RICO Quick Troubleshooting Guide

Curtis 1214 / 1215 / 1219 Controller

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*Notes:

1) Not all parameters listed in the “Handheld Programmer” section have the ability to be changed.
2) Any parameter change should be approved by Rico

APPENDIX A

GLOSSARY OF FEATURES AND FUNCTIONS

Acceleration rate

The acceleration rate is the time required for the controller to increase from 0% to 100% duty factor. The shape of the acceleration curve is controlled by the dynamic throttle response, which is linear.

If you have a MultiMode™ controller, the acceleration rates in Mode 1 and in Mode 2 are independently adjustable via the handheld programmer. If you have a 1207 controller with the MultiMode™ feature disabled (i.e., a single-mode controller), you can adjust the acceleration rate mechanically via the appropriate trimpot located on top of the controller.

Anti-rollback *(see Ramp start)*

Anti-tiedown

Before enabling Mode 1 operation, the anti-tiedown function checks that the mode selection switch has been released after the last cycling of the brake switch. This feature discourages operators from taping or otherwise "tying down" the mode switch. If Mode 1 is already selected before the brake is released, the controller remains in Mode 2 until the mode switch is released and pressed again. For information on how Mode 1 and Mode 2 are selected, see *MultiMode*™.

Arcless contactor switching

The controller output duty factor is quickly reduced to zero any time a direction is de-selected, so that the controller current will be reduced to zero before the direction contactor drops out.

BB *(= Belly Button; see Emergency reverse)*

Brake/seat switch

This is a controller-enable input connected to the brake on a walkie or to the seat of a rider. The brake/seat switch must be closed for the controller to operate. This safety interlock is used on most material handling vehicles.

Cycling the brake/seat switch or KSI clears most faults and enables operation.

Contactor drivers and circuits

The controller can accommodate three external contactors: forward, reverse, and main. Some vehicles may have no main contactor, or the main contactor may be wired directly to the KSI or brake signal, bypassing the controller.

Various protections provided for the contactor drivers ensure that the contactors operate correctly; *see "Fault detection" below.*

Creep speed at first throttle

Creep speed is activated when a direction is first selected. The output maintains creep speed until the throttle is rotated out of the throttle deadband (typically 10% of throttle). Creep speed is adjustable from 0 to 25% of the controller duty factor. This adjustment can be made electronically via the handheld programmer.

Current limiting

Curtis controllers limit the motor current to a preset maximum. This feature protects the controller from damage that might result if the current were limited only by motor demand. PWM output to the power section is reduced smoothly until the motor current falls below the set limit level.

In addition to protecting the controller, the current limit feature also protects the rest of the system. By eliminating high current surges during vehicle acceleration, stress on the motor and batteries is reduced and their efficiency enhanced. Similarly, there is less wear and tear on the vehicle drivetrain.

The main current limit, plug current limit, ramp start current limit, emergency reverse current limit, and optional neutral brake plug current limit are all adjustable via the handheld programmer.

Three of these current limits—main, plug, and ramp start—are independently adjustable in Mode 1 and Mode 2.

Current multiplication

During acceleration and during reduced speed operation, the Curtis controller allows more current to flow into the motor than flows out of the battery. The controller acts like a dc transformer, taking in low current and high voltage (the full battery voltage) and putting out high current and low voltage. The battery needs to supply only a fraction of the current that would be required if a resistive

controller were used. The current multiplication feature gives vehicles using Curtis controllers dramatically greater driving range per battery charge.

Deceleration rate

The deceleration rate is the time required for the controller to decrease from 100% duty factor to zero. The deceleration rate is fixed, and cannot be adjusted. The shape of the deceleration curve is controlled by the dynamic throttle response, which is linear.

Disable recovery *(see Fault recovery)*

Emergency reverse

Emergency reverse is activated when the brake switch is closed (brake released), KSI is activated, and the emergency reverse switch (the BB, or "belly button" switch) is pressed. After the BB switch is released, normal controller operation is not resumed until neutral (no direction) is selected or until the brake is cycled (brake, then brake release). However, repeatedly pressing the BB switch will reactivate the emergency reverse function each time.

Because emergency reverse immediately powers the reverse contactor, some arcing may occur.

Fault detection

An internal microcontroller automatically maintains surveillance over the functioning of the controller. When a fault is detected, the appropriate fault code is signalled via the LED, which is externally visible on the front face of the controller. The diagnostic codes flashed by the LED are listed in Section 5, Troubleshooting.

If the fault is critical, the controller is disabled. More typically, the fault is a remediable condition and temporary—for example, an undervoltage fault is cleared when the condition is removed.

