Manual

Model **1212C**

CANopen Permanent Magnet Controller for Class III Vehicles

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Read Instructions Carefully!

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The Curtis Difference
You feel it when you drive it

1 — OVERVIEW

Intended Use

The Curtis 1212C motor speed controller provides efficient control of permanent magnet drive motors for battery-powered industrial vehicles. The 1212C is optimized for use on light-duty Class III pallet trucks, floor care machines such as sweepers and scrubbers, and similar industrial vehicles.

However, the controller's flexible programmability means the 1212C can be configured for **any** low power permanent magnet motor application. You can use a Curtis programming device to configure the 1212C. Curtis programming devices also provide monitoring and diagnostic capabilities.

The 1212C complies with CANopen DS 301. The controller's object dictionary includes all parameters. In addition, the 1212C provides preconfigured PDOs for CAN bus communications with a CAN tiller and a battery monitoring system (BMS).

Figure 1
Curtis 1212C Motor Controller

FEATURES

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

Smooth and Secure Control

- 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.
- Charger inhibit input prevents driving while charger is attached.
- Key Off Decel function ensures a smooth "brake to stop" when the key is turned off while driving or when a fault occurs that requires the vehicle to stop.
- Anti-Rollback and Anti-Roll Forward functions provide safe vehicle control on hills and ramps.
- Boost Current function provides superior performance with transient loads such as starting on a hill, crossing thresholds, climbing obstacles, etc.

Easy Installation and Setup

- Industry standard footprint, mounting centers, and wiring allows drop-in replacement of other controllers.
- Industry standard logic connectors and FASTON terminals.
- The controller is programmable with a Curtis programming device or can be supplied pre-programmed.
- Supports voltage, 3-wire resistance, CAN, single ended, and wigwag throttles.

Safety and Reliability

- High RF immunity prevents speed variation and shutdowns in noisy RF environments.
- Controller power circuits and microprocessor software are continuously monitored for proper operation.
- On power-up, the system automatically checks the throttle, brake, and associated wiring, and disables driving if a fault is found.
- Emergency reverse with belly button switch input.
- Meets or complies with relevant US and international regulations. For details, see Specifications.

CAN Features

- Complies with CANopen DS 301.
- Predefined PDOs for communicating with a CAN tiller and a battery monitoring system (BMS).

Additional Features

- Automatic compensation for changes in motor condition ensures optimum drive performance at all times.
- Two programmable speed modes.
- Battery Discharge Indicator (BDI) output.
- Adjustable brake hold voltage reduces heating of the brake coil.
- Motor temperature sensor input.

CONVENTIONS

The following topics describes terms and notations used in this manual.

Numeral System Notation

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

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

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

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

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

Miscellaneous Conventions

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

GETTING THE MOST OUT OF YOUR CURTIS CONTROLLER

Familiarity with your Curtis controller will help you install, configure, and operate it properly. Curtis thus encourages you to carefully read this manual. If you have questions, please contact the Curtis distributor from where you obtained the controller or the Curtis sales-support office in your region.

2 — INSTALLATION AND WIRING

⚠ CAUTION

Working on electric vehicles is potentially dangerous. You should protect yourself against runaways and high current arcs as described below:

RUNAWAYS—Some conditions could cause the vehicle 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—Always open the battery circuit before working on the motor control circuit. Wear safety glasses, and use properly insulated tools to prevent shorts.

MOUNTING THE CONTROLLER

The controller can be oriented in any position, but the location should be carefully chosen to keep the controller clean and dry. If a clean, dry mounting location cannot be found, a cover must be used 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 M4 (#8) screws.

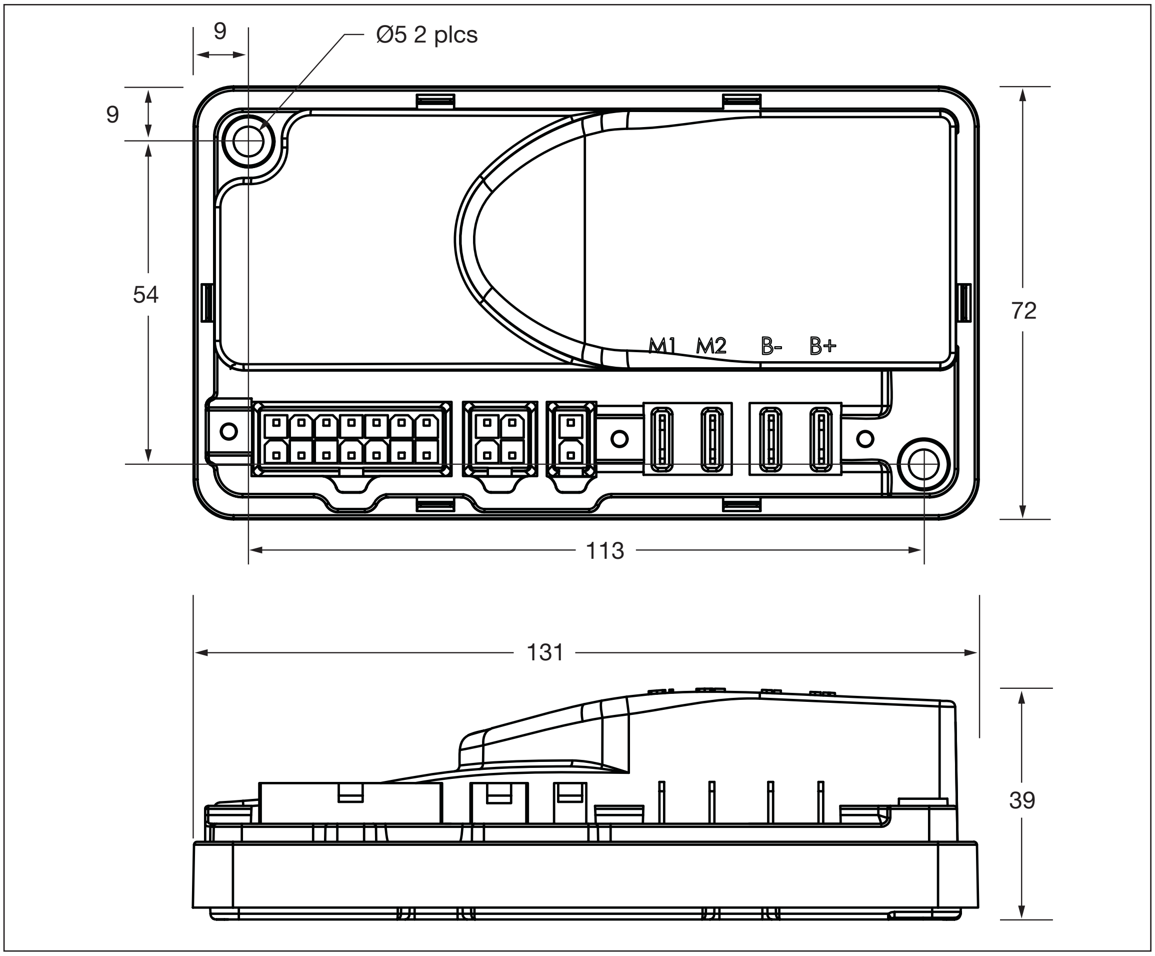


Figure 2

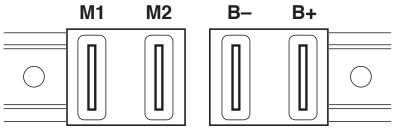
Mounting Dimensions in millimeters (mm)

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; see Appendix A, Vehicle Design Considerations Regarding Electromagnetic Compatibility (EMC).

CONNECTIONS: HIGH CURRENT

Four 1/4" FASTON terminals are provided for the high current connections.

The motor connections (**M1**, **M2**) and battery connections (**B+**, **B–**) have one terminal each.



The controller provides reverse polarity protection. Reversal of the B+ and B– connections on an otherwise properly wired controller will prevent precharge from occurring and the main relay from being activated. The controller will not operate and will not be damaged.

The polarity of the motor's **M1** and **M2** connections will affect 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 button (the belly button switch) is pressed.

BATTERY VOLTAGE AND CUTBACKS

The controller's nominal battery voltage is 24V.

The controller linearly cuts back on current when the overvoltage or undervoltage cutback voltage is reached, and shuts off current when the cutoff voltage is reached.

The following table describes the overvoltage and undervoltage cutback voltages:

Description	Cutback Voltage	Cutoff Voltage
Undervoltage cutback	17V	14V
Overvoltage cutback	32V is the default. You can change this voltage with the Over Voltage Cutback parameter.	34V

CONNECTIONS: LOW CURRENT

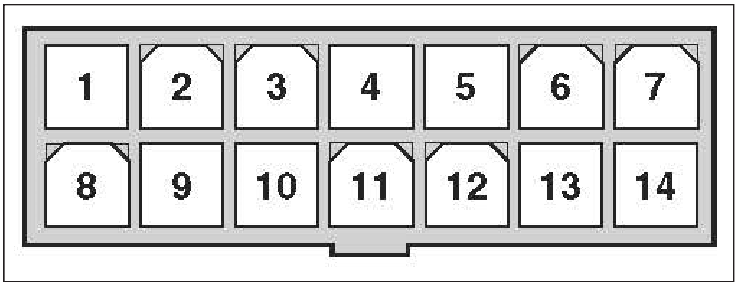
The low current connections are provided by the 3 connectors listed in the following table:

Connector	Description
J1	Logic connector
J2	Communication connector
J3	EM Brake connector

The following topics describe the low current connectors.

Logic Connector (J1)

The 14-pin logic connector (J1) is used for inputs, outputs, and low power drivers. The mating connector is a Molex Mini-Fit-Jr. receptacle, part number 39-01-2140, with appropriate 45750-series crimp terminals.



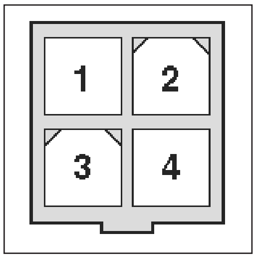
The following table describes the logic connector's pins.

Table 1 Logic Connector Pins (J1)

J1 Pin	Description
1	Pot wiper (resistive or voltage throttle)
2	Pot high If the vehicle uses a non-resistive throttle, pins J1-2 and J2-8 can be used for a motor temperature sensor.
3	Driver 1, which can be used for the following functions: • Lift driver • Lift lockout driver
4	Mode input
5	Keyswitch input (KSI)
6	Interlock input
7	CAN low
8	Pot low **Note:** If the vehicle uses a non-resistive throttle, pins J1-8 and J2-2 can be used for a motor temperature sensor.
9	AUX switch input. If Driver 1 is used as a lift or lockout driver, the input can be used for the functions described in AUX Switch Input.
10	Forward input
11	Driver 2, which can be used for the following functions: • Lower valve driver • BDI output • Horn driver
12	Reverse input
13	CAN high
14	Emergency reverse input (belly button switch)

Communication Connector (J2)

A 4-pin connector (J2) is provided for a Curtis programmer and a battery charger. Pin J2-3 can also be used for an external status LED. The mating connector is a Molex Mini-Fit-Jr. receptacle, part number 39-01-2040, with appropriate 45750-series crimp terminals.

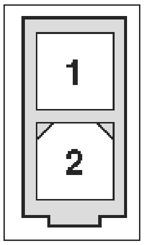


The following table describes the pins:

J2 Pin	Description
1	Rx
2	I/O GND
3	The following functions: • Tx • Charger inhibit • External status LED
4	B+

EM Brake Connector (J3)

A 2-pin connector (J3) is provided for the electromagnetic brake. The mating connector is a Molex Mini-Fit-Jr. receptacle, part number 39-01-2020, with appropriate 45750-series crimp terminals.



J3 Pin	Description
1	EM Brake+
2	EM Brake–

WIRING DIAGRAM

Figure 3 shows a typical installation for a vehicle with a CAN throttle. Driver 1 is used to drive the lift; Driver 2 is used to drive the lower valve.

The right side of the diagram includes sections that show how to connect a Curtis 3140 gauge, a charger, an external status LED, and a Curtis handheld programmer.

Note: For information on connecting other types of throttles, see Throttle Wiring.

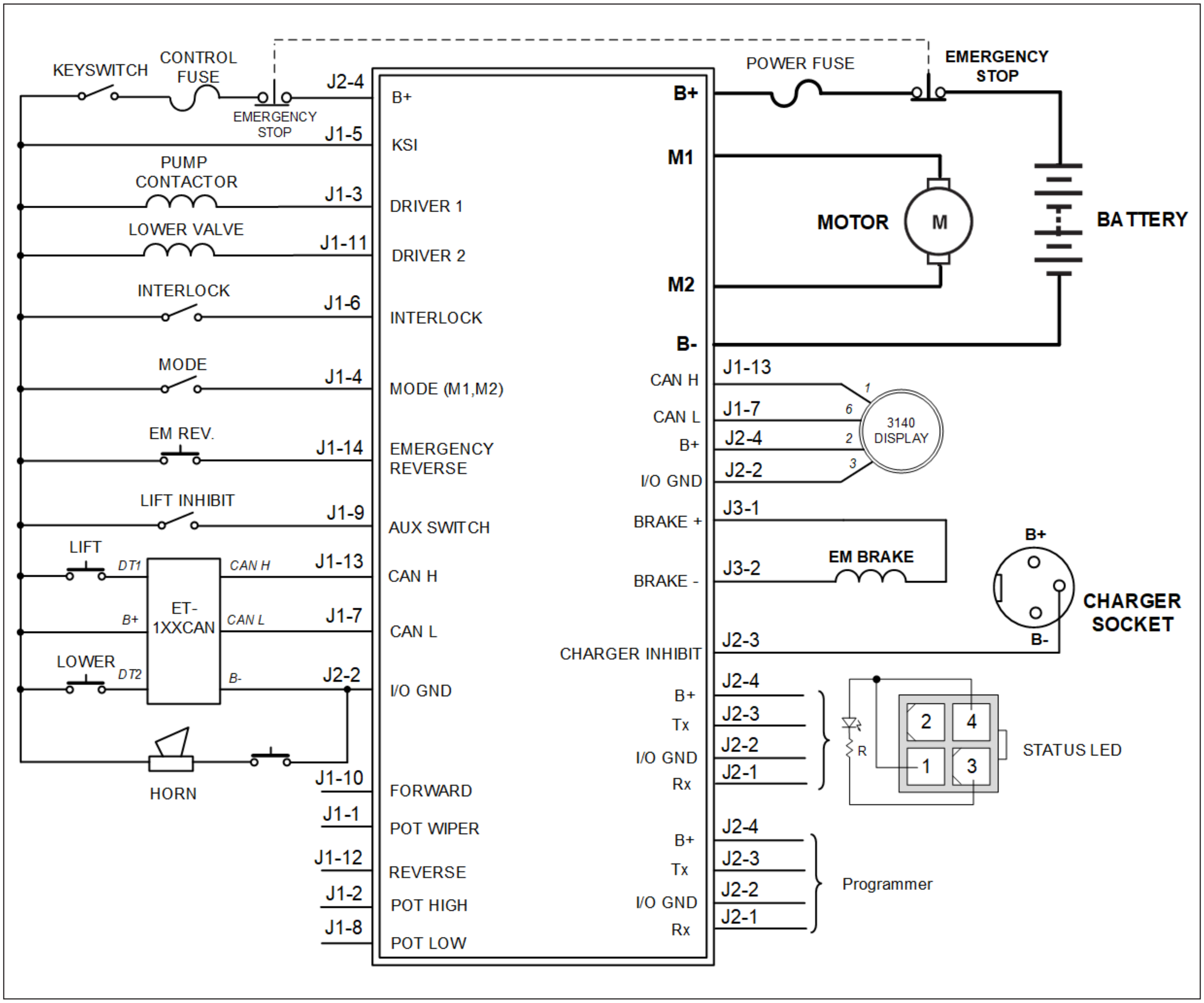


Figure 3

Wiring Diagram

THROTTLE WIRING

The 1212C supports the following types of throttles:

- 3-wire 5kΩ pot throttles (wigwag, single-ended, and inverted single-ended)
- 0–5V voltage throttles (wigwag, single-ended, and inverted single-ended)
- CANopen throttles (wigwag and single-ended)

Specify the throttle type with the Throttle menu's Type parameter.

