reports the Driver n fault if the controller detects an open coil: On = Check Off = Don't check
Driver *n* Compensation	On/Off	Off	Specifies whether the controller adjusts the driver's pull-in and holding voltages to compensate for differences between the nominal and actual voltages: On = Enable compensation Off = Disable compensation

Current Limits Menu

The following table describes the parameters on the Current Limits menu.

Note: The percentages are of the controller's fully rated current. See Table 35

CONTROLLER SETUP MENU — CURRENT LIMITS MENU

PARAMETER	VALUES	DEFAULT	DESCRIPTION
Mode 1 Drive Current Limit	20-100%	100%	Sets the maximum current the controller supplies to the motor while driving. You can set different limits for speed modes 1 and 2. **Note:** Reducing the current limit will reduce the maximum drive torque.
Mode 2 Drive Current Limit	20-100%	100%	
Boost Enable	On/Off	On	Enables or disables the Boost Current feature, which provides a brief boost of current to maintain performance when the vehicle encounters transient loads. For example, the controller might boost the current when the vehicle starts on a hill or crosses an obstacle. The Boost Current Limit and Boost Time parameters define the current for and duration of boost operations.
Boost Current Limit	100-120%	120%	Specifies the current supplied by the controller during boost operations.
Boost Time	0-10s	10s	Specifies the maximum duration of boost operations.
Regen Current Limit	20-100%	50%	Sets the maximum current the controller supplies to the motor during regenerative operation when regen occurs while the vehicle is braking.
Brake Current Limit	20-100%	100%	Sets the maximum current the controller supplies to the motor during brake operation. **Note:** "Brake operation" means that operator applies the throttle in the direction opposite to which the vehicle is traveling.
EMR Current Limit	20-100%	50%	Sets the maximum current the controller supplies to the motor during emergency reverse.

Motor Setup Menu

The Motor Setup menu contains the following menus:

The following topics describe these menus.

Motor Menu

The following table describes the parameters on the Motor menu.

MOTOR SETUP MENU — MOTOR MENU

PARAMETER	VALUES	DEFAULT	DESCRIPTION
System Resistance	0-800mΩ	50mΩ	Sets the resistance that the controller will use for load compensation and speed estimation. The system resistance is the overall amount of resistance for the motor, brushes, wiring, and connections. The controller's performance depends upon an accurate System Resistance value. To calculate the correct value, see Set the System Resistance on page 64.
Resistance Auto Comp	On/Off	Off	Sets whether the controller automatically measures motor resistance before the brake is released. To measure the resistance, the controller uses the current limit specified by the Auto Comp Current Limit parameter. **Note:** The measured motor resistance plays an important role in IR compensation.
Auto Comp Current Limit	5-50%	30%	Sets the current limit the controller uses to automatically measure motor resistance. The value is a percentage of the controller's 1 minute current rating. See Table 35 on page 91.
Speed Scaler	20-35V (24V model) 20-45V (36V model) 20-55V (36/48V model)	27V (24V model) 40V (36V model) 52V (36/48V model)	Sets the maximum voltage that the controller can apply to the motor. This parameter eliminates variations in maximum speed that would otherwise occur when driving with a fully charged battery versus a partially discharged battery. For example, if Speed Scaler is set to 23V, the maximum vehicle speed will be the same when the actual battery voltage is at any voltage between 23V and the overvoltage threshold.
Current Rating	10%-100%	40%	Specifies the motor's current rating as a percentage of the controller's current rating. Use the current rating provided by the motor's manufacturer. For example, if the motor's current rating is 65A and the controller's 1 minute current rating is 130A, the parameter should be set to 50%.
Max Current Time	0-120s	120s	Sets the maximum amount of time the motor is allowed to run at the Mode 1/2 Drive Current Limit.
Cutback Gain	0-100	0%	Specifies how quickly the controller cuts back the drive current to the motor's current rating when the motor overheats. The cutback occurs after the Max Current Time expires. A higher value provides a quicker cutback.
Fault Stall Time	1-32s	5s	Sets the time, in seconds, between when the vehicle stalls and when the controller reports the Stall Detected fault.

Compensation Menu

Use the Compensation parameters to configure the motor resistance that the controller applies to compensate for the following conditions:

- Increased load caused by uneven terrain.
- The operator releases the throttle to neutral at near-zero speeds while the vehicle is on a slope.

The following table describes the parameters on the Compensation menu.

Note: For steps on configuring these parameters, see Adjust IR Compensation on page 68.

MOTOR SETUP MENU — COMPENSATION MENU

PARAMETER	VALUES	DEFAULT	DESCRIPTION
IR Comp	0-100%	70%	Sets the resistance that the controller applies to compensate for increased load caused by uneven terrain. The value is a percentage of the System Resistance parameter. See page 52. Higher values increase the vehicle's ability to overcome load disturbances, while lower values provide smoother operation.
Anti-Rollback Comp	0-125%	90%	Sets the resistance that the controller applies to prevent rollback when the operator releases the throttle to neutral while the speed is near zero. The value is a percentage of the System Resistance parameter. Higher values provide more hill-holding force.

Speed Sensor Menu

The following table describes the parameters on the Speed Sensor menu. For more information on using a speed sensor, see page 25.

MOTOR SETUP MENU — SPEED SENSOR MENU

PARAMETER	VALUES	DEFAULT	DESCRIPTION
Speed Sensor Enable [PCF]	On/Off	Off	Specifies whether the speed sensor function is on. When Speed Sensor Enable is on, Analog 6 is used as the sensor's input and Switch 6's state is always off.
Limit Max Speed	On/Off	On	Specifies whether the controller uses the speed sensor to limit the vehicle's maximum speed. The Max Speed parameter defines the maximum speed.
Encoder Fault Threshold	5-50%	25%	Sets the threshold above which the controller will report an Encoder Fault. The controller reports this fault when the motor's duty cycle is higher than the threshold and the controller does not receive any pulses from the speed sensor.
Pulses/Rev	1-32	16	Sets the speed sensor's pulses per revolution. The controller uses this value to calculate the vehicle speed.
Max Speed	100-6000 RPM	3000 RPM	Sets the maximum speed of the motor, in RPM, to which the controller limits the vehicle when Limit Max Speed is on. **Note:** To monitor the vehicle speed, use the Motor RPM field; see page 59.

MOTOR SETUP MENU — SPEED SENSOR MENU, cont'd

PARAMETER	VALUES	DEFAULT	DESCRIPTION
Kp	0-100%	20%	Specifies how aggressively the controller attempts to limit the motor speed to the Max Speed. Larger values provide a shorter response time. Following are some guidelines: • If the value is too high, the vehicle might oscillate when the controller tries to limit the speed. • If the value is too low, the vehicle could significantly exceed the Max Speed.
Ki	0-100%	20%	Specifies the integral gain used to force a zero steady state error to limit the motor to the Max Speed. Larger values provide a shorter response time. Following are some guidelines: • If the value is too high, the vehicle might oscillate when the controller tries to limit the speed. • If the value is too low, the controller could take a long time to reduce motor speed to the Max Speed.

Motor Temperature Control Menu

The following table describes the parameters on the Motor Temperature Control menu. For more information on using a motor temperature sensor, see page 26.