The automatic fault detection system includes:

— emergency reverse circuit check
— F/R contactor coil open / shorted driver
— F/R contactor driver overcurrent / contactor coil short
— F/R contactor welded

— M- fault
— memory checks upon start-up
— overvoltage cutoff
— power supply out of range (internal)
— throttle fault
— undervoltage cutback
— watchdog (external)
— watchdog (internal).

Fault recording

Fault events are recorded in the controller's memory. Multiple occurrences of the same fault are recorded as one occurrence.

The fault event list can be loaded into the programmer for readout. The Special Diagnostics mode provides access to the controller's diagnostic history file—the entire fault event list created since the diagnostic history file was last cleared. The Diagnostics mode, on the other hand, provides information about only the currently active faults.

Fault recovery (including recovery from disable)

Almost all faults require a cycling of the KSI or brake/seat switch input to reset the controller and enable operation.

The only exceptions are these:

FAULT	RECOVERY
anti-tiedown	release and re-select Mode 1
contactor overcurrent	when condition clears
emergency reverse	re-apply BB or cycle brake
HPD	lower throttle to below HPD threshold
overvoltage	when battery voltage drops below overvoltage
SRO	when proper sequence is followed
thermal cutback	when temperature changes
throttle fault	clears when condition is gone
undervoltage	when battery voltage rises above undervoltage
(all other faults)	*(cycle KSI or brake/seat switch)*

High-pedal-disable (HPD)

The HPD feature prevents controller output if the controller is turned on while the throttle is not in neutral. The controller can be programmed to have HPD based either on brake/seat switch input or on KSI.

Brake-type HPD

To start a vehicle with brake-type HPD, the controller must receive a brake/seat switch input before receiving a throttle input. Controller operation will be disabled immediately if pedal demand (throttle input) is greater than 25% duty factor at the time the brake/seat switch is closed. Normal controller operation is regained by reducing the throttle demand to less than 25%.

Sequencing delay, which can be set with the handheld programmer, provides a variable delay before disabling the controller. If the brake/seat switch is opened while the throttle is above the HPD threshold (25%), HPD is not activated if the brake/seat switch is then closed before the delay time elapses.

KSI-type HPD

The HPD feature can be activated by KSI input instead of brake/seat switch input, if preferred. To start a vehicle with this type of HPD, the controller must receive a KSI input before receiving a throttle input.

KSI

KSI (Key Switch Input) provides power to the controller's logic board, and initializes and starts diagnostics. In combination with the brake input, KSI enables all logic functions.

Some vehicles may have no keyswitch (KSI simply tied to B+) or may have the key permanently turned on.

LED

An LED on the controller's front face flashes a code if a fault is detected by the controller. The fault codes are listed in Table 2 (page 21). The fault code will continue to flash until the fault condition has been cleared during active fault detection. This will typically happen after cycling KSI for power-up fault conditions, and cycling the brake/seat switch for faults detected during operation.

MOSFET

A MOSFET (**m**etal **o**xide **s**emiconductor **f**ield **e**ffect **t**ransistor) is a type of transistor characterized by its fast switching speeds and very low losses.

MultiMode™

The MultiMode™ feature of these controllers allows the vehicle to be operated with two distinct sets of characteristics. The two modes can be programmed to be suitable for operation under different conditions, such as slow precise maneuvering in Mode 2 and faster, long distance travel in Mode 1. The following parameters can be set independently in the two modes:

— main current limit
— plug current limit
— ramp start current limit
— acceleration rate
— maximum speed

The operating mode is selected by means of the mode selection switch. As a factory standard, Mode 1 is selected when the mode selection switch (Pin 3) is pulled high. Otherwise, the controller operates by default in Mode 2. When the controller transitions between modes, it automatically changes the main current limit, the plug current limit, the ramp start current limit, the acceleration rate, and the maximum speed to their individual mode-specific settings.

If the anti-tiedown feature is active, Mode 1 must be re-selected each time the brake is released.

Neutral brake

The optional neutral brake feature provides automatic plug braking in neutral. If this option is not selected, the vehicle is free to coast in neutral. The neutral brake plug current limit is programmable.

Overtemperature

At overtemperature (from 85°C to 95°C), the drive current limit is linearly decreased from full set current down to zero. (Plug current, however, is not reduced—in order to provide full vehicle braking under all thermal conditions.) The operating PWM frequency is shifted to 1.5 kHz when the controller is operating in the overtemperature range.