Note: The pot high and pot low inputs are not protected against a short circuit to B+.

The following topics describe how to wire the various types of throttles. If the throttle you plan to use is not covered, contact the Curtis distributor from where you obtained the controller or the Curtis sales-support office in your region.

3-Wire 5kΩ Potentiometer Throttle

The following diagram shows how to wire a 3-wire 5kΩ pot throttle:

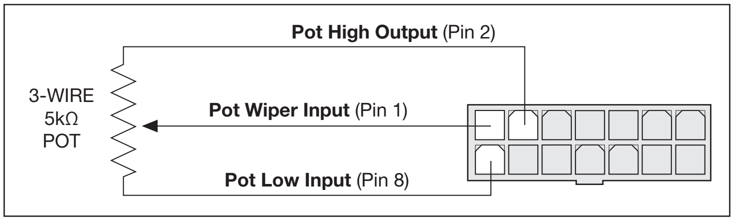


Figure 4
Wiring for a 3-Wire 5KΩ Pot Throttle

The overall pot resistance should be 4.3–7.0kΩ. Values outside this range will trigger a Throttle Fault.

The controller provides full pot fault protection against open or shorted wires anywhere in the throttle assembly.

The pot high and pot low inputs are for the throttle's upper and lower voltages, respectively. The inputs that represent full throttle and neutral depend upon whether the throttle is single-ended or inverted single-ended, as described in the following table:

Throttle Type	Full Throttle	Neutral
Single-ended	Pot high	Pot low
Inverted single-ended	Pot low	Pot high

Voltage Throttle

The following diagram shows how to wire a voltage throttle:

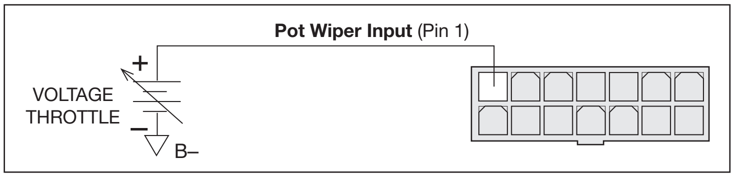


Figure 5

Wiring for a Voltage Throttle

The voltage range must be between the values specified by the Pot High and Pot Low parameters. If the throttle voltage is outside that range, a Throttle Fault will occur.

Note: If a voltage throttle is used, it is the responsibility of the OEM to provide appropriate throttle fault detection.

CAN Throttle

When a CAN throttle is used, the throttle signal is transmitted over the CAN bus and received by RPDO1. TPDO1 and RPDO1 also transmit and receive signals for related functions. See PDO1 — Communicating with a CAN Tiller.

INPUTS AND OUTPUTS (I/Os)

The following topics describe how to connect and configure the I/Os.

Note: Unless otherwise indicated, I/Os are protected against short circuits.

Digital Input Specifications

The following inputs are digital inputs. These inputs must be connected to B+ via a switch:

- Mode switch (J1-4)
- Interlock input (J1-6)
- Forward input (J1-10)
- Reverse input (J1-12)
- Emergency reverse input (J1-14)

The following table describes the specifications for the digital inputs:

Specification	Value
Input current @ nominal battery voltage	Approximately 0.2–0.7mA
Maximum threshold voltage — Low	7.5V
Minimum threshold voltage — High	9.0V
Debouncing time (in software)	8ms

Analog Input Specifications

The pot wiper (J1-1) and AUX switch (J1-9) inputs are analog inputs. The following table describes the specifications for the analog inputs:

Specification	Value
Input resistance (to B– ground)	10kΩ ± 10%
Input filter R-C time constant	1ms maximum
Voltage range	0.0–5.0V
Minimum resolution	12-bit

Driver Output Specifications

The Driver 1 (J1-3), Driver 2 (J1-11), and EM Brake– (J3-2) outputs are low side drivers. The following table describes the specifications for the driver outputs:

Specification	Value
Maximum output current	1.5A
Maximum voltage raise (to B–) @ 1.5A	2.0V
Minimum EM brake coil resistance	20Ω

Keyswitch (KSI)

The vehicle should have a keyswitch connected to pin J1-5 and B+ (J2-4) as shown in Figure 3. The keyswitch provides power for all low power circuits, including drivers and the precharge function.

The keyswitch input's maximum input current is 250mA. This does not include current draw from coil loads and the external power supply.

Note: The precharge function provides a limited current charge to the controller's internal capacitor bank for an indefinite period. This prevents the relay contacts from arcing during closure.

Interlock Input

The interlock signal can come from the keyswitch, a NO interlock switch, or CAN. Use the Interlock Type parameter to specify the source of the interlock signal.

If the vehicle uses an interlock switch, connect the switch to pin J1-6.

Note: To prevent the interlock from opening if the switch bounces or is momentarily cycled, set the Sequencing Delay parameter to a non-zero value.

The controller's HPD and SRO functions prevent the vehicle from moving if the interlock and other inputs are turned on in sequences that can result in unexpected vehicle movement. For more information, see the descriptions of the following parameters:

- HPD
- SRO

For parameters that configure interlock braking, see Interlock Braking Menu.

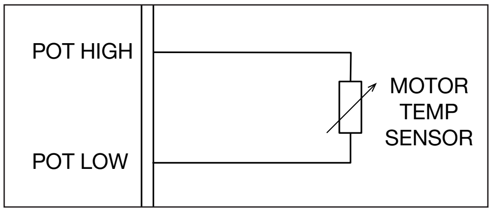
Motor Temperature Sensor

If you are using a voltage or CAN throttle, the controller provides an input for a 1kΩ NTC motor temperature sensor. The pot low input (J1-8) is used to measure the temperature voltage.

Note: A motor temperature sensor cannot be used with a resistive throttle.

If the voltage detected by the sensor exceeds the voltage specified with the Motor Temp Alarm parameter, a Motor Overtemperature fault will occur and the controller will reduce the speed to speed mode 2's maximum speed.

To wire a motor temperature sensor, connect it to pot high (J1-2) and pot low (J1-8) as shown in the following diagram:



Emergency Reverse Input (Belly Button Switch)

The emergency reverse input (pin J1-14) is for a belly button switch. If the operator activates emergency reverse, the vehicle will decelerate to a stop and then drive in the opposite direction.

The emergency reverse switch can be an NC or NO switch connected to pin J1-14 or a switch connected to a CAN tiller. The EMR Type parameter specifies which type of switch is used.

Note: If the emergency reverse switch is connected to a CAN tiller, the emergency reverse signal is received by RPDO1. See RPDO1.

Mode Input

The controller provides two speed modes; see Speed and Mode Menus. Vehicles can use either a switch connected to pin J1-4 or CAN as the speed mode input. The Mode Digital Input parameter specifies whether a switch or CAN is used.

Note: The controller is in speed mode 2 when the mode input is on. On indicates the input is connected to B+.

Forward and Reverse Switches

If the vehicle uses a single-ended throttle, the controller provides inputs for forward and reverse switches. Connect the forward switch to pin J1-10 and the reverse switch to pin J1-12.

If you are using a single-ended CAN throttle, the forward and reverse signals are transmitted over the CAN bus and received by RPDO1. See PDO1 — Communicating with a CAN Tiller.

Emergency Stop Switch

To ensure operator safety, it is recommended that the vehicle include an emergency stop switch. Curtis recommends that the emergency stop switch has dual contacts connected to the battery and keyswitch as shown in Figure 3.

To specify a fast response for emergency stops, set the Key Off Decel parameter to less than 1.0 seconds.

Battery Discharge Indicator (BDI)

Driver 2 (pin J1-11) can drive a BDI panel meter that shows the battery pack's state of charge as a percentage of the batteries' ampere-hour capacity. The batteries must be put through a full charge cycle with the controller installed before the BDI will begin operation.

Note: You need an exclusive PCBA to use Driver 2 as a BDI output. To obtain the PCBA, contact the Curtis sales-support office in your region.

To configure Driver 2 as a BDI output, set the Driver2 Type parameter to 2. When Driver 2 is used to drive a BDI, the driver provides a 0–5V output that indicates the battery capacity.

The source of the signal used to calculate the BDI can be the controller's internal BDI, a Curtis 3140 gauge, or a battery monitoring system (BMS). Use the BDI Source parameter to specify the source.

Note: The Curtis 3140 or a BMS communicates with the controller via the CAN bus. See RPDO2 — Receiving Data from a Battery Monitoring System.

To configure the BDI, perform the steps in Battery Discharge Indicator (BDI) Setup.

Charger Inhibit

The charger inhibit function disables driving and engages the electromagnetic brake while the battery is charging.

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

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

Circuitry Protection Devices

To protect against accidental shorts, a low current fuse, appropriately sized for the maximum current draw, should be connected in series with the B+ logic supply. A fuse is also recommended in the high power circuit from the battery to the controller's B+ terminal. This fuse will protect the power system from external shorts and should be sized appropriately for the maximum rated current of the controller. See Figure 3.

I/O Ground

Pin J2-2 provides the ground connection. The pin is connected to B– and is not protected against a short circuit to B+.

External Status LED

The controller can drive an external LED that signals the controller's status. The LED indicates whether the controller is operating normally or if a fault is active. For information on how the LED indicates faults, see LED Diagnostics.

Note: The controller can use pin J2-3 as an external Status LED only if pin J2-1 senses a high level signal.

Connect the LED to pins J2-3 and J2-4, and short pin J2-1 to pin J2-4, as shown in Figure 3.

The LED driver provides a maximum current of 15mA with an appropriately-sized resistor in series. The recommended resistor — designed to limit driver current to 15 mA when active — is 2.4kΩ, 0.5 W. Alternatively, an LED with a built-in resistor that is rated for 24V operation can be used.

Lift Driver

If the vehicle has a CAN throttle, the Driver 1 output (pin J1-3) can drive a lift. The lift command is transmitted over the CAN bus to RPDO1.

To use Driver 1 to drive a lift, take the following steps:

1. Set the Driver1 Type parameter to 1.
2. Set the Driver1 Fault Check parameter to indicate whether the controller should check for the Driver 1 Fault.
3. Optionally, you can specify to disable the driver for one of the following conditions:

Condition to Disable Driver	Steps
If the lift switch is closed before the keyswitch is turned on	See Lift Switch for Pump SRO Conditions.
If a CAN signal indicates the lift message is active before the keyswitch is turned on	Set the Pump SRO Type parameter to 2.
If the lift lockout signal from a Curtis 906 battery gauge is low	See Curtis 906 Battery Gauge.
If a lift inhibit switch is turned on	See Lift Inhibit Switch.

Lift Lockout Driver

The Driver 1 output (pin J1-3) can drive a lift contactor. When the lift lockout signal is low, the controller disables Driver 1 to stop lift operation.

To configure Driver 1 as the lift lockout driver, take the following steps:

1. Set the Driver1 Type parameter to 2.
2. Specify the lift lockout signal's source:
   - To use a Curtis 906 battery gauge, see Curtis 906 Battery Gauge.
   - To use the controller's internal BDI, set the Lift Lockout Threshold parameter to the BDI level below which the lift should be shut down.
3. If you are not using the AUX switch input (pin J1-9) for a Curtis 906 gauge, you can use the input to disable the driver for one of the following conditions:

Condition to Disable Driver	Steps
If the lift switch is closed before the keyswitch is turned on	See Lift Switch for Pump SRO Conditions.
If a lift inhibit switch is turned on	See Lift Inhibit Switch.

Lower Valve Driver

If the controller has a CAN throttle, the Driver 2 output (pin J1-11) can drive the lower valve. The lower valve command is transmitted over the CAN bus to RPDO1.

To have the controller drive the lower valve, perform the following steps:

1. Set the Driver2 Type parameter to 1.
2. Set the Driver2 Fault Check parameter to indicate whether the controller checks for the Driver 2 Fault.
3. To disable Driver 2 if a CAN signal indicates the lift message is active before the keyswitch is turned on, set the Pump SRO Type parameter to 2.

AUX Switch Input

If Driver 1 is used as a lift or lift lockout driver, the AUX switch input (pin J1-9) can be used for the following purposes:

- A lift switch that the controller checks for pump SRO conditions. See Lift Switch for Pump SRO Conditions.
- A Curtis 906 battery gauge for the lift lockout signal. See Curtis 906 Battery Gauge.
- A lift inhibit switch. See Lift Inhibit Switch.

Note: The AUX Switch Input Type parameter specifies how the input is used.