MOTOR SETUP MENU — MOTOR TEMPERATURE CONTROL MENU

PARAMETER	VALUES	DEFAULT	DESCRIPTION
Sensor Enable [PCF]	On/Off	Off	Specifies whether the motor temperature control function is enabled: When Sensor Enable is on, the controller will apply the motor temperature control features when the motor temperature is between the Temperature Hot and Temperature Max temperatures.
Sensor Type	1-5	3	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 If these 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. **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	–20°C – 20°C	0°C	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: • When a sensor is placed in the motor at a location with a known offset to the critical temperature. • When the sensor itself has a known offset.

MOTOR SETUP MENU — MOTOR TEMPERATURE CONTROL MENU, cont'd

PARAMETER	VALUES	DEFAULT	DESCRIPTION
Braking Thermal Cutback Enable	On/Off	Off	Sets 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, direction reversal braking, neutral braking, and speed limit braking. Off = The controller does not cut back regen braking currents. Regardless of whether this parameter is on or off, the controller cuts back on the drive current if the motor reaches the Temperature Hot threshold. **Note:** If the vehicle has mechanical brakes, turning this parameter on might help reduce motor heating.
Temperature Hot	0-250°C	145°C	Specifies the temperature at which the controller starts cutting back current.
Temperature Max	0-250°C	160°C	Specifies the temperature at which the controller cuts back all current.
Motor Temp LOS Max Speed	0-100%	50%	Specifies the maximum speed for a vehicle when the controller generates a Motor Temp Sensor fault. 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) by reducing the maximum speed by the specified percentage.

4 — MONITOR MENU

The Monitor menu lets you use Curtis programming devices to observe real-time data for the vehicle. You can use this data when you are configuring programmable parameters and troubleshooting the system. For information on programming devices, see page 90.

The Monitor menu contains the following menus:

CONTROLLER MENU

The following table describes the fields on the Controller menu.

MONITOR MENU — CONTROLLER MENU

FIELD	VALUES	DESCRIPTION
Armature PWM	0-100%	Indicates the controller output's duty cycle.
Armature Current	0-150A	Indicates the controller's phase current.
Current Limit	0-150A	Indicates the controller's current limit.
Controller Temp Cutback	*0-100%*	Displays the current available as a result of the temperature cutback function. The value is a percentage of the Current Limit. 100% indicates the controller isn't cutting back on current.
Overvoltage Cutback	0-100%	Indicates the current available due to overvoltage cutback. 100% indicates the controller isn't cutting back current.
Undervoltage Cutback	0-100%	Indicates the current available due to undervoltage cutback. 100% indicates the controller isn't cutting back current.
Motor Temp Cutback	0-100%	Indicates the current available due to motor temperature control cutback. 100% indicates the controller isn't cutting back current.
Temperature	–40°C – 120°C	Indicates the controller's internal temperature.
Master Timer	0–429496729.5s	Indicates the total time, in seconds, that the controller has been powered on during its lifetime. This value cannot be reset.
Throttle Command	–100% – 100%	Indicates the requested speed. **Note:** The speed request is impacted if the controller has a fault or is applying a limited operating strategy (LOS) or emergency reverse speed.
Forward	On/Off	Indicates whether the forward direction is selected.
Reverse	On/Off	Indicates whether the reverse direction is selected.
Mode	1-2	Indicates the active speed mode.
Interlock	On/Off	Indicates whether the interlock is on.

MONITOR MENU — CONTROLLER MENU, cont'd

FIELD	VALUES	DESCRIPTION
Charger Inhibit	On/Off	Indicates whether the charger inhibit function is active.
Lift Lockout	On/Off	Indicates whether the hydraulic lift lockout function is active. The Lift Lockout Threshold parameter specifies the battery level at which the controller activates hydraulic lift lockout. See page 42.
Emer Rev	On/Off	Indicates whether the emergency reverse function is active.
Hydraulic Input	On/Off	Indicates whether the hydraulic function is active.
Load Hold Input	On/Off	Indicates whether the load hold function is active.
Push Status	0-255	Indicates the status of the push function.
Mismatch Error	0-255	Indicates the mismatch type if a Parameter Mismatch fault is active. The following list describes the parameter values: 1 = The throttle deadband is misconfigured. For example, this fault would occur if the value of the Forward Deadband parameter is greater than the value of the Forward Max parameter. 3 = The Aux 1 or Aux 2 output is configured as the belly button check output, but Driver 2 is not set as a high side driver. 4 = The speed mode's Max Speed parameter is less than its Min Speed parameter. 5 = The EMR Input Type specifies complementary switches but the NO or NC switch is not assigned. 6 = The Aux 1 and Aux 2 drivers are being used by the same function. Values other than those listed above are reserved for future use.
Supervision Error	*0-65535*	If a Supervision fault is active, this field provides diagnostic information on the fault's cause. See Table 29.

Table 29 Supervision Error Field Values

Value	Description
200	The primary and supervisory microprocessors' keyswitch input voltages do not match.
301	The primary and supervisory microprocessors' Switch 1 statuses do not match.
302	The primary and supervisory microprocessors' Switch 2 statuses do not match.
303	The primary and supervisory microprocessors' Switch 3 statuses do not match.
304	The primary and supervisory microprocessors' Switch 4 statuses do not match.
305	The primary and supervisory microprocessors' Switch 5 statuses do not match.
306	The primary and supervisory microprocessors' Switch 6 statuses do not match.
307	The primary and supervisory microprocessors' Switch 7 statuses do not match.
308	The primary and supervisory microprocessors' Switch 8 statuses do not match.
309	The primary and supervisory microprocessors' Switch 9 statuses do not match.
310	The primary and supervisory microprocessors' Switch 10 statuses do not match.
311	The primary and supervisory microprocessors' Switch 11 statuses do not match.
312	The primary and supervisory microprocessors' Switch 12 statuses do not match.
313	The primary and supervisory microprocessors' Switch 13 statuses do not match.

BATTERY MENU

The following table describes the fields on the Battery menu.

MONITOR MENU — BATTERY MENU

FIELD	VALUES	DESCRIPTION
BDI	0-100%	Indicates the battery's state of charge For more information, see BDI Setup Menu on page 41.
Keyswitch Voltage	0-80V	Indicates the keyswitch voltage.
Capacitor Voltage	0-80V	Indicates the voltage of the controller's internal capacitor.

OUTPUTS MENU

The following table describes the fields on the Outputs menu.

MONITOR MENU — OUTPUTS MENU

FIELD	VALUES	DESCRIPTION
Main Contactor Driver PWM	0-100%	Indicates the main contactor's PWM output.
EM Brake Driver PWM	0-100%	Indicates the electromagnetic brake's PWM output request.
Hydraulic Contactor Driver PWM	0-100%	Indicates the hydraulic contactor driver's PWM output request.
Load Hold Contactor Driver PWM	0-100%	Indicates the load hold contactor driver's PWM output request.
Aux 1 Contactor Driver PWM	0-100%	Indicates the Aux 1 driver's PWM output request.
Aux 2 Contactor Driver PWM	0-100%	Indicates the Aux 2 driver's PWM output request.
Horn Driver Status	On/Off	Indicates the horn driver's status.
Driver 1 PWM	0-100%	Indicates the actual duty cycle of Driver1.
Driver 2 PWM	0-100%	Indicates the actual duty cycle of Driver2.
Driver 3 PWM	0-100%	Indicates the actual duty cycle of Driver3.
External 5 Volts	0.0-6.0V	Indicates the voltage of the external +5V output.
External 14 Volts	0.0-16.0V	Indicates the voltage of the external +14V output.

MOTOR MENU

The following table describes the fields on the Motor menu.

MONITOR MENU — MOTOR MENU

FIELD	VALUES	DESCRIPTION
Motor Temperature	–40 – 250°C	Indicates the temperature read by the temperature sensor.
Motor Speed Percentage	0%-100%	Indicates the motor speed. 100% represents the motor speed when the voltage drop on the motor armature is greater than or equal to the Speed Scaler parameter's voltage.
Motor RPM	–6000 – 6000 RPM	Indicates the motor speed detected by the speed sensor.
Motor Resistance Used	0-32767mΩ	Indicates the motor resistance used by the controller. When the Motor Resistance Measured value changes, the controller gradually updates the Motor Resistance Used value.
Motor Resistance Measured	0-32767mΩ	Indicates the motor resistance detected by the controller. This value will differ from the Motor Resistance Used value when the Resistance Auto Comp parameter is on. See page 52.
Max Speed Limit	On/Off	Indicates whether the vehicle's speed exceeds the speed limit specified with the Max Speed parameter (page 53): On = The vehicle is exceeding the speed limit. Off = The vehicle is at or below the speed limit.

INPUTS MENU

The Inputs menu contains the following menus:

- Switches Menu
- Analog Inputs Menu (page 61)
- Control Inputs Menu (page 61)

Switches Menu

The following table describes the fields on the Switches menu.

MONITOR MENU — INPUTS MENU — SWITCHES MENU

FIELD	VALUES	DESCRIPTION
Switch 1	On/Off	Indicates the switch's state.
Switch 2	On/Off	Indicates the switch's state.
Switch 3	On/Off	Indicates the switch's state. Switch 3 is active low. When connected to B–, the status is ON.
Switch 4	On/Off	Indicates the switch's state.
Switch 5	On/Off	Indicates the switch's state.
Switch 6	On/Off	Indicates the switch's state.
Switch 7	On/Off	Indicates the switch's state.
Switch 8	On/Off	Indicates the switch's state.
Switch 9	On/Off	Indicates the switch's state.
Switch 10	On/Off	Indicates the switch's state.
Switch 11	On/Off	Indicates the switch's state.
Switch 12	On/Off	Indicates the switch's state.
Switch 13	On/Off	Indicates the switch's state.

Analog Inputs Menu

The following table describes the fields on the Analog Inputs menu.

MONITOR MENU — INPUTS MENU — ANALOG INPUTS MENU

FIELD	VALUES	DESCRIPTION
Throttle Pot Percent	0-100%	Indicates the amount of throttle voltage or resistance as a percentage of full throttle.
Mapped Throttle Percent	0-100%	Indicates the controller output for the throttle request as a percentage of the maximum output. The value depends upon the Forward Map and Reverse Map parameters. For example, if Forward Map is 50%, the Mapped Throttle Percent and Throttle Pot Percent values will have a linear relationship. See Throttle Menu on pages 33-34.
Speed Limit Pot Percent	0-100%	Indicates the wiper voltage of the speed limit pot as a percentage of the maximum voltage allowed for the speed limit pot's analog input.
Analog 1 Voltage **Analog 2 Voltage** **Analog 3 Voltage** **Analog 4 Voltage** **Analog 5 Voltage** **Analog 6 Voltage**	0.0V – 12.0V	Indicates the analog input's voltage.
Analog 1 Percent **Analog 2 Percent** **Analog 3 Percent** **Analog 4 Percent** **Analog 5 Percent** **Analog 6 Percent**	0-100.0%	Indicates the normalized analog input.

Control Inputs Menu

The following table describes the fields on the Control Inputs menu.

MONITOR MENU — INPUTS MENU — CONTROL INPUTS MENU

FIELD	VALUES	DESCRIPTION
Interlock Input	On/Off	Indicates the input's state.
Forward Input	On/Off	Indicates the input's state.
Reverse Input	On/Off	Indicates the input's state.
Mode Input	On/Off	Indicates the input's state.
EMR NO Input	On/Off	Indicates the input's state.
EMR NC Input	On/Off	Indicates the input's state. **Note:** The EMR NC input is a normally closed input, so the polarity (On/Off) between EMR NC and the assigned switch is reversed.
Hydraulic Input	On/Off	Indicates the input's state.
Load Hold Input	On/Off	Indicates the input's state.
Push Input	On/Off	Indicates the input's state.
Charger Inhibit Input	On/Off	Indicates the input's state.

5 — INITIAL SETUP

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

Step 1: 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. Doublecheck all wiring to ensure that it is consistent with the wiring guidelines. See Installation and Wiring on page 4.
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. Plug the programming device into the controller. The programmer 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 2: 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 » Application Setup » Throttle to access the throttle-related parameters. See Throttle Menu on pages 33-34.
2. Set the Direction Source parameter to match the vehicle's throttle type.
3. Tune the deadband by performing the steps in Configure the Deadband on page 63.
4. Configure the wiper voltage required to produce 100% controller output by performing the steps in Configure the Wiper Voltage on page 63.
5. Verify that the throttle is correctly configured. See Confirm Throttle Operation on page 64.

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. Select Monitor » Inputs » Analog Inputs.
2. Apply full throttle and observe the Mapped Throttle Percent value. This value should be 100% at full throttle. If the Mapped Throttle Percent value is less than 100%, perform the following steps:
   a. Select Program » Application Setup » Throttle.
   b. Decrease the Forward Max value.
   c. Apply full throttle and observe the Mapped Throttle Percent value.
   d. If the value is less than 100%, repeat these steps until the value is 100%.
3. Slowly reduce the throttle until the Mapped Throttle Percent value drops below 100%, then note the throttle position.

   The throttle position represents the extra range of motion allowed by the throttle mechanism. If the extra range is too large, you can increase the throttle's active range and provide more vehicle control by taking the following steps.

   a Select Program » Application Setup » 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 begin to rotate in the selected direction. 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 pages 33-34.

⚠ CAUTION

The polarity of the motor's M1 and M2 connections affects the operation of the emergency reverse feature. The forward and reverse switches and the M1 and M2 connections must be configured so that the vehicle drives away from the operator when the emergency reverse switch (the belly button switch) is activated.

Step 3: Verify the Vehicle's Configuration

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

1. Select Monitor » Inputs » Switches.
2. Cycle each switch and make sure that the switch state changes from on to off, or vice versa.
3. Select Monitor » Inputs » Analog Inputs.
4. Turn the speed limit pot, then verify that the Speed Limit Pot Percent field changes.
5. Apply the throttle, then verify that the Throttle Pot Percent field changes.
6. Verify that you've correctly set the functions meeting the vehicle's requirements, such as emergency reverse, HPD, and so on.
7. Verify the Charger Inhibit Input Source parameter (page 49) is correctly set by plugging in the charger and applying the throttle. If the motor does not run, the parameter is correctly set.
8. After you have validated the parameter settings, lower the vehicle drive wheels onto the ground.

Step 4: Set the System Resistance

It is critical that you accurately set the System Resistance parameter. To do so, take the following steps.

Note: You must perform these steps quickly and with the motor cold. Performing these steps with a warm motor will result in incorrect settings. If you need to repeat these steps, allow ample time for the motor to completely cool.

1. Position the vehicle up against an immovable object such as a wall or high curb.
2. Plug the programmer into the controller.
3. Turn the keyswitch on.
4. Select Program » Controller Setup » Current Limits.
5. Set Boost Enable to Off.
6. Set the Auto Comp Current Limit parameter to 30%.
7. Select Monitor » Motor.