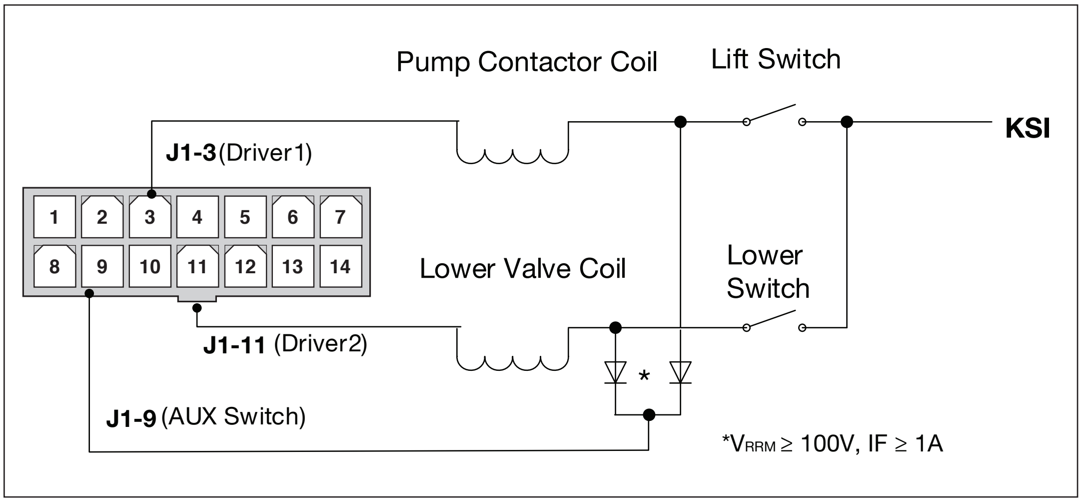
Lift Switch for Pump SRO Conditions

The AUX switch input can be connected to the lift switch. The controller will disable Driver 1 if the Pump SRO Fault occurs.

Note: The fault occurs if the lift switch is on before the keyswitch is turned on.

To use the AUX switch to check for the Pump SRO Fault, take the following steps:

1. Wire the switches and coils to the AUX switch input (pin J1-9) as shown below:



2. Set the AUX Switch Input Type parameter to 1.
3. Set the Pump SRO Type parameter to 1.

Curtis 906 Battery Gauge

If Driver 1 is used as a lift or lift lockout driver, the AUX switch input (pin J1-9) can be connected to a Curtis 906 battery gauge that provides the lift lockout signal. When the meter's signal is low, Driver 1 will be disabled.

To use a Curtis 906 battery gauge as the lift lockout source, take the following steps:

1. Set the BDI Source parameter to 1.
2. Set the AUX Switch Input Type parameter to 2.

Lift Inhibit Switch

The AUX switch input (pin J1-9) can be connected to a lift inhibit switch. The switch can be either an NO or NC switch. When the switch is on, Driver 1 will be disabled.

If the vehicle uses a lift inhibit switch, set the AUX Switch Input Type parameter to 3 or 4 to indicate whether the switch is NC or NO.

Horn Driver

If the vehicle uses a CAN throttle, the controller can use the Driver 2 output to drive a horn. The horn signal is transmitted over the CAN bus to RPDO1.

To configure Driver 2 to drive a horn, connect the horn to pin J1-11 and set the Driver2 Type parameter to 3.

EM Brake

The low side EM Brake driver provides fault diagnostics for the EM brake coil and EM brake driver being open or shorted. If a fault is detected, the controller puts the vehicle in neutral. The EM brake is primarily used as a holding brake after the vehicle has stopped.

Connect the EM brake to pins J3-1 and J3-2 as shown in Figure 3, then use the Fault Check parameter to enable or disable EM fault detection.

CAN Connections

The controller implements the CANopen protocol and provides CAN low (J1-7) and CAN high (J1-13) ports.

CAN bus nodes typically are wired using a daisy chain topology with 120Ω terminating resistors at each end. If the controller is the last node in the chain, you should include an external 120Ω terminating resistor in the wiring harness.

Note: The controller does not have an internal 120Ω CAN terminating resistor.

The following table describes the CAN ports' specifications:

Specification	Value
Protected voltage	–5 – +30V
Minimum baud rate	125 kb/s
Maximum baud rate	1 MB/s

3 — PROGRAMMABLE PARAMETERS

The 1212C controller provides parameters that can be programmed with a Curtis handheld programmer or the 1314 PC Programming Station. Use these parameters to customize a vehicle's performance and functionality.

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

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

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

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

- Parameter and CAN Index: The parameter name and the CAN index and sub-index. This column also identifies parameters marked as [PCF].
- Values and Raw Values: The allowed values as displayed in Curtis programming devices, followed by the allowed values in raw units suitable for CAN.

DRIVE MENU

In addition to the following parameters, the Drive menu contains the Speed menu.

Note: For the acceleration and deceleration parameters in the following table, larger values represent slower response times.

DRIVE MENU

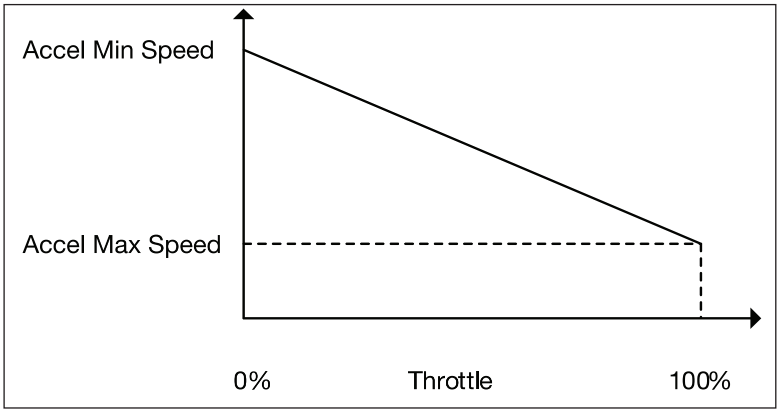
PARAMETER	VALUES RAW VALUES	DESCRIPTION
Accel Max Speed `0x220000`	0.2–8.0s 102–4095	Specifies the rate at which the vehicle accelerates when full throttle is applied while the vehicle is moving forward. The maximum value is restricted by Accel Min Speed. The acceleration rate is linearly scaled between Accel Min Speed and Accel Max Speed; see Figure 6.
Accel Min Speed `0x220100`	0.2–8.0s 102–4095	Specifies the rate at which the vehicle accelerates while moving forward after the throttle is rotated out of neutral. The minimum value is restricted by Accel Max Speed.
Decel High Speed `0x220200`	0.2–8.0s 102–4095	Specifies the rate at which the vehicle decelerates when throttle is reduced while the vehicle is moving forward at high speed. The maximum value is restricted by Decel Low Speed. The deceleration rate is linearly scaled between Decel Low Speed and Decel High Speed; see Figure 7.
Decel Low Speed `0x220300`	0.2–8.0s 102–4095	Specifies the rate at which the vehicle decelerates when throttle is reduced while the vehicle is moving forward at low speed. The minimum value is restricted by Decel High Speed.
Rev Accel Max Speed `0x220400`	0.2–8.0s 102–4095	Specifies the rate at which the vehicle accelerates when full throttle is applied while the vehicle is moving in reverse. The maximum value is restricted by Rev Accel Min Speed. The acceleration rate is linearly scaled between Rev Accel Min Speed and Rev Accel Max Speed; see Figure 6.

DRIVE MENU, cont'd

PARAMETER	VALUES RAW VALUES	DESCRIPTION
Rev Accel Min Speed `0x220500`	0.2–8.0s 102–4095	Specifies the rate at which the vehicle accelerates in reverse when the throttle is rotated out of neutral. The minimum value is restricted by Rev Accel Max Speed.
Rev Decel High Speed `0x220600`	0.2–8.0s 102–4095	Specifies the rate at which the vehicle decelerates when throttle is reduced while the vehicle is moving in reverse at high speed. The maximum value is restricted by Rev Decel Low Speed. The deceleration rate is linearly scaled between Rev Decel Low Speed and Rev Decel High Speed; see Figure 7.
Rev Decel Low Speed `0x220700`	0.2–8.0s 102–4095	Specifies the rate at which the vehicle decelerates when throttle is reduced while the vehicle is moving in reverse at low speed. The minimum value is restricted by Rev Decel High Speed.
Key Off Decel `0x220800`	0.2–4.0s 102–2048	Specifies the rate at which the vehicle decelerates at key-off or in the event of a major fault. For guidelines on setting this parameter, see Set the Key Off Deceleration Rate.
Soft Start `0x220B00`	0–100% 0–122	Softens the bump associated with gear slack in the transaxle when throttle is applied from neutral. Larger values provide a softer slack take-up.
Gear Soften `0x220C00`	0–100% 0–154	Softens the bump associated with gear slack in the transaxle when throttle is released and then reapplied while the vehicle is still moving. Larger values provide a softer slack take-up. For information on setting the Gear Soften and Soft Start parameters, see Fine-Tuning the Vehicle's Response Smoothness.
Creep Speed `0x220D00`	0–10% 0–410	Specifies the requested speed when the throttle first rotates out of neutral. Creep Speed defines the minimum possible speed request. Larger values provide a faster minimum speed. **Note:** Creep Speed helps prevent rollback on inclines when the brake is released with very little throttle applied.
Soft Stop Speed `0x220E00`	0–30% 0–1229	Specifies the speed at which a softer deceleration is initiated when the throttle is released to neutral. Larger values start softening the deceleration sooner.

Figure 6

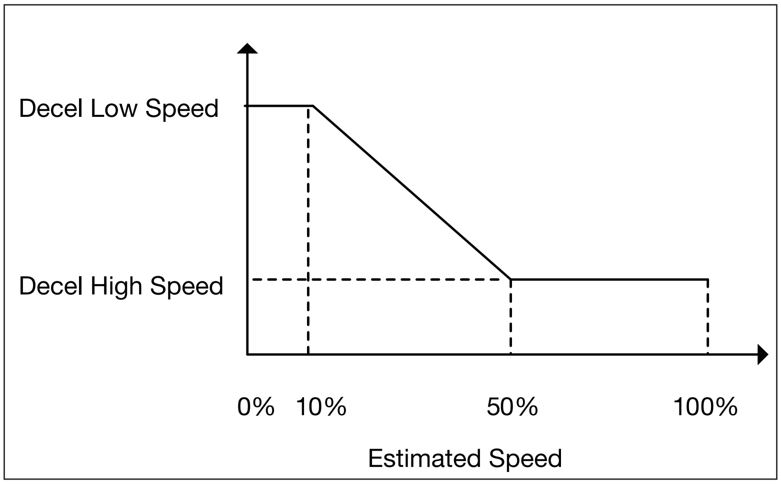
Minimum and Maximum Acceleration Rates



Note: The diagram refers to the Accel Min Speed and Accel Max Speed parameters. However, the same concept also applies to the Rev Accel Min Speed and Rev Accel Max Speed parameters.

Figure 7

Minimum and Maximum Deceleration Rates



Note: The diagram refers to the Decel Low Speed and Decel High Speed parameters. However, the same concept also applies to the Rev Decel Low Speed and Rev Decel High Speed parameters.

Speed and Mode Menus

The controller provides two speed modes, known as mode 1 and mode 2. These modes can be programmed to provide two different sets of forward and reverse maximum speeds. Mode 1 can be configured for higher-speed driving, while mode 2 can be configured for a lower speed. For example, mode 1 could be configured for outdoors driving and mode 2 could be configured for indoors maneuvering.

The controller reduces the speed to the mode 2 maximum speed if a Motor Overtemperature fault occurs.

The Speed menu contains the Mode 1 and Mode 2 menus. Both menus contain parameters with the same names, so the following table describes both menus' parameters. The first column contains the CAN indexes for mode 1 and mode 2, respectively.

Note: The parameter values are percentages of the full throttle command.

SPEED AND MODE MENU

PARAMETER CAN INDEX	VALUES RAW VALUES	DESCRIPTION

Max Speed
`0x230000`
`0x230400`
	0–100%
	0–4095
		Specifies the speed at full throttle in the forward direction.

Rev Max Speed
`0x230200`
`0x230600`
	0–100%
	0–4095
		Specifies the speed at full throttle in the reverse direction.

THROTTLE MENU

The Throttle menu parameters specify the throttle type and configure the throttle functions. For instructions on configuring the throttle parameters, see Configure Throttle.

Note: A few of the parameters define the relationship between the throttle position and throttle request. For more information, see Throttle Response Parameters.

The following table describes the throttle parameters:

THROTTLE MENU

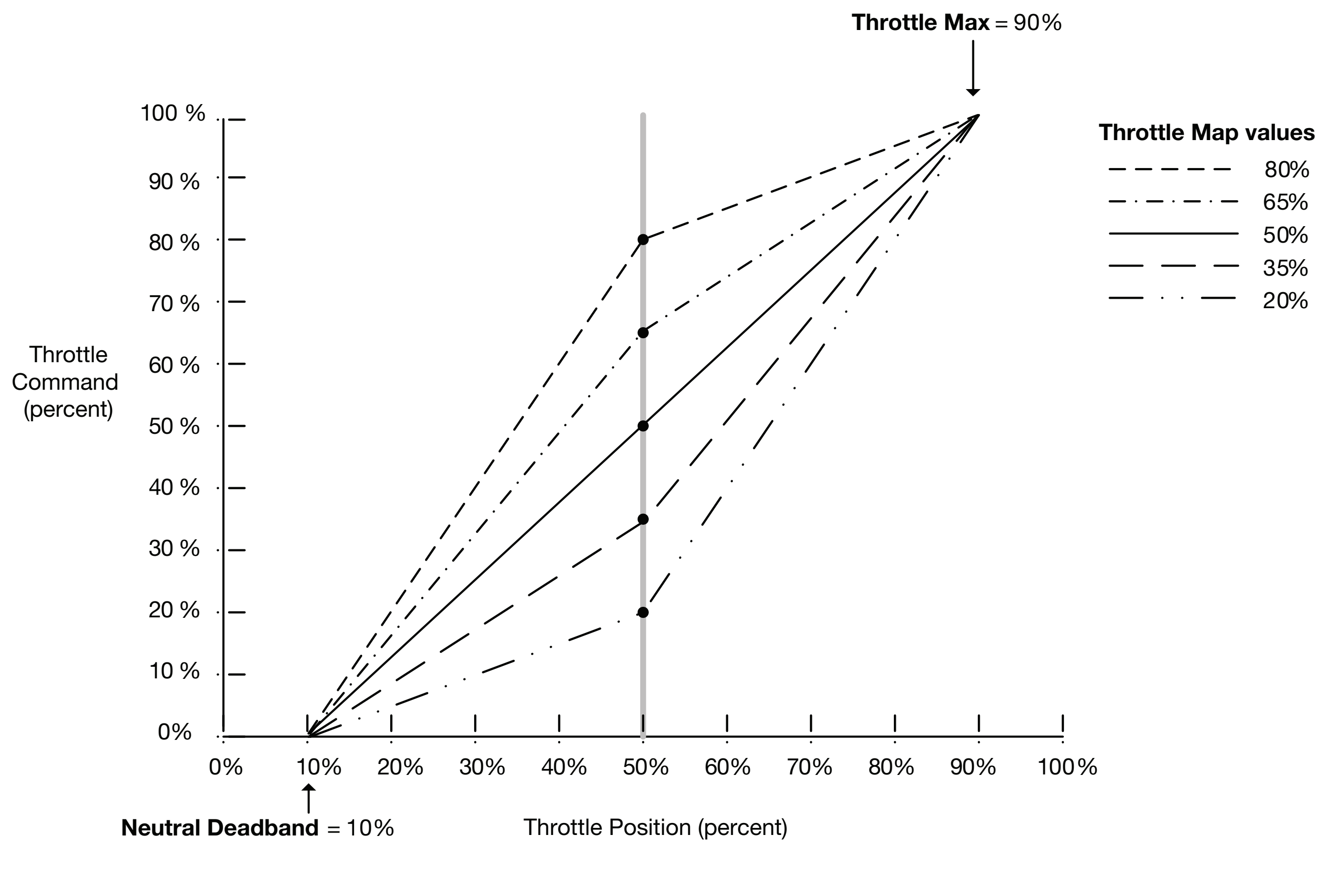
PARAMETER CAN INDEX	VALUES RAW VALUES	DESCRIPTION
Type **[PCF]** 0x240000	0–7 0–7	Specifies the throttle type: 0 = Wigwag 5kΩ, 3 wire pot 1 = Single-ended 0–5kΩ, 3 wire pot (Neutral is requested when the pot wiper is at Pot Low.) 2 = Inverted single-ended 5k–0Ω, 3 wire pot (Neutral is requested when the pot wiper is at Pot High.) 3 = Wigwag voltage 4 = Single-ended voltage (Neutral is requested when the pot wiper is less than or equal to the Neutral Deadband parameter.) 5 = Inverted single-ended voltage (Neutral is requested when the pot wiper is greater than or equal to the Throttle Max parameter.) 6 = Wigwag CAN throttle 7 = Single-ended CAN throttle
Pot High 0x240100	3.0–5.0V 2457–4095	Specifies the maximum voltage for voltage throttles. **Note:** If the throttle voltage is outside the range defined by the Pot Low and Pot High parameters, a Throttle Fault occurs.
Pot Low 0x240200	0.0–2.0V 0–1638	Specifies the minimum voltage for voltage throttles.
CAN Throttle High 0x300000	0–32767 0–32767	Specifies the maximum throttle request for CAN throttles. **Note:** If the throttle request is outside the range defined by the CAN Throttle Low and CAN Throttle High parameters, a Throttle Fault occurs.
CAN Throttle Low 0x300100	–32768 – +32767 –32768 – +32767	Specifies the minimum throttle request for CAN throttles.
Neutral Deadband 0x240500	5–30% 205–1229	Specifies the throttle position at which the vehicle moves out of neutral. When the throttle position is less than or equal to Neutral Deadband, the throttle request is 0%.
Throttle Max 0x240300	40–100% 1638–4095	Specifies the throttle position that indicates the maximum throttle request. When the throttle position is greater than or equal to Throttle Max, the throttle request is 100%.
Throttle Map 0x240400	20–80% 819–3276	Specifies the throttle request when the throttle position is at 50%. For example, 60% indicates the throttle request is 60% at half-throttle. The following list provides guidelines for setting Throttle Map: • 50% indicates a linear relationship between the throttle position and throttle request. • Values below 50% provide enhanced slow speed maneuverability. • Values above 50% give the vehicle a faster, more responsive feel at low throttle.

THROTTLE MENU, cont'd

PARAMETER CAN INDEX	VALUES RAW VALUES	DESCRIPTION
HPD `0x2A0000 (bit 0)`	Off/On 0–1	Specifies whether the HPD (High Pedal Disable) function is enabled. 0 indicates on. The HPD function prevents the vehicle from driving and generates an HPD Fault if a direction switch is on and the throttle is not in neutral before the interlock switch is turned on. **Note:** If the HPD Fault is not cleared within 10 seconds, a Wiring Fault occurs and the keyswitch must be cycled.
SRO `0x320400`	0–2 0–2	Specifies how the SRO (Static Return to Off) function works: 0 = SRO is disabled. 1 = An SRO Fault occurs if a direction switch is on before the interlock input is turned on. 2 = An SRO Fault occurs if the interlock input or a direction input is on before the keyswitch is turned on.

Throttle Response Parameters

The Neutral Deadband, Throttle Max, and Throttle Map parameters determine the controller's response to the throttle position. The following diagram shows how these parameters work:



The following list describes the parameters in the diagram:

- Neutral Deadband is set to 10%, indicating that the vehicle is in neutral when the throttle position is less than 10%.
- Throttle Max is set to 90%, indicating that 100% throttle is requested when the throttle position reaches 90%.
- The lines connecting the Neutral Deadband and Throttle Max values represent the relationship of the throttle position and throttle command for various Throttle Map values.

Note: When Throttle Map is greater than 50%, the throttle is more responsive at throttle positions below 50%, and less responsive at positions above 50%. The opposite is true when Throttle Map is less than 50%.

MAIN RELAY MENU

MAIN RELAY MENU

PARAMETER CAN INDEX	VALUES RAW VALUES	DESCRIPTION
Main On Interlock `0x2A0000 (bit 6)`	Off/On 0–1	Specifies whether the main relay is activated by the keyswitch or the interlock: Off = Keyswitch On = Interlock
Pull-In Voltage `0x2B0200`	18.0–24.0V 180–240	Specifies the initial voltage of the relay when the driver is first turned on. The controller allows a high initial voltage to ensure the relay closes. After 1 second, the voltage decreases to the specified Holding Voltage.
Holding Voltage `0x2B0300`	16.8–24.0V 168–240	Specifies the voltage the controller applies to the relay after the relay closes. Set the Holding Voltage high enough so that the relay remains closed under all shock and vibration conditions that the vehicle is expected to encounter.
Open Delay `0x2B0400`	0.0–40.0s 0–400	Specifies how long the relay remains closed after the interlock input is turned off. The delay applies only when the Main On Interlock parameter value is On. **Note:** If you change the value, cycle the keyswitch. The controller does not apply the updated value until the keyswitch is cycled.

INTERLOCK BRAKING MENU

If interlock braking is enabled, when the interlock is turned off the controller attempts to stop the vehicle with regen braking and the EM brake. The following parameters configure interlock braking.

Note: If interlock braking is disabled when the interlock is turned off, the controller disables the full bridge driver after the time specified by the Sequencing Delay parameter expires, and allows the vehicle to roll freely.

INTERLOCK BRAKING MENU

PARAMETER CAN INDEX	VALUES RAW VALUES	DESCRIPTION
Enable `0x2A0100 (bit 5)`	Off/On 0–1	Specifies whether interlock braking is enabled: On = Enabled Off = Disabled
Interlock Decel `0x320100`	0.2–4.0s 102–2048	Specifies the rate at which the vehicle decelerates after the interlock is turned off. Larger values represent slower response times.
Interlock Brake Timeout `0x320200`	0.0–8.0s 0–500	Specifies the maximum allowable duration of an interlock braking event. The timer starts when the interlock is turned off. If the time expires before the vehicle has stopped, the controller engages the EM brake.

CURRENT MENU

CURRENT MENU

PARAMETER CAN INDEX	VALUES RAW VALUES	DESCRIPTION
Main Current Limit `0x250000`	15–90A 60–360	Specifies the maximum current the controller supplies to the motor during normal driving. **Note:** Reducing the current limit protects the motor from potentially damaging current and reduces the maximum torque applied to the drive system.
Braking Current Limit `0x250100`	15–90A 60–360	Specifies the maximum current the controller supplies to the motor during braking.
Boost Current `0x250200`	15–90A 60–360	Specifies the maximum current the controller supplies to the motor for the boost current function. Boost current provides a brief increase of current to improve performance with transient loads such as starting on a hill, crossing a threshold, climbing obstacles, etc.
Boost Time `0x250300`	0–10s 0–10	Specifies the maximum length of a boost current event.

INPUTS MENU

The following table describes the parameters on the Inputs menu.

Note: Some of the parameters let you specify CAN for input sources. The CAN signals for these inputs are received by RPDO1; see RPDO1.

INPUTS MENU

PARAMETER CAN INDEX	VALUES RAW VALUES	DESCRIPTION
Interlock Type **[PCF]** 0x320000	0–2 0–2	Specifies the interlock input: 0 = Keyswitch 1 = NO Switch 2 = CAN (SDO)
Sequencing Delay 0x2B0000	0–1000 ms 0–1000	Specifies the time during which the interlock cycles before an HPD Fault or SRO 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.
AUX Switch Input Type **[PCF]** 0x320A00	0–4 0–4	Specifies how the AUX switch input (pin J1-9) is used: 0 = The input is disabled. 1 = Pump SRO check. If the lift or lower switch is closed when the keyswitch is turned on, the Pump SRO Fault occurs. See Lift Switch for Pump SRO Conditions. 2 = Lift lockout signal from a Curtis 906 battery gauge. See Curtis 906 Battery Gauge. 3 = A normally closed (NC) lift inhibit switch. 4 = A normally open (NO) lift inhibit switch. **Note:** The AUX switch input is used when the Driver1 Type parameter is set to 1 or 2.
Pump SRO Type **[PCF]** 0x320700	0–2 0–2	Specifies the input that the controller checks for the Pump SRO Fault: 0 = Disable checking for the fault. 1 = Aux switch input. If the AUX Switch Input Type parameter is 1 and the lift or lower switch is on when the keyswitch is powered on, the fault will occur. 2 = CAN (RPDO1). If RPDO1 indicates the lift or lower switch is on when the keyswitch is powered on, the fault will occur.
Mode Digital Input 0x2A0100 (bit 1)	Off/On 0–1	Specifies the speed mode input: On = A switch connected to the mode input (pin J1-4) Off = CAN (RPDO1)

DRIVERS MENU

The following table describes the parameters for configuring Driver 1 and Driver 2.

DRIVERS MENU

PARAMETER CAN INDEX	VALUES RAW VALUES	DESCRIPTION
Driver1 Type **[PCF]** `0x320800`	0–2 0–2	Specifies how Driver 1 (pin J1-3) is used: 0 = Disabled. 1 = Lift driver — see Lift Driver. 2 = Lift lockout driver — see Lift Lockout Driver.
Driver2 Type **[PCF]** `0x320900`	0–3 0–3	Specifies how Driver 2 (pin J1-11) is used: 0 = Disabled. 1 = Lower valve driver. See Lower Valve Driver. 2 = BDI output. **Note:** You need an exclusive PCBA to use Driver 2 as a BDI output. To obtain the PCBA, contact the Curtis sales-support office in your region. 3 = Horn driver.
Driver1 Fault Check `0x2A0000 (bit 1)`	Off/On 0–1	Indicates whether the controller checks for the Driver 1 Fault.
Driver2 Fault Check `0x2A0000 (bit 5)`	Off/On 0–1	Indicates whether the controller checks for the Driver 2 Fault.
SRO Lift Inhibit `0x2A0100 (bit 0)`	Off/On 0–1	Indicates whether the lift driver output is shut down when an SRO Fault occurs.

EM BRAKE MENU

EM BRAKE MENU

PARAMETER CAN INDEX	VALUES RAW VALUES	DESCRIPTION
Delay `0x250400`	0.0–1.0s 0–63	Specifies the interval between when the controller commands zero speed and engages the EM brake.
Fault Check `0x2A0000 (bit 3)`	Off/On 0–1	Enables or disables fault detection for the EM brake.
Hold Voltage `0x250500`	16.8–24V 168–240	Specifies the voltage the controller applies to the brake coil after the EM brake has been engaged. Specify a voltage high enough to ensure that the brake remains released under all shock and vibration conditions that the vehicle is expected to encounter. **Note:** The controller applies a high initial voltage to the brake coil when the brake is first engaged. After approximately one second, this peak voltage drops to the Hold Voltage.

MOTOR MENU

MOTOR MENU

PARAMETER CAN INDEX	VALUES RAW VALUES	DESCRIPTION
System Resistance `0x260000`	0–800mΩ 0–956	Specifies the resistance that the controller uses for load compensation and speed estimation. The system resistance is the total resistance of the motor, brushes, wiring, and connections. The controller's performance depends upon an accurate System Resistance value; see Set the System Resistance.
Resistance Auto Comp `0x2A0100 (bit 2)`	Off/On 0–1	Specifies whether the controller measures motor resistance before the brake is released.
Auto Comp Current Limit `0x260100`	5–50% 13–128	Specifies the current limit the controller uses to measure motor resistance. The value is a percentage of the Main Current Limit parameter.
Speed Scaler `0x260200`	20–27V 185–250	Specifies the maximum voltage that the controller can apply to the motor. Typically this is set to the maximum voltage that the motor's back EMF can reach. The following equation calculates the back EMF, with V_{motor} representing the voltage measured between the motor's terminals: $V_{BEMF} = V_{motor} - I * R$ Speed Scaler 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 `0x260300`	0–50A 0–200	Specifies the motor's current rating. Use the rating provided by the motor's manufacturer.
Max Current Time `0x260400`	0–120s 0–120	Specifies how long the motor runs at full current when the motor overheats. Once this time expires, the controller cuts back current.
Cutback Gain `0x260500`	0–100% 0–255	Specifies how quickly the controller cuts back the drive current when the motor overheats and the specified Max Current Time has expired. Higher values provide a quicker cutback.
Motor Temp Alarm `0x320300`	0.0–5.0V 0–4095	Specifies the motor temperature sensor voltage that indicates the maximum motor temperature. If the voltage detected by the sensor exceeds the specified voltage, a Motor Overtemperature fault occurs and the controller switches to low speed mode (speed mode 2). A value of 0.0 disables the motor temperature sensor.