Note: You'll monitor the Motor Resistance Measured field in the following steps. For safety consideration, the Motor Resistance Measured value is clamped to two times or half of the parameter System Resistance. If Resistance Measured is clamped, customer need to adjust System Resistance to an appropriate value according to motor manufacture.

8. With the speed limit pot set at maximum, apply the throttle full forward, driving the vehicle against the immovable object.
9. Note the Motor Resistance Measured field's value.
10. Repeat steps 8 and 9 three more times.
11. Select Program » Motor Setup » Motor.
12. Set the Resistance Auto Comp parameter to On.
13. Set the System Resistance parameter to the average of the 4 Motor Resistance Measured values.
14. Before tuning the vehicle as described on page 66, reset the following parameters to their original values:
    - Auto Comp Current Limit
    - Resistance Auto Comp
    - Boost Enable

6 — TUNING VEHICLE PERFORMANCE

You can customize many aspects of vehicle performance by adjusting the 1226 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.

You must understand the programmable parameters to take advantage of the controller's features; see page 27.

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

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

The controller's maximum and minimum speed parameters define the speed at the speed limit pot's maximum and minimum positions. 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 minimum and maximum speeds for both speed modes. For information on these parameters, see Mode 1 and Mode 2 Menus on page 28:

- Min Speed
- Rev Min Speed
- Max Speed
- Rev Max 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 1226 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 Understanding Low and High Speed Acceleration on page 31.

1. Select Program » Application Setup » 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 » Application Setup » 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 parameters until you are satisfied with the vehicle's low speed acceleration.
    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 parameters 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 parameters 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 parameters 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:

- Optimize the response smoothness by performing the steps in Fine-tune the Vehicle's Response Smoothness on page 69.
- 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 Understanding Low and High Speed Brake Deceleration Rates on page 32.

Step 3: Configure the Key Off Deceleration Rate

You can configure the rate at which a vehicle decelerates when the vehicle is turned off while it is moving. When the key is switched off or a major fault occurs, the controller slows down the vehicle by the specified rate.

To adjust the key off deceleration rate, take the following steps.

1. Drive at a high speed, then turn the key off. The vehicle should decelerate as quickly as possible but without making the vehicle unstable.
2. If you are not satisfied with the deceleration, adjust it by performing the following steps.
    a. Select Program » Application Setup » Speed Mode » Other.
    b. Adjust the Key Off Decel parameter; see page 29.
    c. Repeat these steps until you are satisfied with the deceleration rate.

Step 4: Adjust IR Compensation

Use the IR Comp and Anti-Rollback Comp parameters to configure the motor resistance that the controller applies to compensate for the following conditions:

- Increased load caused by uneven terrain. (IR Comp)
- The throttle is released to neutral and the vehicle speed is near zero. (Anti-Rollback Comp)

For details on these parameters, see Compensation Menu on page 53.

The values of both parameters are percentages of the System Resistance parameter. These parameters thus rely on the System Resistance parameter being set correctly; see page 64.

Configuring the IR Comp parameter involves a trade-off. When you increase the vehicle's ability to overcome load disturbances, the vehicle's operating smoothness decreases, as described below:

- A properly set IR Comp value allows the vehicle to continue creeping at low speed if the vehicle contacts a bump in a doorway's threshold.
- However, if the IR Comp value is too high, the vehicle will be jumpy during normal driving. Small throttle movements will no longer provide gentle linear acceleration, but instead will initiate accelerations with a sharp jerk.

The tuning goal is to find a balance between adequate load response and normal acceleration and deceleration response.

The typical IR Comp range is 50%–80%. If you find that you can only achieve acceptable performance by setting IR Comp outside the 50%–80% range, the System Resistance parameter is probably configured incorrectly.

Note: Significant changes to the IR Comp value will affect the minimum and maximum speeds that you previously set. If you make significant changes to IR Comp, it is recommended that you repeat the steps in this chapter.

The controller applies anti-rollback compensation just before the vehicle stops when the throttle is released to neutral. Anti-Rollback Comp is typically set about 20% higher than IR Comp.

Table 30 provides guidelines for adjusting these parameters.

Table 30 IR Comp and Anti-Rollback Comp Guidelines

Issue	Diagnosis
The vehicle is extremely jumpy. In other words, the vehicle responds abruptly to small throttle changes.	IR Comp is probably set too high.
The vehicle speed varies dramatically when cresting a hill.	IR Comp is probably set too low.
The vehicle rolls the other direction near the end of a stop on flat ground.	Anti-Rollback Comp is probably set too high.
The vehicle is still moving on a modest ramp when the EM brake is applied.	Anti-Rollback Comp is probably set too low.
The vehicle seems to decelerate to a stop in a nonlinear fashion.	Anti-Rollback Comp is probably set too high.

Step 5: Fine-tune the Vehicle's Response Smoothness

You can soften and smooth vehicle response by configuring the Gear Soften and Soft Start parameters:

- Gear Soften defines how the vehicle decelerates when the throttle is released to neutral and accelerates when the throttle is reapplied.
- Soft Start defines how the vehicle accelerates when starting from neutral.

For details on these parameters, see Other Menu on page 29.

Note: The Gear Soften and Soft Start parameters have the most noticeable effect on older, worn transaxles.

To tune the vehicle's response smoothness, take the following steps.

1. Select Program » Application Setup » Speed Mode » Other.
2. Set Gear Soften to 0%.
3. Set Soft Start to 0%.
4. Configure the Gear Soften parameter by taking the following steps:
    a. While driving at both high and low speeds, release the throttle to neutral, then reapply the throttle before coming to a complete stop. Notice how the transaxle gears bump as you reapply the throttle.
    b. Change Gear Soften from 0% to 100% and repeat the previous step. Notice how increasing the parameter softens the slope transition while adding a small amount of nonlinearity to the acceleration rate.
    c. Set Gear Soften to a value that you think will provide the desired softening and acceleration or deceleration.
    d. While driving at both high and low speeds, release the throttle to neutral, then reapply the throttle before coming to a complete stop.
    e. Repeat the previous two steps until the vehicle drives smoothly and with a high degree of responsiveness.

Some users prefer a softened feel, while others set Gear Soften to 0% because they prefer a linear vehicle response. When you set this parameter, take into consideration that softened slack take-up is easier on the transaxle gears and may extend the transaxle operating life.

Note: You probably won't notice much of a difference if you're using a brand new, tight transaxle.

5. Configure Soft Start by taking the following steps.

    a. Release the vehicle to neutral.

    b. Apply full throttle. Notice how the transaxle gears bump when you apply the throttle.

Note: You'll feel a transaxle bump only if the gears are meshed in the opposite direction when torque is applied. You may need to nudge the vehicle backwards against the brake when experimenting with this parameter.

    c. Release the vehicle to neutral.

    d. Set Soft Start to 40%.

A Soft Start value between 0%-40% is recommended. Values in the 0%-40% range avoid excessive delay when starting from neutral.

    e. Apply full throttle. Notice how increasing the parameter softens the vehicle startup while adding a small amount of nonlinearity to the acceleration rate.

    f. Repeat the previous steps until you are satisfied with the way the vehicle accelerates from neutral.

These setup and tuning procedures cover the most critical aspects of vehicle performance. Additional parameters can be used to make further adjustments, if necessary. See Programmable Parameters on page 27.

7 — 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:

Note: For more information on the parameters you'll use, see BDI Setup Menu on page 41.

Step 1: Set Parameters to Initial Values

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

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

Table 31 Parameters for Configuring BDI

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 field.
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 1226 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 steps:

- 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.

8 — DIAGNOSTIC AND TROUBLESHOOTING

The 1226 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.

For information on programming devices, see page 90.

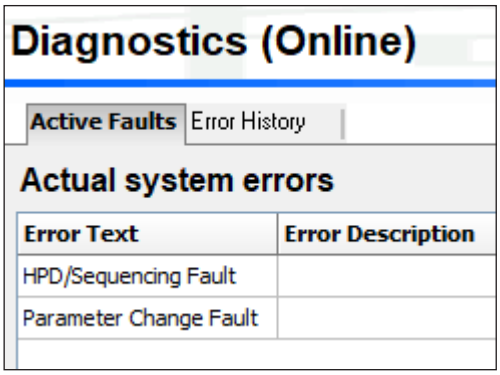
PROGRAMMING DEVICE DIAGNOSTICS

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 page 56.
- Active faults and a history of faults are displayed in the Diagnostics menu.

For example, Figure 13 shows that the HPD/Sequencing and Parameter Change faults are active.

Figure 13
Diagnostics Menu Faults



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

LED DIAGNOSTICS

The 1226 controller has red and yellow status LEDs. Table 32 describes how the LEDs indicate the controller's status.

Table 32 LED Statuses

Status	Red Light	Yellow Light
OK	Off	The flash cycle is 1.5s. The LED blinks for 500ms, followed by a 1s delay.
Downloading Firmware	On	On
Nonoperational	On	Off
Fault	Flashes the first digit of the fault code.	Flashes the second digit of the fault code. For details, see the following section.
Invalid Software	Fast Flash	Off

Fault Codes

Fault codes consist of two digits, with the digits delimited by a comma. For example, the Parameter Change fault's code is 5,2.

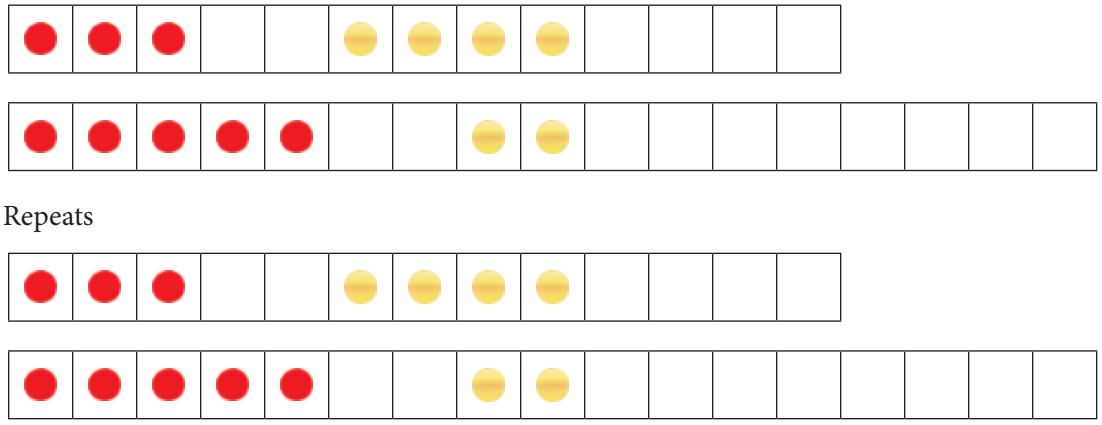
The red status LED shows the fault code's first digit and the yellow LED shows the second digit. The fault LEDs' flash cycle operates as follows:

- The red LED is on for 250ms, followed by a 250ms delay.
- The yellow LED is on for 250ms, followed by a 250ms delay.
- A 2s delay occurs, then the cycle is repeated until the fault is cleared.

If there are multiple active faults, the controller flashes each fault code using the sequence described above. After fault codes for all active faults have been flashed, an additional 2s follows the last fault code.

Figure 14 shows how the status LEDs flash when both the 3,4 and 5,2 faults are active. Each block in the diagram represents 500ms.

Figure 14
Fault Code LEDs



Note: Fault codes are described in Table 33.

External Status LED

One of the controller's LED drivers can be used to display fault codes with an LED in the operator's control panel. During normal operation the status LED is steadily on.

If a fault is active, the external status LED continuously flashes the fault code until the fault is cleared. The flash sequence operates as follows:

- The first digit is flashed, with 0.13s between flashes.
- A 1.1s delay occurs.
- The second digit is flashed, with 0.13s between flashes.
- A 3.57s delay occurs, then the sequence repeats until the fault is cleared.

To enable the external status LED, you must configure the External Status LED Enable and External Status LED Driver parameter. See pages 46 and 50 respectively.

Note: Vehicles can use the horn to sound the fault codes. To enable audible fault codes, set the Type parameter on the Horn menu. See page 44.

Troubleshooting Faults

When the controller detects a fault, the controller operates in a manner that is safe in the presence of that fault. Depending on the severity of the fault, the 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.

Table 33 describes the fault codes and how to troubleshoot them.

Note: The Fault and Fault Action column includes both the fault name and the actions the controller takes when the fault is detected.

Table 33 Faults

Code	Fault and Fault Action	Possible Causes	Set and Clear Conditions
1,2	Controller Overcurrent *ShutdownMotor* *ShutdownMainContactor* *ShutdownEMBrake* *ShutdownThrottle*	• External short of phase M1 or M2 motor connections. • The controller is defective.	**Set:** The phase current exceeds the current limit. **Clear:** Check the connections, then cycle the keyswitch.
1,3	Current Sensor *ShutdownMotor* *ShutdownMainContactor* *ShutdownEMBrake* *ShutdownThrottle*	The controller is defective.	**Set:** The controller's current sensors have invalid offset readings. **Clear:** Cycle the keyswitch.
1,4	Precharge Failed *ShutdownMotor* *ShutdownMainContactor* *ShutdownEMBrake* *ShutdownThrottle*	• An external load on the capacitor bank (Brake+ connection terminal or B+ connection terminal for the external contactor model) prevents the capacitor bank from charging. • The controller is defective	**Set:** The precharge failed to charge the capacitor bank. **Clear:** Cycle the keyswitch.
1,5	Controller Severe Undertemp *ShutdownMotor* *ShutdownMainContactor* *ShutdownEMBrake* *ShutdownThrottle*	The controller is operating in an extremely cold environment.	**Set:** The heatsink temperature is below –40°C. **Clear:** Raise the heatsink temperature to above –40°C, then cycle the keyswitch.
1,6	Controller Severe Overtemp *ShutdownMotor* *ShutdownMainContactor* *ShutdownEMBrake* *ShutdownThrottle*	The controller is operating in an extremely hot environment.	**Set:** The heatsink temperature is above 85°C. **Clear:** Decrease the heatsink temperature to below 85°C, then cycle the keyswitch.
1,7	Severe B+ Undervoltage *Current limit decreases to 0*	• A system other than the controller is draining the battery. • The battery resistance is too high. • The battery is disconnected. • The B+ fuse is blown. • The main contactor did not close. • Undervoltage parameters are incorrectly configured.	**Set:** The voltage is below the Severe Undervoltage threshold. **Clear:** Address the possible causes, then cycle the keyswitch.
1,9	Severe B+ Overvoltage *ShutdownMotor* *ShutdownMainContactor* *ShutdownEMBrake* *ShutdownThrottle*	• The user overvoltage parameter is incorrectly configured. • The battery resistance is too high for the regen current. • The battery disconnected during regen braking.	**Set:** The voltage is above the Severe Overvoltage threshold. **Clear:** Address the possible causes, then cycle the keyswitch.
2,3	Controller Overtemp Cutback *Reduced drive torque* *Reduced regen braking torque*	• 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.	**Set:** The controller's heatsink temperature exceeded 75°C. **Clear:** Address the possible causes.