BDI MENU

You can use any lead battery with the controller. However, the battery's duty cycle, power level, and charger are factors that impact the controller's BDI function.

You must configure the BDI parameters to reflect your battery's characteristics by performing the steps in Battery Discharge Indicator (BDI) Setup.

The following table describes the BDI parameters.

Note: The minimum and/or maximum values of some parameters are restricted by other parameters.

BDI MENU

PARAMETER CAN INDEX	VALUES RAW VALUES	DESCRIPTION
Full Voltage `0x270000`	20.0–28.0V 2143–3000	Specifies the voltage at which the battery is fully charged. The value should be the voltage level of the fully-charged battery pack. The minimum and maximum values are restricted by the following parameters: • Minimum: Empty Voltage • Maximum: Start Charge Voltage and Reset Voltage
Empty Voltage `0x270100`	16.0–24.0V 1714–2572	Specifies the voltage at which the battery is fully discharged. The maximum value is restricted by Full Voltage.
Full Charge Voltage `0x270200`	24.0–32.0V 2572–3429	Specifies the battery voltage above which charging is considered finished. The minimum value is restricted by Start Charge Voltage.
Start Charge Voltage `0x270300`	21.0–29.0V 2250–3107	Specifies the battery voltage above which charging starts if a charger is connected. The minimum and maximum values are restricted by the following parameters • Minimum: Full Voltage • Maximum: Full Charge Voltage
Reset Voltage `0x270400`	20.0–28.0V 2143–3000	Specifies the battery voltage at which the controller resets the BDI percentage to 100% after the charger is disconnected and the controller is powered up. The value should be 1–2V above the nominal battery voltage. The minimum value is restricted by Full Voltage.
Discharge Time `0x270600`	1–600 minutes 1–600	Specifies the discharge rate, which is the minimum time for decreasing the BDI percentage from 100% to 0% if the battery voltage is lower than Empty Voltage. Larger values are for larger batteries, which charge more slowly.
Charge Time `0x270700`	1–600 minutes 1–600	Specifies the charge rate, which is the number of minutes it takes for the BDI percentage to increase from 0% to 100% while the battery is being charged. Larger values are for larger batteries, which charge more slowly.
BDI Reset Percent `0x270500`	0–100% 0–100	Specifies the percentage of battery voltage above which the BDI percentage will not reset when the keyswitch is turned on. When a battery has a high BDI percentage, its float voltage when the keyswitch is powered on could cause false BDI resets. This parameter lets you preempt this problem by specifying a minimum threshold for resetting the BDI percentage. When the keyswitch is first powered on, the BDI percentage will reset to 100% only if **both** of the following are true: • The B+ Voltage is greater than the Reset Voltage value. • The BDI percentage is less than the BDI Reset Percent value. **Note:** The BDI variable displays the BDI percentage.

BDI MENU, cont'd

PARAMETER CAN INDEX	VALUES RAW VALUES	DESCRIPTION
Low BDI Level `0x270800`	0–100% 0–100	Specifies the battery discharge level at which the maximum speed will be limited in order to protect the battery from deep discharge. Specifying 0% disables this function, thus allowing the battery to completely discharge.
Low BDI Max Speed `0x270900`	10–100% 410–4095	Specifies the maximum vehicle speed if the BDI percentage falls below the Low BDI Level. The value is a percentage of the speed mode's maximum speed.
Lift Lockout Threshold `0x270A00`	0–50% 0–50	Specifies the BDI percentage at or below which the controller disables the lift to prevent battery damage.
BDI Source `0x320E00`	0–2 0–2	Specifies the source used to calculate the BDI percentage: 0 = The 1212C controller. 1 = A Curtis 3140 gauge. For information on related parameters, see 3140 Menu. 2 = A battery management system (BMS). The BMS Node ID parameter specifies the BMS's node ID.

COMPENSATION MENU

COMPENSATION MENU

PARAMETER CAN INDEX	VALUES RAW VALUES	DESCRIPTION
Anti-Rollback Comp `0x280100`	0–125% 0–160	Specifies the motor load compensation after the throttle is released to neutral and the speed is near zero. Higher values provide more hill-holding force. Note: For guidelines on setting the parameter, see Adjust Anti-Rollback Compensation.

EMERGENCY REVERSE MENU

EMERGENCY REVERSE MENU

PARAMETER CAN INDEX	VALUES RAW VALUES	DESCRIPTION
EMR Type **[PCF]** `0x2D0300`	0–2 0–2	Specifies the belly button switch (emergency reverse switch) input: 0 = A normally open (NO) switch connected to pin J1-14. 1 = A normally closed (NC) switch connected to pin J1-14. 2 = A switch connected to the CAN tiller. The emergency reverse signal is received by RPDO1; see RPDO1.
EMR Fwd Only `0x2A0100 (bit 3)`	Off/On 0–1	Specifies whether emergency reverse can be activated while driving in either direction: On = Emergency reverse can be activated only while driving forward. Off = Emergency reverse can be activated while driving in either direction.
Speed `0x290000`	10–100% 410–4095	Specifies the maximum speed when emergency reverse is active. The value is a percentage of the maximum speed for reverse, which is defined by the Rev Max Speed parameter.
Time Limit `0x290100`	0.0–10.0s 0–153	Specifies how long emergency reverse is active after the vehicle starts moving in reverse. If emergency reverse should not have a time limit, specify 0.0s.
Decel Rate `0x290200`	0.2–8.0s 102–4095	Specifies the rate at which the vehicle brakes to a stop when emergency reverse is activated while the vehicle is moving forward.
Accel Rate `0x290300`	0.2–8.0s 102–4095	Specifies the rate at which the vehicle accelerates in the opposite direction after emergency reverse stops the vehicle.
Max Braking Current `0x290400`	15–90A 60–360	Specifies the maximum motor current when the vehicle brakes to a stop after emergency reverse is activated.
EMR Interlock `0x2A0100 (bit 6)`	Off/On 0–1	Specifies whether the interlock must be cycled before the operator resumes driving after an emergency reverse operation. On indicates that the interlock must be cycled.

CANOPEN MENU

The CANopen menu contains parameters that configure the controller's CANopen features. The CANopen menu also contains the 3140 settings menu.

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

CANOPEN MENU

PARAMETER CAN INDEX	VALUES RAW VALUES	DESCRIPTION
Auto Operation State `0x2A0000 (bit 2)`	Off/On 0–1	Specifies the controller's CANopen NMT state after the controller has powered up: On = Operational Off = Pre-operational
Node ID `0x2F0000`	1–127 1–127	Specifies the controller's node ID.
Baud Rate `0x2F0100`	0–4 0–4	Specifies the CAN baud rate: 0 = 125 kb/s 1 = 250 kb/s 2 = 500 kb/s 3 = 800 kb/s 4 = 1 mb/s
Heartbeat Rate `0x101700`	16–200ms 4–50	Specifies the cyclic rate of the controller's heartbeat messages.
PDO Timeout Time `0x2F0400`	0–500ms 0–125	Specifies the RPDO1 timeout interval. If RPDO1 does not receive data before the timeout elapses, a PDO Timeout fault will occur. To disable the timeout, specify 0.
Slave PDO Timeout Time `0x320600`	0–200ms 0–50	Specifies the RPDO2 timeout interval. If RPDO2 does not receive data before the timeout elapses, a fault occurs. The fault depends upon whether a Curtis 3140 gauge or a BMS is being used: • Curtis 3140 gauge: Gage PDO Timeout • BMS: BMS PDO Timeout To disable the timeout, specify 0.
Emergency Message Rate `0x2F0300`	16–200ms 4–50	Specifies the minimum time between emergency messages transmitted by the controller. An interval between emergency messages prevents the controller from generating an excessive number of emergency messages that could otherwise flood the CAN bus.
BMS Node ID `0x2D0100`	1–127 1–127	Specifies the node ID of the battery monitoring system (BMS).

3140 Menu

The following parameters configure the controller for use with a Curtis 3140 gauge.

3140 MENU

PARAMETER CAN INDEX	VALUES RAW VALUES	DESCRIPTION
Gage Node ID `0x2D0000`	1–127 1–127	Specifies the 3140 gauge's node ID.
Backlight Percent `0x320D00`	0–100% 0–100	Specifies the 3140 gauge's backlight percentage.

MISCELLANEOUS MENU

MISCELLANEOUS MENU

PARAMETER CAN INDEX	VALUES RAW VALUES	DESCRIPTION
Sleep `0x2B0100`	0–60 minutes 0–60	Specifies the interval between the last throttle request or serial communication and when the controller goes into sleep mode. To disable the sleep function, specify 0.
First-on Mode `0x2A0000 (bit 4)`	Off/On 0–1	Specifies whether the traction and lift can work together: Off = The traction and lift can work together. On = The traction and lift cannot work together. This saves battery capacity.
Over Voltage Cutback `0x320C00`	31.0–33.0V 3323–3538	Specifies the overvoltage cutback threshold. For more information, see Battery Voltage and Cutbacks.
Hourmeter Type `0x320F00`	0–1 0–1	Specifies whether the hourmeter is enabled when the keyswitch or the interlock is turned on: 0 = Keyswitch 1 = Interlock

4 — MONITOR MENU

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

The Monitor menu contains the following menus:

- Voltage Menu
- Controller Menu
- Inputs and Outputs Menu
- CAN Status Menu

VOLTAGE MENU

VOLTAGE MENU

VARIABLE CAN INDEX	VALUES RAW VALUES	DESCRIPTION
KSI Voltage `0x400000`	0.0–38.2V 0–4095	Indicates the keyswitch voltage.
Battery Voltage `0x400200`	0.0–38.2V 0–4095	Indicates the battery voltage.
Cap Voltage `0x400300`	0.0–38.2V 0–4095	Indicates the voltage of the controller's internal capacitor bank.
Motor Voltage `0x400800`	–27.4 – +27.4V –4095 – +4095	Indicates the voltage drop between the motor terminals.
Pot Low Voltage `0x405100`	0.0–5.0V 0–4095	Indicates the pot low voltage.

CONTROLLER MENU

The following table describes the variables on the Controller menu.

Note: The Controller menu also contains the Switches menu.

CONTROLLER MENU

VARIABLE CAN INDEX	VALUES RAW VALUES	DESCRIPTION
Temp `0x400100`	–55 – +120°C –550 – +1200	Indicates the controller's internal temperature.
Motor Thermal Cutback `0x400900`	0–100% 0–4095	Indicates the current available as a result of the overtemperature cutback function. The value is a percentage of the Main Current Limit parameter. 100% indicates no cutback.
Armature Current `0x400A00`	–90 – +90A –360 – +360	Indicates the motor's armature current.
Current Limit `0x400E00`	–90 – +90A –360 – +360	Indicates the controller's current limit. This includes all current limits, such as that for boost mode, overtemperature protection, and so on.
Resistance `0x400D00`	0–854mΩ 0–1023	Indicates the system resistance.
Throttle `0x400500`	–100–100% –4096 – +4095	Indicates the throttle request.
BDI `0x200600`	0–100% 0–100	Indicates the battery capacity as a percentage of the fully charged battery's capacity.
Hourmeter `0x200A00`	0–99999.9 hours 0–999999	Indicates how many hours of operation have occurred since the hourmeter was last reset.

Switches Menu

The following parameters indicate the status of switches connected to the logic connector.

SWITCHES MENU

VARIABLE CAN INDEX	VALUES RAW VALUES	DESCRIPTION
Mode Switch `0x401000 (bit 2)`	Off/On 0–1	Indicates the status of the mode switch (pin J1-4).
Forward Switch `0x401000 (bit 6)`	Off/On 0–1	Indicates the status of the forward switch (pin J1-10).
Reverse Switch `0x401000 (bit 5)`	Off/On 0–1	Indicates the status of the reverse switch (pin J1-12).
Interlock Switch `0x401000 (bit 3)`	Off/On 0–1	Indicates the status of the interlock switch (pin J1-6).
EMR Switch `0x401000 (bit 1)`	Off/On 0–1	Indicates the status of the emergency reverse switch (pin J1-14).
AUX Switch `0x401200 (bit 2)`	Off/On 0–1	Indicates the status of the AUX input switch (pin J1-9).

INPUTS AND OUTPUTS MENU

INPUTS AND OUTPUTS MENU

VARIABLE CAN INDEX	VALUES RAW VALUES	DESCRIPTION
Mode Input `0x404B00 (bit 2)`	Off/On 0–1	Indicates the status of the mode input.
Forward Input `0x404B00 (bit 6)`	Off/On 0–1	Indicates the status of the forward input.
Reverse Input `0x404B00 (bit 5)`	Off/On 0–1	Indicates the status of the reverse input.
Interlock Input `0x404B00 (bit 3)`	Off/On 0–1	Indicates the status of the interlock input.
EMR Input `0x404B00 (bit 1)`	Off/On 0–1	Indicates the status of the emergency reverse input.
Lift Lockout Input `0x401700 (bit 7)`	Off/On 0–1	Indicates the status of the lift lockout input.
Neutral State `0x401300 (bit 4)`	Off/On 0–1	Indicates whether the vehicle is in neutral. On indicates neutral.
Main Relay `0x401600 (bit 5)`	Off/On 0–1	Indicates the status of the main relay driver.
EM Brake `0x401300 (bit 7)`	Off/On 0–1	Indicates the status of the EM brake driver.
Driver1 `0x401800 (bit 6)`	Off/On 0–1	Indicates the status of Driver 1.
Driver2 `0x401800 (bit 7)`	Off/On 0–1	Indicates the status of Driver 2.

CAN STATUS MENU

CAN STATUS MENU

VARIABLE CAN INDEX	VALUES RAW VALUES	DESCRIPTION
CAN NMT State `0x1B0000`	0–127 0–127	Indicates the controller's NMT state. States are represented by the following values: 0 = Initialization 4 = Stopped 5 = Operational 127 = Pre-operational

5 — FUNCTIONS MENU

The following table describes the functions on the Functions menu.

FUNCTIONS MENU

FUNCTION CAN INDEX	VALUES RAW VALUES	DESCRIPTION
Restore Parameters `0x401A00 (bit 6)`	No/Yes 0–1	Resets all parameters to their factory default settings. To reset, specify Yes. If you reset the parameters, a Parameter Change Fault will occur and you will need to cycle the keyswitch.
Clear Hourmeter `0x401500 (bit 6)`	No/Yes 0–1	Resets the hourmeter to 0.0 hours. To reset, specify Yes.