Table 33 Faults, cont'd

Code	Fault and Fault Action	Possible Causes	Set and Clear Conditions
2,4	Undervoltage Cutback *Reduced drive torque*	• The batteries need recharging. • The undervoltage parameters are incorrectly configured. • A system other than the controller is draining the battery. • The battery resistance is too high. • The battery is disconnected. • The B+ fuse is blown. • The main contactor did not close.	**Set:** The capacitor bank voltage dropped below the Undervoltage threshold. **Clear:** Address the possible causes.
2,5	Overvoltage Cutback *Reduced brake torque.*	• The regen braking current elevated the battery voltage. • The User Overvoltage parameter is incorrectly configured. • The battery resistance is too high for the regen current. • The battery disconnected during regen braking. **Note:** The controller generates this fault only during regen braking.	**Set:** The controller's capacitor bank voltage exceeded the Overvoltage threshold. **Clear:** Address the possible causes.
2,6	Ext 5V Supply Failure *Disable the 5V and 14V supply*	The external load impedance on the 5V power supply is too low.	**Set:** The power supply's voltage is outside the range of 4.5V-6V. **Clear:** Adjust the external load and cycle the keyswitch.
2,7	Ext 14V Supply Failure *Disable the 5V and 14V supply*	The external load impedance on the 14V power supply is too low.	**Set:** The power supply's voltage is outside the range of 12V-16V. **Clear:** Adjust the external load and cycle the keyswitch.
2,8	Motor Temp Hot Cutback *Reduced drive torque* *If the Braking Thermal Cutback Enable parameter is On, regen braking torque is reduced.*	• The motor temperature is at or above the temperature specified with the Temperature Hot parameter. • The Temperature Hot parameter is incorrectly configured.	**Set:** The motor temperature is at or above the Temperature Hot parameter setting. **Clear:** Take one of the following steps: • Cool the motor until its temperature is below the Temperature Hot parameter value. • Adjust the Temperature Hot parameter. See Motor Temperature Control Menu on page 54.
2,9	Motor Temp Sensor Fault *MaxSpeed reduced (LOS, Limited Operating Strategy)* *Motor temperature cutback disabled.*	• The motor thermistor is incorrectly connected. • The sensor polarity between pins J1-5 and J1-6 is incorrect. • The motor temperature and sensor parameters are incorrectly configured. See Motor Temperature Control Menu on page 54.	**Set:** The resistance of the motor thermistor input (J1-6) is lower than 100Ω or greater than 10kΩ. **Clear:** Address the possible causes.

Table 33 Faults, cont'd

Code	Fault and Fault Action	Possible Causes	Set and Clear Conditions
2,10	Main Driver *ShutdownMotor* *ShutdownMainContactor* *ShutdownEMBrake* *ShutdownThrottle*	• The main driver is open or shorted. • The controller's or contactor coil's connector pins are dirty. • Bad connector crimps or faulty wiring. **Note:** This fault applies only to models with external contactors.	**Set:** The Main Contactor driver is either open or shorted. **Clear:** Repair the wiring and connections, then cycle the keyswitch.
3,1	EMbrake Driver *ShutdownEMBrake* *ShutdownThrottle*	• The driver is open or shorted. • The controller's or EM brake coil's connector pins are dirty. • Bad connector crimps or faulty wiring.	**Set:** The electromagnetic brake driver is either open or shorted. **Clear:** Repair the wiring and connections, then cycle the keyswitch.
3,2	Hydraulic Driver *Shut down the assigned driver*	• The driver is open or shorted. • The controller's or contactor coil's connector pins are dirty. • Bad connector crimps or faulty wiring.	**Set:** The driver for the Hydraulic contactor is either open or shorted. **Clear:** Repair the wiring and connections, then cycle the keyswitch.
3,3	Load Hold Driver *Shut down the assigned driver*	• The driver is open or shorted. • The controller's or contactor coil's connector pins are dirty. • Bad connector crimps or faulty wiring.	**Set:** The driver for the Load Hold contactor is either open or shorted. **Clear:** Repair the wiring and connections, then cycle the keyswitch.
3,4	AUX 1 Driver *Shut down the assigned driver*	• The driver is open or shorted. • The controller's or contactor coil's connector pins are dirty. • Bad connector crimps or faulty wiring.	**Set:** The driver for the Aux 1 contactor is either open or shorted. **Clear:** Repair the wiring and connections, then cycle the keyswitch.
3,5	AUX 2 Driver *Shut down the assigned driver*	• The driver is open or shorted. • The controller's or contactor coil's connector pins are dirty. • Bad connector crimps or faulty wiring.	**Set:**The driver for the Aux 2 contactor is either open or shorted. **Clear:** Repair the wiring and connections, then cycle the keyswitch.
3,6	Encoder Fault *ShutdownEMBrake* *ShutdownThrottle* *ShutdownMotor*	• Motor encoder failure. • Bad connector crimps or faulty wiring.	**Set:** The controller detected a motor encoder failure. **Clear:** Check the crimps and wiring, then cycle the keyswitch.
3,7	Motor Open *ShutdownMotor* *ShutdownMainContactor* *ShutdownEMBrake* *ShutdownThrottle*	• The motor phase is open. • Bad crimps or faulty wiring.	**Set:** The controller detected that the motor phase is open. **Clear:** Make sure the motor is connected to the M1 and M2 connectors, then cycle the keyswitch.
3,8	Main Contactor Welded *ShutdownMotor* *ShutdownMainContactor* *ShutdownEMBrake* *ShutdownThrottle*	• The main contactor tips are welded closed. • Motor phase M1 or M2 is disconnected or open. • An alternate voltage path, such as an external circuit to B+, is providing current to the capacitor bank (B+ connection terminal).	**Set:** Prior to the main contactor closing, the capacitor bank voltage (B+ connection terminal) was loaded via the motor for a short time, but the voltage did not discharge. **Clear:** Address the possible causes, then cycle the keyswitch.

Table 33 Faults, cont'd

Code	Fault and Fault Action	Possible Causes	Set and Clear Conditions
3,9	Main Contactor Did Not Close *ShutdownMotor* *ShutdownMainContactor* *ShutdownEMBrake* *ShutdownThrottle*	• The main contactor tips are oxidized, burnt, or not making good contact. • An external load on the capacitor bank (B+ connection terminal) 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 on page 37. • 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.	**Set:** The capacitor bank voltage (B+ connection terminal) did not charge to B+ when the main contactor was commanded to be closed. **Clear:** Address the possible causes, then cycle the keyswitch.
3,10	Throttle Input *ShutdownThrottle*	• The throttle's input voltage is outside the voltage range of the throttle's analog input. • The Analog 1 Type parameter is incorrectly configured.	**Set:** The throttle input voltage is outside the range defined by the analog input's Low and High parameters. **Clear:** Address the possible causes, then cycle the keyswitch.
4,3	NV Memory Failure *ShutdownMotor* *ShutdownMainContactor* *ShutdownEMBrake* *ShutdownThrottle* *ShutdownInterlock* *ShutdownDriver1* *ShutdownDriver2* *ShutdownDriver3*	• Failure to read or write to nonvolatile (NV) memory. • Internal controller fault.	**Set:** The controller's operating system was not able to read or write to EEPROM memory. **Clear:** Download the correct firmware and default parameter settings, then cycle the keyswitch.
4,4	HPD/Sequencing Fault *ShutdownThrottle*	• The keyswitch, interlock, direction, and throttle switches were not applied in the correct order. • Faulty wiring, crimps, or switches for the keyswitch, interlock, direction switches, or throttle. • Moisture in the keyswitch, interlock, direction switches, or throttle.	**Set:** The controller detected that the keyswitch, interlock, direction, and throttle switches were not cycled in the correct order after an HPD action. **Clear:** Cycle the switches in the correct order as described in Understanding the HPD/SRO Function on page 36. If that doesn't clear the fault, check the wiring and for moisture, then cycle the switches in the correct order.