6 — CANOPEN COMMUNICATIONS

The 1212C controller complies with the CAN in Automation (CiA) CANopen DS 301 specification.

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

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

This chapter describes the controller's CANopen features and object dictionary.

BYTE AND BIT SEQUENCE ORDER

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

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

The following example shows how an SDO writes the data 04E2h to the object with the index and sub-index 334C-01h:

0	1	2	3	4	5	6	7
Control Byte	Index		Sub-index	Data			
22h	4Ch	33h	01h	E2h	04h	00h	00h

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

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

NMT STATE CONFIGURATION

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

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

MESSAGE CAN-IDS

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

EMERGENCY MESSAGES AND FAULTS

The controller transmits an emergency message when a fault is generated or cleared. Emergency messages consist of eight bytes, with the five least significant bytes identifying the faults. Each of these bytes corresponds to a *fault category*, and the bits within a category identify active faults.

For example, if bit 1 of byte 3 is 1b, the Pump SRO Fault, which belongs to fault category 1, is active.

Note: For a more detailed example, see Emergency Message Example.

The following table describes the emergency message bytes, and Table 2 describes faults' categories and bits.

BYTE(S)	NAME	DESCRIPTION
0–1	Error Category	The value is 1000h.
2	Error Register	Indicates if a fault is active: • 0 = No active fault • 1 = One or more active faults **Note:** The value is identical to the CANopen Error Register object's value.
3	Fault Category 1	Indicates fault(s) that belong to the corresponding fault category.
4	Fault Category 2	
5	Fault Category 3	
6	Fault Category 4	
7	Fault Category 5	

Table 2 Fault Categories and Bits

Fault	Fault Category	Fault Bit
Low BDI	1	0
Pump SRO Fault	1	1
SRO Fault	1	2
HPD Fault	1	3
Wiring Fault	1	4
Throttle Fault	1	5
Precharge Fault	1	6
Main Driver Fault	1	7
Main Relay Welded	2	0
Main Relay DNC	2	1
Brake Off Fault	2	2
Motor Overtemperature	2	3
Battery Disconnect Fault	2	4
Brake On Fault	2	5
Current Sense Fault	2	6
Hardware Fault	2	7
Software Fault	3	0
Parameter Change Fault	3	1
Motor Short	3	2
Motor Open	3	3
Controller Overcurrent	3	4
Motor Temp Hot Cutback	3	5
Controller Overtemp Cutback	3	6
Controller Undertemp Cutback	3	7
Controller Severe Overtemp	4	0

Table 2 Fault Categories and Bits, cont'd

Fault	Fault Category	Fault Bit
Overvoltage Cutback	4	1
Severe Overvoltage	4	2
Undervoltage Cutback	4	3
Severe Undervoltage	4	4
Parameter Fault	4	5
Gage PDO Timeout	4	6
PDO Timeout	5	0
Driver 1 Fault	5	1
Driver 2 Fault	5	2
BMS PDO Timeout	5	4
EMR Sequencing Fault	5	5

Note: The Emergency COB ID object indicates the COB-ID for emergency messages.

Emergency Message Example

The following table shows a trace of the controller's emergency messages:

Trace	Description
`00 10 01 00 00 00 02 00`	The Overvoltage Cutback fault occurs. (Bit 1 of byte 4 is set.)
`00 10 01 00 00 00 06 00`	The Severe Overvoltage Fault occurs and the Overvoltage Cutback Fault is still active. (Bits 1–2 of byte 4 are set.)
`00 10 00 00 00 00 00 00`	Both faults are cleared.

EXPEDITED SDOS

The controller supports expedited SDOs, which have the following COB-IDs:

- Receive SDOs (SDO RX) = 0600h + the controller's node ID
- Transmit SDOs (SDO TX) = 0580h + the controller's node ID

All expedited SDO request messages consist of eight bytes, which are described in the following table:

Byte(s)	Description
0	The control byte.
1–2	The CAN object's index.
3	The CAN object's sub-index.
4–7	The data being transferred.

The following table describes the control byte fields:

Bit(s)	Description
5–7	The *command specifier*, which indicates the SDO's transfer type. The following list describes the transfer types: • 001b = Write data • 011b = Confirm a write • 010b = Request data • 010b = Device responds with requested data • 100b = Abort SDO
4	*Reserved.* Always 0b.
2–3	The *n* field, which always equals 00b.
1	The *e* field, which indicates the transfer type: • 0b = Normal (segmented) transfer • 1b = Expedited transfer The 1212C controller sets this bit to 1b when transferring data.
0	The *s* field, which always equals 0b.

Note: Some CANopen systems use the *n* and *s* fields to indicate unused bytes. The controller always transfers eight bytes, so it sets the *n* and *s* fields to 0.

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

Transfer Type	Command Byte
Write data	22h
Confirm a write	60h
Request data	40h
Device responds with requested data	42h
Abort SDO	80h

PDOs

The controller provides the following preconfigured PDOs:

- RPDO1 and TPDO1 communicate with a CAN tiller.
- RPDO2 receives data from a battery monitoring system.

The following topics describe the PDOs.

PDO Timing

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

The PDO Timeout Time and Slave PDO Timeout Time parameters specify the RPDO1 and RPDO2 timeout intervals, respectively.

PDO1 — Communicating with a CAN Tiller

If the vehicle has a CAN throttle, you can use RPDO1 and TPDO1 to communicate with a CAN tiller. The tiller periodically transmits data to RPDO1 and the controller responds with TPDO1.

The following list describes the PDO1 COB-IDs:

- RPDO1 = The sum of 0200h and the controller's node ID
- TPDO1 = The sum of 0180h and the controller's node ID

The following topics describe RPDO1 and TPDO1.

RPDO1

RPDO1 receives data from the CAN tiller. The data for RPDO1's two least significant bytes depends upon whether the Throttle menu's Type parameter is 6 or 7. The following table describes RPDO1's bytes:

Byte(s)	Type = 6	Type = 7
0	The switch flag byte, which uses the following bits to control the following switches. 1 indicates the switch is active: • Bit 0 = Neutral. 1 indicates neutral. • Bit 1 = Belly button switch (emergency reverse switch) • Bit 2 = Mode switch. 1 indicates speed mode 2. • Bit 3 = *Reserved* • Bit 4 = Lift switch • Bit 5 = Lower switch • Bits 6–7 = *Reserved*	The switch flag byte, which uses the following bits to control the following switches. 1 indicates the switch is active: • Bit 0 = Reverse switch • Bit 1 = Forward switch • Bit 2 = Mode switch. 1 indicates speed mode 2. • Bit 3 = Belly button switch (emergency reverse switch) • Bit 4 = Lift switch • Bit 5 = Lower switch • Bits 6–7 = *Reserved*
1	The most significant bit is a stuffing bit. The other bits are reserved.	*Reserved*.
2–3	The throttle request. The value should be within the range specified by the CAN Throttle Low and CAN Throttle High parameters, otherwise a Throttle Fault will occur.	
4–7	*Reserved*.	

Note: To control the belly button and mode switches with PDO1, the switches must be configured as CAN switches with the EMR Type and Mode Digital Input parameters, respectively.

TPDO1

TPDO1 responds with data for the CAN tiller. The following table describes TPDO1's bytes:

Byte(s)	Description
0	The System Action object (0x400600), which indicates various actions. The following list shows the values that represent the actions: • 0h = No action • 1h = Open motor armature • 2h = Short motor armature • 4h = Kill main relay • 8h = Kill EM brake • 10h = Kill throttle • 20h = Kill Driver 1 • 40h = Kill Driver 2
1–2	The Switches object (0x401000), which indicates the state of the controller's switches. 1 indicates the switch is active: • Bit 0 = Charger inhibit switch • Bit 1 = Emergency reverse switch • Bit 2 = Mode switch • Bit 3 = Interlock switch • Bit 4 = *Reserved* • Bit 5 = Reverse switch • Bit 6 = Forward switch • Bits 7–15 = *Reserved*
3–4	The AUX Switch AD Data object (0x402D00), which indicates the AD value of the Aux switch input (pin J1-9).
5–6	The Pot Wiper AD Data object (0x402C00), which indicates the AD value of the pot wiper input (pin J1-1).
7	*Reserved*.

RPDO2 — Receiving Data from a Battery Monitoring System

RPDO2 receives data transmitted by a battery monitoring system (BMS). The controller uses the BMS' state of charge percentage to handle the following conditions:

Condition	Controller Action
The state of charge percentage is less than the Low BDI Level parameter.	• The controller's maximum speed is limited to that specified by the Low BDI Max Speed parameter. • The LOW BDI fault occurs.
The state of charge percentage is less than the Lift Lockout Threshold parameter.	The controller shuts down the lift driver.

The COB-ID of RPDO2 messages is the sum of 0280h and the battery monitoring system's node ID, which is specified with the BMS Node ID parameter.

The following table describes RPDO2's bytes:

Byte(s)	Description
0–1	The system voltage. The values 0–10000 represent 0–1000V.
2–3	The system current. The values 0–10000 represent 0–1000A.
4	The state of charge percentage. The values 0–255 represent 0–100%.
5	The battery's amp hours, with 0–255 representing 0–255Ah.
6	The status flag, with the following bits representing the following statuses. 1 indicates the status is active: • Bit 0 = Overvoltage status • Bit 1 = Over discharge status • Bit 2 = Communication outage status • Bit 3 = Undervoltage status • Bit 4 = Overcurrent status • Bit 5 = Overtemperature protect status • Bit 6 = Temperature protect status • Bit 7 = Battery charging status
7	*Reserved.*

CANOPEN OBJECT DICTIONARY

The following table describes the objects in the controller's CANopen object dictionary.

Note: This table does not include the objects for parameters and Monitor menu variables. For descriptions and CAN indexes of these objects, see Chapter 3 and Chapter 4.

Name	Index	Sub-Index	Description	Read / Write	Values
Device Type	1000h	00h	Indicates whether a device follows a standard CiA device profile. The controller does not follow a standard CiA profile, so the value is always 0.	RO	0
Error Register	1001h	00h	Indicates if a fault is active: 0 = No active fault 1 = One or more active faults	RO	0–1
Emergency COB ID	1014h	00h	Indicates the Emergency Message COB-ID.	RO	0h–0FFh
Heartbeat Rate	1017h	00h	Indicates the cyclic rate of the controller's heartbeat messages. The value is a multiple of 4ms. For example, a value of 25 indicates a 100ms heartbeat rate.	RW	4–50
Identity Object	1018h	Provides information on the controller.			
		00h	Indicates the size of the object.	RO	01h
		01h	Indicates the CiA-assigned identifier of Curtis Instruments. The value is always 4349h.	RO	4349h

7 — DIAGNOSTICS AND TROUBLESHOOTING

The 1212C controller provides diagnostic information to help technicians troubleshoot drive system problems. You can view the diagnostic information using Curtis programming devices, an external status LED, and CANopen emergency messages.

Faults are identified with the fault codes and fault names listed in Table 3, Troubleshooting Chart.

CURTIS PROGRAMMER DIAGNOSTICS

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

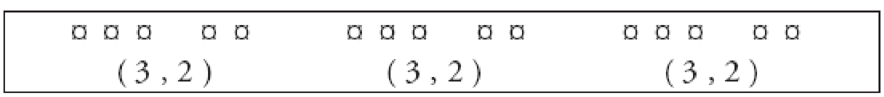
For information on programming devices, see Curtis Programming Devices.

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

LED DIAGNOSTICS

You can connect an external status LED to display fault codes; see External Status LED. During normal operation, with no faults present, the status LED flashes once per second. If the controller detects a fault, the status LED continuously flashes a 2-digit fault code until the fault is corrected.

For example, the fault code for the Brake On Fault is 3,2. The following diagram shows the fault's flash sequence:



CANOPEN DIAGNOSTICS

When a fault occurs, the controller sends an emergency message that includes the fault code. For more information, see Emergency Messages and Faults.

FAULT HANDLING AND FAULT CODES

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

For example, when an SRO fault occurs, the controller prevents the vehicle from driving until the operator turns off the direction and interlock inputs.

The following table describes how to troubleshoot faults. The first column contains the fault codes. The second column contains the fault names and the actions the controller takes when faults occur. The remaining columns provide information for diagnosing and recovering from faults.

Table 3 Troubleshooting Chart

Fault Code	Fault Fault Actions	Description and Possible Causes	Recovery
1,1	Motor Temp Hot Cutback *Current limit cutback*	• Excessive load on the vehicle. • Controller is operating in an extremely high temperature. **Note:** The Cutback Gain parameter specifies how quickly the current limit cutback occurs.	Reduce the motor temperature.
1,2	Throttle Fault *Shut down throttle*	The throttle input is out of range. The range depends upon the throttle type: • Voltage throttles: The pot wiper voltage is outside the range specified by the Pot Low and Pot High parameters. • Resistive throttles: The pot low input voltage is less than 250mV or greater than 490mV. • CAN Throttle: The throttle signal is outside the range specified by the CAN Throttle Low and CAN Throttle High parameters. Possible causes include: • Throttle input wire is open or shorted. • Throttle pot is defective.	Address the possible causes.
1,3	Undervoltage Cutback *Current limit cutback*	The battery voltage is below 17V. Possible causes include: • Battery resistance is too high. • Battery was disconnected while driving.	Raise the battery voltage to above 17V.
1,4	Overvoltage Cutback *Current limit cutback*	The battery voltage is above the voltage specified by the Over Voltage Cutback parameter. Possible causes include: • Battery was disconnected during regen braking. • Battery or battery cable resistance is too high for the regen current.	Lower the battery voltage to below the overvoltage threshold.
1,5	Severe Overvoltage *Shut down throttle* *Shut down EM brake driver* *Shut down motor driver*	The battery voltage is above 34V. Possible causes include: • Battery disconnected during regen braking. • Battery or battery cable resistance is too high for the regen current.	Lower the battery voltage to below 34.0V.
1,6	Severe Undervoltage *Shut down throttle* *Shut down EM brake driver*	Battery voltage is below 14V. Possible causes include: • Battery resistance is too high. • Battery disconnected while driving.	Raise the battery voltage to above 14V.
2,1	SRO Fault *Shut down throttle*	Incorrect sequence of direction, interlock, and keyswitch inputs. The SRO parameter specifies the fault condition.	Turn off the direction and interlock inputs.
2,2	EMR Sequencing Fault *Shut down throttle* *Shut down EM brake driver*	The emergency reverse switch (belly button switch) is on before the keyswitch is turned on. This fault can occur if the switch is stuck.	Release the emergency reverse switch.
2,3	Main Driver Fault *Shut down throttle* *Shut down main relay*	• Internal relay driver is open or shorted. • Internal relay coil is defective.	Cycle the keyswitch.