Table 33 Faults, cont'd

Code	Fault and Fault Action	Possible Causes	Set and Clear Conditions
4,5	LED Driver 1 *ShutdownLED1Driver*	• The driver is shorted to B–. • Driver overcurrent. • Defective hardware.	**Set:** The driver is shorted or is consuming more than 30mA. **Clear:** Address the possible causes, then cycle the keyswitch.
4,6	LED Driver 2 *ShutdownLED2Driver*		
4,7	LED Driver 3 *ShutdownLED3Driver*		
4,8	Horn Driver *ShutdownHorn*	• The driver is shorted. • Driver overcurrent.	**Set:** The horn is shorted to B– when the horn driver is configured as a high side driver or to B+ when configured as a low side driver or is consuming more than 30mA. **Clear:** Address the possible causes, then cycle the keyswitch.
4,9	BB Wiring Fault *ShutdownThrottle* *ShutdownEMBrake* *ShutdownMainContactor*	Bad crimps or faulty wiring for the emergency reverse normally open switch. **Note:** For information on the belly button check, see page 20.	**Set:** The wire connecting Driver 2 and the emergency reverse normally open switch is broken. **Clear:** Fix the wiring, then cycle the keyswitch.
4,10	Emer Rev HPD *ShutdownThrottle* *ShutdownEMBrake*	The throttle, direction, and interlock inputs were not returned to neutral after an emergency reverse operation.	**Set:** The operator attempted to drive after an emergency reverse without first clearing the throttle, direction, and interlock inputs. **Clear:** If the EMR Dir Interlock parameter's value is On, clear the interlock, throttle, and direction inputs. Otherwise, clear the throttle and direction inputs.
5,2	Parameter Change Fault *ShutdownMotor* *ShutdownMainContactor* *ShutdownEMBrake* *ShutdownThrottle*	A parameter marked as [PCF] was changed but the keyswitch was not cycled.	**Set:** A parameter that requires the keyswitch to be cycled has changed. **Clear:** Cycle the keyswitch.
5,3	EMR Switch Redundancy *ShutdownInterlock* *ShutdownEMBrake*	• Either or both Emergency Reverse input switches are inoperative, resulting in an invalid state. See Table 18. • There is dirt or moisture in the switches.	**Set:** The emergency reverse NO and NC switches are in an invalid state. **Clear:** Address the possible causes, then cycle the keyswitch.
5,8	Stall Detected *ShutdownEMBrake* *ShutdownThrottle* *ShutdownMotor*	The motor has stalled.	**Set:** The controller did not detect motor movement. **Clear:** Cycle the keyswitch.

Table 33 Faults, cont'd

Code	Fault and Fault Action	Possible Causes	Set and Clear Conditions
7,7	Supervision *ShutdownMotor* *ShutdownMainContactor* *ShutdownEMBrake* *ShutdownThrottle* *ShutdownInterlock* *ShutdownDriver1* *ShutdownDriver2* *ShutdownDriver3*	The controller failed. **Note:** When a Supervision fault is active, the Supervision Error field displays a value that provides information on the cause. See Table 29.	**Set:** Internal controller failure. **Clear:** Cycle the keyswitch.
8,8	Internal Hardware *ShutdownMotor* *ShutdownMainContactor* *ShutdownEMBrake* *ShutdownThrottle*	An internal controller fault occurred.	**Set:** The controller detected an internal fault. **Clear:** Cycle the keyswitch.
8,10	Parameter Out Of Range *ShutdownMotor* *ShutdownMainContactor* *ShutdownEMBrake* *ShutdownThrottle*	A parameter is set to an invalid value.	**Set:** The controller detects an invalid parameter value. **Clear:** Update the parameter to a valid value.
9,4	Emer Rev Timeout *ShutdownThrottle* *ShutdownEMBrake*	• An emergency reverse operation ended because the operation exceeded the EMR Time Limit; see page 43. • The emergency reverse input is stuck in the on position.	**Set:** An emergency reverse operation stopped when it reached the specified time limit. **Clear:** Turn off the emergency reverse switch.
9,5	Parameter Mismatch *ShutdownMotor* *ShutdownMainContactor* *ShutdownEMBrake* *ShutdownThrottle* *ShutdownVehicle*	Two or more parameters are set to conflicting values. The Mismatch Error field identifies the cause. See page 57.	**Set:** The controller detects conflicting parameter values. **Clear:** Adjust the parameters, then cycle the keyswitch.
9,9	Driver 1 *ShutdownDriver1*	• The coil is open or shorted. • Dirty connector pins for the controller or the contactor coil. • Bad connector crimps or faulty wiring. • Driver overcurrent	**Set:** The driver is open or shorted. **Clear:** Address the possible causes, then cycle the keyswitch.
9,10	Driver 2 *ShutdownDriver2*		
10,1	Driver 3 *ShutdownDriver3*		
10,3	Driver Assignment *ShutdownDriver{n}*	A driver output is being used for two or more functions.	**Set:** A driver assignment conflict is detected. **Clear:** Resolve the driver conflict, then cycle the keyswitch.

Table 33 Faults, cont'd

Code	Fault and Fault Action	Possible Causes	Set and Clear Conditions
10,4	Analog 1 Out of Range *No fault action*	• The analog input's voltage is above the voltage specified by the High parameter. • The analog input's voltage is below the voltage specified by the Low parameter.	**Set:** The input voltage is not within the range of voltages defined by the input's High and Low parameters. **Clear**: Either return the voltage to within the configured range or reconfigure the parameters, then cycle the keyswitch.
10,5	Analog 2 Out of Range *No fault action*		
10,6	Analog 3 Out of Range *No fault action*		
10,7	Analog 4 Out of Range *No fault action*		
10,8	Analog 5 Out of Range *No fault action*		
10,9	Analog 6 Out of Range *No fault action*		
10,10	Analog Assignment *No fault action*	An analog input is being used for two or more functions.	**Set:** The controller detected an analog assignment conflict. **Clear:** Resolve the conflict, then cycle the keyswitch.
11,4	EMR SRO *ShutdownThrottle*	The emergency reverse switch was on when the keyswitch was powered on.	**Set:** The operator turned the keyswitch on while the emergency reverse switch was on. **Clear:** Turn off the emergency reverse switch, then cycle the keyswitch.
11,5	Load Hold SRO *ShutdownDriver*	The load hold switch was on when the keyswitch was powered on.	**Set:** The operator turned the keyswitch on while the load hold switch was on. **Clear:** Turn off the load hold switch, then cycle the keyswitch.
11,6	Hydraulic SRO *ShutdownDriver*	The hydraulic lift switch was on when the keyswitch was powered on.	**Set:** The operator turned the keyswitch on while the hydraulic lift switch was on. **Clear:** Turn off the hydraulic lift switch, then cycle the keyswitch.