Table 3 Troubleshooting Chart, cont'd

Fault Code	Fault Fault Actions	Description and Possible Causes	Recovery
2,4	Main Relay Welded *Shut down throttle* *Shut down main relay*	• Internal relay welded. • The controller detected an incorrect battery voltage or capacitor bank voltage.	Address the possible causes, then cycle the keyswitch.
2,5	Main Relay DNC *Shut down throttle* *Shut down main relay*	• Internal relay is stuck open. • Internal relay tips are oxidized or are not making good contact. • The controller detected an incorrect battery voltage or capacitor bank voltage.	Address the possible causes, then cycle the keyswitch.
2,6	Pump SRO Fault *Shut down Driver 1 and/or Driver 2*	The lift or lower switch is closed before the keyswitch is turned on. The lift or lower switch might be stuck. **Note:** Whether Driver 1 and/or Driver 2 is shut down depends upon the Driver1 Type parameter and/or Driver2 Type parameter.	Turn the lift or lower switch off, then cycle the keyswitch.
3,1	Wiring Fault *Shut down throttle*	The HPD Fault has been active for 10 seconds. Possible causes include: • Misadjusted throttle. • Broken throttle pot or throttle mechanism.	Address the possible causes, then cycle the keyswitch.
3,2	Brake On Fault *Shut down throttle* *Shut down EM brake driver*	• EM brake driver is shorted. • EM brake coil is open.	Address the possible causes.
3,3	Precharge Fault *Shut down throttle*	• Precharge circuit is damaged. • Excessive load on the capacitor bank prevented it from charging.	Address the possible causes, then cycle the keyswitch.
3,4	Brake Off Fault *Shut down throttle* *Shut down EM brake driver*	• EM brake driver is open. • EM brake coil is shorted.	Address the possible causes.
3,5	HPD Fault *Shut down throttle*	• A direction input is on and the throttle is above neutral when the interlock input is turned on. • An emergency reverse operation has concluded, but the throttle has not been returned to neutral. • The throttle is stuck.	Reduce the throttle to neutral and turn off the direction and interlock inputs.
4,1	Current Sense Fault *Shut down throttle* *Shut down EM brake driver* *Shut down main relay* *Shut down motor driver*	• Motor or motor wiring is shorted. • Defective controller.	Address the possible causes, then cycle the keyswitch.
4,2	Controller Overcurrent *Shut down throttle* *Shut down EM brake driver* *Shut down main relay* *Shut down motor driver*	The controller might be defective.	Cycle the keyswitch.

Table 3 Troubleshooting Chart, cont'd

Fault Code	Fault Fault Actions	Description and Possible Causes	Recovery
4,3	Hardware Fault *Shut down throttle* *Shut down EM brake driver* *Shut down main relay* *Shut down motor driver*	• Motor voltage does not correspond to the throttle request. • Defective controller.	Cycle the keyswitch.
4,4	Software Fault *Shut down throttle* *Shut down EM brake driver* *Shut down main relay*	• Defective firmware. • Defective controller.	Cycle the keyswitch.
4,5	Battery Disconnect Fault *Shut down throttle* *Shut down EM brake driver*	• Battery was accidentally disconnected during regen braking. • Battery is not connected. • Faulty connection to the battery terminals.	Address the possible causes, then cycle the keyswitch.
4,6	Motor Overtemperature *Motor speed reduced to the maximum speed for mode 2*	The motor temperature is above the threshold specified by the Motor Temp Alarm parameter.	Reduce the motor temperature.
5,1	Low BDI *Motor speed reduced to that specified by the Low BDI Max Speed parameter*	The battery discharge level is lower than the Low BDI Level parameter.	Address the possible causes.
5,2	Controller Overtemp Cutback *Current limit cutback*	The heatsink temperature is above 80°C. Possible causes include: • Excessive load on the vehicle. • Controller is operating in a high temperature.	Lower the heatsink temperature to below 80°C.
5,3	Controller Severe Overtemp *Current limit reduced to 0*	The heatsink temperature is above 105°C. Possible causes include: • Excessive load on the vehicle. • Controller is operating in a high temperature.	Lower the heatsink temperature to below 105°C.
5,4	Controller Undertemp Cutback *Current limit cutback starts at –10°C and is reduced to 50% at –25°C*	The heatsink temperature is below –25°C. Possible causes include: • Controller is operating in a low temperature. • The temperature sensor is broken.	Raise the heatsink temperature to above –25°C.
5,5	Parameter Change Fault *Shut down throttle* *Shut down EM brake driver* *Shut down main relay* *Shut down Driver 1* *Shut down Driver 2*	A parameter that requires cycling the keyswitch was changed, but the keyswitch has not been cycled. **Note:** Parameters that require cycling the keyswitch are marked as [PCF] in the Programmable Parameters chapter.	Cycle the keyswitch.
5,6	Parameter Fault *Shut down throttle* *Shut down EM brake driver* *Shut down main relay*	• Defective firmware. • Defective controller.	Cycle the keyswitch.

Table 3 Troubleshooting Chart, cont'd

Fault Code	Fault Fault Actions	Description and Possible Causes	Recovery
6,1	Motor Short *Shut down throttle* *Shut down EM brake driver* *Shut down main relay* *Shut down motor driver*	The motor wires are shorted.	Repair the wiring, then cycle the keyswitch.
6,2	Motor Open *Shut down throttle* *Shut down EM brake driver* *Shut down main relay*	• The motor is not connected to the controller. • Faulty motor cable wiring.	Address the possible causes, then cycle the keyswitch.
6,3	*Gage PDO Timeout* *No fault action*	The time between RPDO2 messages exceeded the time specified by the Slave PDO Timeout Time parameter. The fault occurs when communication between the 1212C controller and the Curtis 3140 gauge has halted.	Address the possible causes, then cycle the keyswitch.
6,4	PDO Timeout *Shut down throttle* *Shut down Driver 1* *Shut down Driver 2*	The time between RPDO1 messages exceeded the time specified by the PDO Timeout Time parameter. The fault occurs when communication between the 1212C controller and the CAN tiller has halted.	Address the possible causes, then cycle the keyswitch.
6,5	BMS PDO Timeout *No fault action*	The time between RPDO2 messages exceeded the time specified by the Slave PDO Timeout Time parameter. The fault occurs when communication between the 1212C controller and the BMS has halted.	Address the possible causes, then cycle the keyswitch.
6,6	Driver 1 Fault *Shut down Driver 1*	Driver 1 is open or shorted. Possible causes include: • Bad connector crimps. • Faulty wiring.	Address the possible causes, then cycle the keyswitch.
6,7	Driver 2 Fault *Shut down Driver 2*	Driver 2 is open or shorted. Possible causes include: • Bad connector crimps. • Faulty wiring.	Address the possible causes, then cycle the keyswitch.

8 — INITIAL SETUP

Before operating the vehicle, carefully complete the following initial setup procedures.

Step 1 Begin the Setup Procedures

1. Jack the vehicle drive wheels up off the ground so that they spin freely.
2. Doublecheck all wiring to ensure that it is consistent with the wiring guidelines described in Installation and Wiring.
3. Make sure all connections are tight.
4. Put the throttle in neutral and open the forward and reverse switches.
5. Turn on the controller.
6. Connect the Curtis programming device.

Step 2 Configure Throttle

It is important to configure the throttle so that the controller output is operating across its full range. The following procedures set the Neutral Deadband and Throttle Max parameters to values that correspond to the absolute full range of the throttle.

When you tune the throttle, include a buffer around the absolute full range of the throttle mechanism. This allows for throttle resistance variations over time and temperature and for variations in the tolerance of potentiometer values between individual throttle mechanisms.

Take the following steps to configure the throttle:

1. Specify the throttle type with the Type parameter (Throttle menu).
2. Follow the instructions in the following topics, in order:
    - Tune the Neutral Deadband
    - Tune Maximum Throttle
    - Confirm Proper Throttle Operation

Tune the Neutral 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, yet without an excessive amount of travel in the neutral zone.

Use the Neutral Deadband parameter to adjust the deadband. Start with a Neutral Deadband value of 10%, which should work for most applications. However, to determine the best value for your system, follow these guidelines:

- If the throttle travels too far when starting out of neutral before the brake disengages, decrease the Neutral Deadband parameter.
- If the brake sometimes doesn't engage when the throttle is returned to neutral, increase the Neutral Deadband parameter.
- If a wigwag or unipolar throttle assembly is being used, check and adjust the Neutral Deadband parameter for the reverse direction. Neutral Deadband should be configured so that the vehicle operates correctly in both the forward and reverse directions.

Tune Maximum Throttle

The Throttle Max parameter (Throttle menu) specifies the throttle position that produces 100% controller output. Take the following steps to configure Throttle Max:

1. Apply full throttle and observe the Throttle variable (Controller menu), which should have a value of 100%.
2. If the Throttle variable is less than 100%, perform the following steps to decrease the Throttle Max parameter to get 100% controller output:
    a. Specify a smaller value for the Throttle Max parameter.
    b. Check whether the Throttle variable is 100%.
    c. If the Throttle value is not 100%, repeat steps 2.a through 2.c until the Throttle variable is 100% at the maximum throttle position.
3. Slowly reduce throttle until the Throttle variable drops below 100%, then note the throttle position, which represents the extra range of motion allowed by the throttle mechanism.
4. If the range of motion is excessive, decrease it by increasing the Throttle Max parameter. A larger Throttle Max value provides a broader throttle range and more vehicle control.
5. Repeat steps 3–4 until the throttle's range of motion is satisfactory.
6. If a wigwag or unipolar throttle is being used, repeat this procedure for the reverse direction. Throttle Max should be set so that the throttle operates correctly in both forward and reverse.

Confirm Proper Throttle Operation

Select a direction and operate the throttle. The motor should begin to turn 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.

Note: If the motor does not run proportionally to the throttle, adjust the values of the Max Speed and Rev Max Speed parameters.

Step 3 Basic Vehicle Checkout

Take the following steps to validate that all functions are working as expected:

1. Using the Switches menu, observe the status of each switch in your application, such as forward, reverse, interlock, etc. Cycle each switch to ensure that the variables display the correct statuses.

    Note: For information on the variables, see Switches Menu.
2. Verify that all functions, such as emergency reverse, are working as expected.
3. Verify that charger inhibit works by plugging in the charger and applying throttle. If charger inhibit is working, the motor should not run.

    Note: If the motor runs when the charger's inhibit pin is connected to the controller's charger inhibit input (pin J2-3), the controller might be defective.
4. If everything checks out, lower the vehicle drive wheels onto the ground.

Step 4 Set the System Resistance

It is critical for performance that the System Resistance parameter is accurately set. To set System Resistance, perform the following procedure quickly and with the motor cold. If you need to repeat the procedure, wait until the motor has completely cooled.

⚠ CAUTION **Performing the procedure with a warm motor will result in an inaccurate System Resistance value.**

Take the following steps to determine the correct System Resistance value:

1. Position the vehicle up against a wall, high curb, or some other immovable object.
2. Turn the keyswitch on.
3. Set the Main Current Limit parameter (Current menu) to 35A.
4. Set the Boost Current parameter (Current menu) to the same value as the Main Current Limit parameter.
5. Go to the Resistance variable (Controller menu).
6. Apply full throttle in the forward direction and drive the vehicle against the immovable object.
7. Note the Resistance variable value.
8. Repeat steps 6–7 three more times. Take these measurements quickly, to minimize motor heating.
9. Set the System Resistance parameter to the average of the four Resistance variable values.
10. Set the Main Current Limit and Boost Current parameters back to their original values.

9 — TUNING VEHICLE PERFORMANCE

Note: You must complete the procedures in Initial Setup before performing the procedures in this chapter.

You can optimize many aspects of vehicle performance by adjusting parameters for maximum speeds, acceleration and deceleration rates, anti-rollback compensation, and response smoothness. Once you have tuned a vehicle system, you can make the parameter values standard for that system or vehicle model.

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

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

- Step 1: Set Forward and Reverse Maximum Speeds
- Step 2: Set the Acceleration and Deceleration Rates
- Step 3: Adjust Anti-Rollback Compensation
- Step 4: Fine-Tuning the Vehicle's Response Smoothness

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

Step 1 Set Forward and Reverse Maximum Speeds

Speed modes 1 and 2 provide parameters that specify maximum speeds for the forward and reverse directions. Adjust the following parameters for both speed modes until you are satisfied with the maximum speeds:

- Max Speed
- Rev Max Speed

For information on these parameters, see Speed and Mode Menus.

Step 2 Set the Acceleration and Deceleration Rates

The controller's acceleration and deceleration features provide smooth throttle response when maneuvering at low speeds and snappy throttle response when traveling at high speeds.

To specify acceleration and deceleration rates, perform the following procedures, in order:

1. Set Acceleration and Deceleration Rates
2. Fine-Tune the Acceleration and Deceleration Rates
3. Set the Key Off Deceleration Rate

Set Acceleration and Deceleration Rates

The Drive menu contains parameters for setting acceleration and deceleration rates for both directions. Take the following steps to set these parameters.

The acceleration and deceleration rates are independent of the active speed mode. However, the procedure instructs you to adjust the high speed rates using the fastest speed conditions (speed mode 1) and low speed rates under the slowest speed conditions (speed mode 2). Tuning the rates under the fastest and slowest speed conditions will result in good performance throughout the entire driving range.

When testing acceleration and deceleration at low speed, it is recommended that you drive the vehicle in a confined area, such as an office, where low speed maneuverability is crucial.

Note: Larger values represent slower response times for all parameters used in this procedure.

1. The controller uses the minimum acceleration rates when the vehicle accelerates after the throttle is rotated out of neutral. These rates are specified by the Accel Min Speed and Rev Accel Min Speed parameters. Take the following steps to configure these parameters:
    a. Put the vehicle in speed mode 2.
    b. Starting from neutral, drive the vehicle forward.
    c. If you are not satisfied with how the vehicle accelerates from neutral, adjust the Accel Min Speed parameter and repeat the previous step.
    d. Starting from neutral, drive the vehicle in reverse.
    e. If you are not satisfied with how the vehicle accelerates from neutral, adjust the Rev Accel Min Speed parameter and repeat the previous step.
2. The controller uses the maximum acceleration rates when full throttle is applied. These rates are specified by the Accel Max Speed and Rev Accel Max Speed parameters. Take the following steps to configure these parameters:
    a. Put the vehicle in speed mode 1.
    b. Drive forward, then apply full throttle.
    c. If you are not satisfied with how the vehicle accelerates when full throttle is applied, adjust the Accel Max Speed parameter and repeat the previous step.
    d. Drive in reverse, then apply full throttle.
    e. If you are not satisfied with how the vehicle accelerates when full throttle is applied, adjust the Rev Accel Max Speed parameter and repeat the previous step.
3. The controller uses the minimum deceleration rates when throttle is reduced while the vehicle is moving at low speed. These rates are specified by the Decel Low Speed and Rev Decel Low Speed parameters. Take the following steps to configure these parameters:
    a. Put the vehicle in speed mode 2.
    b. Drive the vehicle forward at low speed, then release the throttle to neutral.
    c. If you are not satisfied with how the vehicle decelerates, adjust the Decel Low Speed parameter and repeat the previous step.
    d. Drive the vehicle in reverse at low speed, then release the throttle to neutral.
    e. If you are not satisfied with how the vehicle decelerates, adjust the Rev Decel Low Speed parameter and repeat the previous step.
4. The controller uses the maximum deceleration rates when throttle is reduced while the vehicle is moving forward at high speed. These rates are specified by the Decel High Speed and Rev Decel High Speed parameters. Take the following steps to configure these parameters:
    a. Put the vehicle in speed mode 1.
    b. Drive the vehicle forward at a high speed, then release the throttle to neutral.
    c. If you are not satisfied with how the vehicle decelerates, adjust the Decel High Speed parameter and repeat the previous step.

d. Drive the vehicle in reverse at a high speed, then release the throttle to neutral.

e. If you are not satisfied with how the vehicle decelerates, adjust the Rev Decel High Speed parameter and repeat the previous step.

Fine-Tune the Acceleration and Deceleration Rates

1. Drive around in both speed modes while varying the position of the throttle. In most cases, the steps in Set Acceleration and Deceleration Rates will provide good performance. However, if necessary, adjust the parameters used in those steps until you are satisfied with the vehicle's performance.
2. To further soften deceleration, you can increase the Soft Stop Speed parameter (Drive menu).
3. In rare cases, you may want to adjust the Throttle Map parameter, which specifies the relationship between the throttle position and the throttle request. In most cases, setting Throttle Map to 50% is suitable. However, if a vehicle requires a non-linear relationship between throttle position and throttle request, adjust Throttle Map.

   For example, specify a Throttle Map value below 50% if a vehicle requires enhanced maneuverability in confined areas.

Set the Key Off Deceleration Rate

The Key Off Decel parameter (Drive menu) sets the deceleration rate used to stop the vehicle at key-off or in the event of a major fault. When those conditions occur, typically the deceleration rate should be as fast as possible without making the vehicle unstable.

Tip: To specify a fast response for emergency stops, set the Key Off Decel parameter to less than 1.0 seconds.

Take the following steps to set the Key Off Decel parameter:

1. Drive at a fast speed.
2. Turn off the keyswitch.
3. If you are not satisfied with how the vehicle decelerates, adjust the Adjust Key Off Decel and repeat the previous steps.

   Note: The Key Off Decel parameter should be set at a rate faster than or equal to the rate specified with the Decel High Speed parameter.

Step 3 Adjust Anti-Rollback Compensation

The controller applies anti-rollback compensation just before the vehicle stops after the throttle has been released to neutral. The Anti-Rollback Comp parameter (Compensation menu) specifies the degree of compensation.

The following table provides guidelines on setting the Anti-Rollback Comp parameter:

Issue	Diagnosis
The vehicle rolls in 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 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 4 Fine-Tuning the Vehicle's Response Smoothness

You can soften and smooth vehicle response by configuring the Gear Soften and Soft Start parameters (Drive menu). These parameters allow values from 0–100%, with 100% providing a great deal of softening and 0% eliminating the softening.

Note: Gear Soften and Soft Start have a noticeable effect on older, worn transaxles. These parameters do not have much effect on new, tight transaxles.

1. Set the Gear Soften parameter to 0%.
2. Set the Soft Start parameter to 0%.
3. 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, acceleration, and 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 you find a value that you like.

Note: Some users prefer a softened feel, while others prefer setting Gear Soften to 0% to preserve a linear response. When setting Gear Soften, take into consideration that softened slack take-up is easier on the transaxle gears and may extend the transaxle operating life.

4. Configure Soft Start by taking the following steps:
    a. Release the throttle 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 adjusting Soft Start.

    c. Release the throttle to neutral.
    d. Set Soft Start to 40%.
    e. Apply full throttle, then release the throttle to neutral. Notice how increasing the parameter softens the vehicle startup while adding a small amount of nonlinearity to the acceleration rate.
    f. Adjust the Soft Start parameter and repeat the previous step until you find a value that you like.

10 — MAINTENANCE

There are no user serviceable parts in Curtis 1212C controllers. **No attempt should be made 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

Curtis programming devices provide access to the controller's fault history file. The programmer will read out all the faults that the controller has experienced since the last time the history file was 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 1212C 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 EN 13849. EN 13849 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 EN 13849-1 provide guidelines that must be followed in order to achieve compliance. Some industries have developed further standards (called type-C standards) that refer to EN 13849 and specifically outline the path to regulatory compliance. 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 1212C controllers comply with these directives using advanced active supervisory techniques.

To mitigate the hazards typically found in machine operations, EN 13849 requires that safety functions be defined; these must include all the input, logic, outputs, and power circuits that are involved in any potentially hazardous operation. Three safety functions are defined for the Curtis 1212C controller:

1. Crushing due to unintended or uncontrolled movement.
2. Crushing through loss of STO/braking.
3. Loss of stability from excessive speed, as specified by vehicle limits.

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 1212C is summarized in the following table:

Table 4 Safety-Related Performance

Safety Function	Designated Architecture	MTTFd	Diagnostic Coverage	CCF	Performance Level
Uncommanded Powered Movement	Category 2	≥ 22 years	≥ 60%	Pass	b
Motor Braking Torque	Category 2	≥ 22 years	≥ 60%	Pass	b

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. EN 13849 provides a checklist of design techniques that should be followed to achieve sufficient mitigation of CCFs. All circuits used by a safety function must be designed in such a way as to score 65 or better on the CCF score sheet as provided by EN 13849 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 — BATTERY DISCHARGE INDICATOR (BDI) SETUP

The Battery Discharge Indicator (BDI) function provides the battery system's status. The parameters on the BDI menu must be configured for the type and size of the charger, the battery size, and the vehicle's expected drive cycle.

When performing the procedures in this chapter, use the same vehicle and set of batteries throughout. Do not drive the vehicle or charge the batteries except when instructed to do so.

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

1. Set Parameters to Initial Values
2. Set Reset Voltage and Full Charge Voltage
3. Set Full Voltage
4. Set Empty Voltage
5. Set Discharge Time
6. Set Charge Time and Start Charge Voltage
7. Rerun and Verify

Step 1 Set Parameters to Initial Values

Take the following steps to set parameters to initial values:

1. Select Program » BDI to access the BDI menu.
2. Set the following parameters to the following values:

Parameter	Value
Full Voltage	25.0V
Empty Voltage	21.6V
Full Charge Voltage	28.2V
Start Charge Voltage	25.2V
Reset Voltage	25.1V
Discharge Time	30 minutes
Charge Time	30 minutes
Low BDI Level	15%

Step 2 Set Reset Voltage and Full Charge Voltage

1. Plug in the charger and fully charge the batteries.
2. With the charger still attached and running, measure the final battery voltage with a voltmeter.
3. Set the Full Charge Voltage parameter to 0.2V less than the measured voltage.
4. Turn off or disconnect the charger and let the batteries sit for 1 hour.
5. Measure the battery voltage again.
6. Set the Reset Voltage parameter to 0.2V less than the measured voltage.

Step 3 Set Full Voltage

1. Drive the vehicle at a medium speed on a level surface for 10–15 minutes.
2. After this time expires and while driving straight on a level surface, record the battery voltage indicated by the Battery Voltage variable.
3. Set the Full Voltage parameter to the voltage indicated by the Battery Voltage variable.

Step 4 Set Empty Voltage

For some sealed batteries, the value specified in Set Parameters to Initial Values may be too low. Consult the battery manufacturer if you are unsure.

Step 5 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 and BDI percentage.

   Note: The battery voltage and BDI percentage are indicated by the Battery Voltage (Voltage menu) and BDI (Controller menu) variables.
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 6 Set Charge Time and Start Charge Voltage

How you set the Charge Time and Start Charge Voltage parameters depends on how you want the BDI gauge to respond to partial charging. The typical method is to require a full recharge and not to reset the BDI gauge until the battery is fully charged. The 1212C can also be programmed to allow the user to stop charging in mid-cycle and display a partial charge reading.

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

1. To require full charging, set Charge Time to 600 minutes.

   With this setting, the BDI will not recalculate until the very end of the charge cycle, and the Reset Voltage — not the charge time — will trigger the BDI to 100%.
2. To allow partial charging:
   a. 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)
      ```
   b. Starting with the dead battery that resulted when you set the Discharge Time parameter, plug in the charger.
   c. Charge for 10 minutes.
   d. Measure the battery voltage with a voltmeter.
   e. Set the Start Charge Voltage parameter to the measured voltage.

Step 7 Rerun and Verify

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.

APPENDIX D — CURTIS PROGRAMMING DEVICES

Curtis programmers provide programming, diagnostic, and test capabilities for Curtis controllers.

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 E — DECLARATIONS OF CONFORMITY

The Curtis Model 1212C meets the CE Declaration of Conformity and the UKCA Declaration of Conformity.

APPENDIX F — DECOMMISSIONING AND RECYCLING THE CONTROLLER

The controller is for installation into an Original Equipment Manufacturer (OEM) vehicle or machinery.

For controller decommissioning and recycling:

1. Follow the OEM's vehicle decommissioning instructions.
2. Follow all applicable landfill directives or regulations for Electrical and Electronic Equipment (EEE) waste.
3. At the end of its service life, when a product is being dismantled, all electrical waste should be returned to that product manufacturer. Examples: Golf cart manufacturer, Industrial Truck manufacturer, Earth-moving machinery manufacturer, etc.

CURTIS WEEE / ROHS STATEMENT, MARCH 2009

WEEE

The Directive 2002/96/EC as amended, on Waste Electrical and Electronic Equipment (WEEE), was adopted by the European Council and Parliament and the Council of the European Union on January 27, 2003. This appendix provides a general description of Curtis's approach to meeting the requirements of the WEEE legislation. This statement is not intended and shall not be interpreted or construed to be legal advice or to be legally binding on Curtis or any third party.

Commitment

Curtis is committed to a safe and healthy environment and has been working diligently to ensure its compliance with WEEE legislation. Curtis will comply with WEEE legislation by:

- Labelling applicable Curtis Instruments products with the WEEE symbol (see Figure 1).
- Operating a Curtis Instruments recycling/reprocessing system for Curtis Instruments products that are returned to Curtis Instruments in Europe and the UK. However, customers may instead choose to use their local recycling centers and systems.

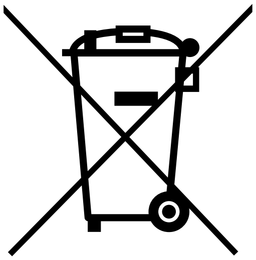


Figure 1
WEEE Symbol

Obligations for Buyers of Electrical and Electronic Equipment

Affected Curtis products that have reached end-of-life must not be disposed as general waste, but instead either put into the collection and recycling system provided in the relevant jurisdiction or returned to Curtis Instruments.

RoHS

Curtis Instruments complies with the Restrictions on the use of Hazardous Substances (RoHS) Directive, 2002/95/EC as amended. Curtis has taken all available steps to eliminate the use of the six restricted hazardous substances listed in the directive wherever possible. As a result of the Curtis RoHS program, many of our instrumentation product lines are now fully RoHS compliant. However, Curtis's electronic motor speed controller products are safety-critical devices, switching high currents and designed for use in extreme environmental conditions. For these product lines, we have successfully eliminated five out of the six restricted hazardous substances. The single remaining issue preventing full RoHS compliance is the unsuitability of the lead-free solders available to date, due to well-documented issues such as tin whiskers, and premature failure (compared with leaded solder) due to shock, vibration, and thermal cycling; this is permitted in accordance with 2002/95/EC as amended by 2017/2102/EU. Curtis is closely monitoring all RoHS developments globally, and in particular is following the automotive industry's attempts to introduce lead-free solder as a result of the End of Life Vehicle (ELV) Directive, and criteria for non-road mobile machinery used exclusively for professional use. To date, all lead-free solder pastes have a significant reduction in reliability compared to leaded soldering. Curtis firmly believes that the operating environments, safety requirements, and reliability levels required of automotive electronics and non-road mobile machinery are directly analogous to those of our speed controller products. Curtis motor speed controllers used on industrial vehicle and machinery applications are exempt under RoHS directive 2002/95/EC as amended. Curtis will work closely with customers to ensure that whenever possible, we are in a position to continue the supply of products should these exemptions expire.

APPENDIX G — SPECIFICATIONS

PWM operating frequency	15.6 kHz
Electrical isolation to heatsink	500VAC
Weight	0.3 kg
Dimensions (W × L × H)	72 x 131 x 39 mm
I/O connections	2 pin, 4 pin, 14 pin
Power connections	4x 0.25 inch FASTON terminals
Storage temperature range	–40 – +85°C
Operating temperature range	–40 – +50°C
Package environmental rating	Electronics sealed to IP54 per IEC60529
EMC	Designed to the requirements of EN 12895:2015
Safety	Designed to the requirements of EN 1175-1:1998+A1:2010 and EN 13849-1
UL	Recognized Component as per UL 583
Communications	CANopen DS301 compliant

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

Table 5 Model Chart

Model Number	Nominal Voltage	Minimum Voltage	Maximum Voltage	Current Rating[1]		
				10 seconds	2 Minutes	1 hour
1212C-25XX	24V	17V	32V	90A	50A	20A

[1] *Current ratings are based on mounting the controller on a 180 mm², 7 mm thick aluminum plate, with an initial heatsink temperature of 25°C. The current is held at the rating being tested for a minimum of 120% of the rated time before thermal limiting begins.*