Table 33 Faults, cont'd

Code	Fault and Fault Action	Possible Causes	Set and Clear Conditions
11,8	SW FAULT *ShutdownMotor* *ShutdownMainContactor* *ShutdownEMBrake* *ShutdownThrottle* *ShutdownInterlock* *ShutdownDriver1* *ShutdownDriver2* *ShutdownDriver3* *ShutdownDriver4* *ShutdownDriver5*	Defective controller.	**Set:** The controller did not power up correctly. **Clear:** Cycle the keyswitch.
11,9	Push SRO *ShutdownEMBrake* *ShutdownThrottle*	The push switch was on when the keyswitch was powered on.	**Set:** The operator turned the keyswitch on while the push switch was on. **Clear:** Turn off the push switch, then cycle the keyswitch.
11,10	BB Wiring LOS *The controller reduces speed to that specified with the BB Wiring LOS parameter.*	Bad crimps or faulty wiring	**Set:** The wire connecting Driver 2 and the emergency reverse NO switch is broken and the BB Wiring Fault LOS Enable parameter is on. **Clear:** Repair the wiring, then cycle the keyswitch.
11,11	Motor Short *ShutdownMotor* *ShutdownEMBrake* *ShutdownMainContactor*	M1 and M2 are shorted	**Set:** The controller detects M1 and M2 are shorted when the interlock is turned on. **Clear:** Fix the connections to M1 and M2, then cycle the keyswitch.

9 — MAINTENANCE

There are no user serviceable parts in the Curtis 1226 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 advisable. 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 1226 CONTROLLER

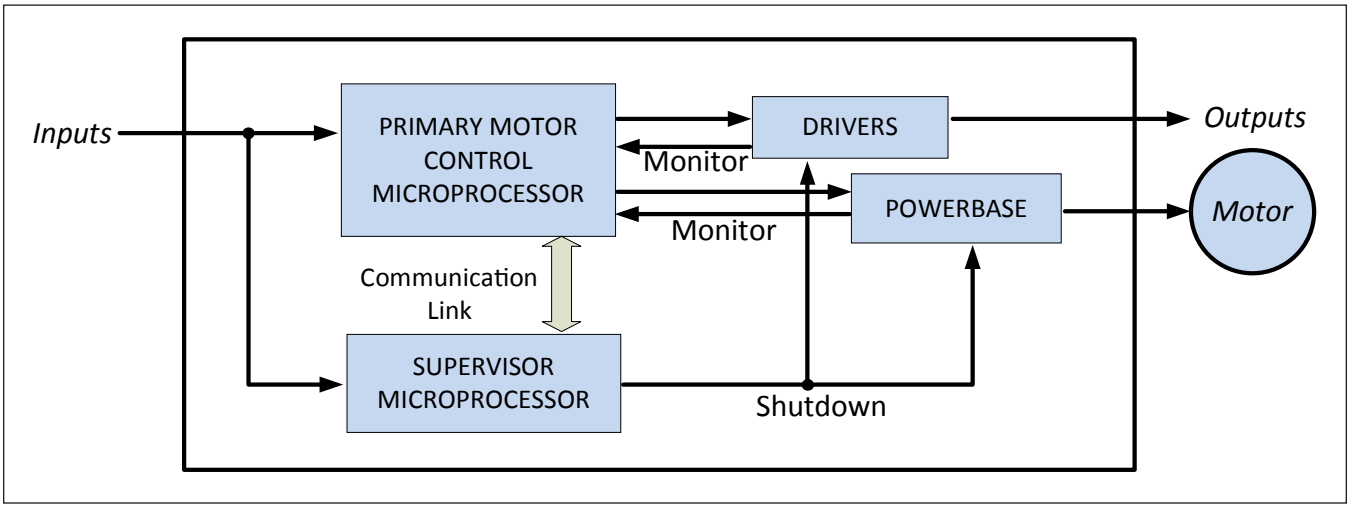
Since January 1, 2012, conformance to the European Machinery Directive has required that the Safety Related Parts of the Control System (SRPCS) be designed and verified upon the general principles outlined in EN13849. EN13849 supersedes the EN954 standard and expands upon it by requiring the determination 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 1226 controllers comply with these directives using advanced active supervisory techniques; see the simplified block diagram in Figure 15.

Figure 15

Safety channel block diagram, Curtis 1226 controller



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. Two safety functions are defined for Curtis 1226 controllers: Uncommanded Powered Motion and Motor Braking Torque.

The Uncommanded Powered Motion safety function provides detection and safe shutdown in the following circumstances: faulted throttle; improper sequence of forward/reverse switches, throttle, and interlock; uncommanded movement; or movement at startup. The Motor Braking Torque safety function provides detection and safe shutdown in the event of the loss of braking torque or emergency reverse.

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 1226 is summarized in Table 34:

Table 34 Safety Performance

Safety Function	Performance Level (PL)	Designated Architecture	MTTFd	DC
Uncommanded Powered Movement and Motor Braking Torque	*c*	Category 2	≥ 16 years	≥ 90%

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 programmers provide programming, diagnostic, and test capabilities for Curtis controllers. The power for operating the programmer is supplied by the host controller via a 4-pin connector. When the programmer powers up, it gathers information from the controller.

Two types of programming devices are available: the 1314 PC Programming Station and the 1313 handheld programmer. The Programming Station has the advantage of a large, easily read screen. On the other hand, the handheld programmer, with its 45×60 mm screen, has the advantage of being more portable and hence convenient for adjusting in the field.

Both 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. Instructions for using the Programming Station are included with the software.

HANDHELD PROGRAMMER (1313)

The 1313 handheld programmer is functionally equivalent to the PC Programming Station; operating instructions are provided in the 1313 manual. This programmer replaces the 1311, an earlier model with fewer functions.

PROGRAMMER FUNCTIONS

Programmer functions include:

- **Parameter adjustment** — provides access to the individual 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.

APPENDIX D — SPECIFICATIONS

Voltage Ranges

Nominal Battery Voltage	Brownout	Severe Undervoltage	Undervoltage	Overvoltage	Severe Overvoltage
24V	8V	9.6V	12V	30V	34V
36V	12V	14.4V	18V	45V	54V
36/48V	12V	14.4V	18V	60V	72V

PWM operating frequency	14.7 kHz
Electrical isolation to heatsink	500 VAC (minimum)
Package environmental rating	Electronics sealed to IP54 per IEC 60529.
Storage ambient temperature range	–40°C to 85°C
Operating ambient temperature range	–40°C to 50°C
Weight	0.7 kg
Dimensions (W×L×H)	95 × 150 × 54 mm
EMC	Designed to the requirements of EN 12895:2015+A1:2019.
Safety	Designed to the requirements of EN1175-1:1998+A1:2010 and EN ISO 13849-1:2015.
UL	UL 583

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

Table 35 Model Chart

Model Number	Battery Voltage	Drive Current 1 Minute[1]	Drive Current 1 Hour (S2-60)[2]	Boost Current 10 Seconds	Internal Relay or Contactor
1226-2201	24V	130A	70A	150A	Internal Relay
1226-3101	36V	90A	50A	110A	Internal Relay
1226-5201	36V/48V	130A	50A	150A	Contactor

[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 m^2 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.*