Overvoltage protection

Overvoltage resets the microprocessor, inhibits the PWM, and opens the contactors, thereby shutting down the controller. Overvoltage can result during battery charging or from an improperly wired controller. Controller operation resumes when the voltage is brought within the acceptable range. The cutoff voltage and re-enable voltage are percentages of the battery voltage, and are set at the factory.

Plug braking

Plug braking takes place when a series motor is driven electrically in a direction opposite from the direction it is turning. The 1214-/15-/19-8 controls the field current to obtain smooth and controlled plug braking torque. During plug braking, the maximum current limit is automatically changed to the plug current limit, and the PWM frequency is changed to 1.5 kHz. NOTE: Plug current limit controls the field current; the armature current in plug mode will be higher than the field current.

There are two types of plug braking control—fixed and variable. The fixed plug current limit is set to a fixed level. The variable plug current limit varies the current limit to correspond to the throttle position.

The Mode 1 and Mode 2 plug current limits are independently adjustable via the handheld programmer.

PWM

Pulse width modulation (PWM), also called "chopping," is a technique that switches battery voltage to the motor on and off very quickly, thereby controlling the speed of the motor. Curtis 1200 series controllers use high frequency PWM—15 kHz—which permits silent, efficient operation.

Quick-start

Upon receiving a quick throttle demand from neutral, the controller will exceed normal acceleration momentarily in order to overcome inertia. The "quick-start" algorithm is applied each time the vehicle passes through neutral and is not in plug mode. If the vehicle is in plug, the quick-start function is disabled, allowing normal plug braking to occur. The quick-start throttle factor is adjustable via the handheld programmer.

Ramp shape (throttle map)

"Ramp shape" is a programmable parameter that determines the static throttle map of the 1214-/15-/19-8 controller. Eleven preprogrammed ramp shapes are available, in 5% steps between 20% and 70% (20, 25, 30, 35, 40, 45, 50, 55, 60, 65, and 70%). The ramp shape number refers to the PWM output at half throttle, as a percentage of its full range. For example, if maximum speed is set at 100% and creep speed is set at 0, a ramp shape of 50% will give 50% output at half throttle. The 50% ramp shape corresponds to a linear response. The six "even number" ramp shapes for maximum and creep speeds set at 100% and 0 are shown in Figure A-1.

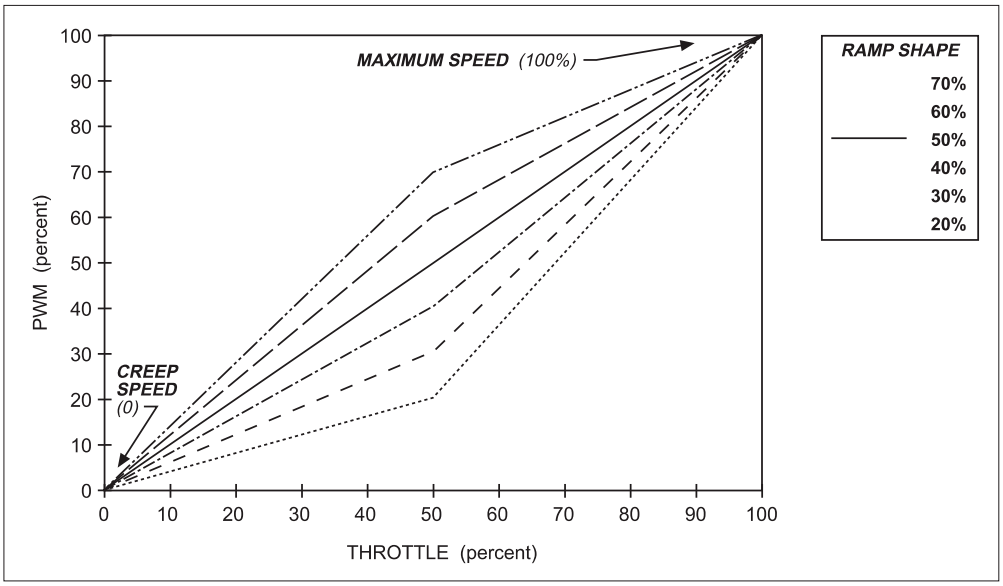


Fig. A-1 *Ramp shape (throttle map) for controller with maximum speed set at 100% and creep speed set at 0.*

Changing either the maximum speed setting or the creep speed setting changes the output range of the controller. Ramp shape output is always a percentage of that range. Ramp shapes with the creep speed setting raised to 10% are shown in Figure A-2. In Figure A-3, the creep speed is kept at 10% and the maximum speed setting dropped to 60%.

Fig. A-2 *Ramp shape (throttle map) for controller with maximum speed set at 100% and creep speed set at 10%.*

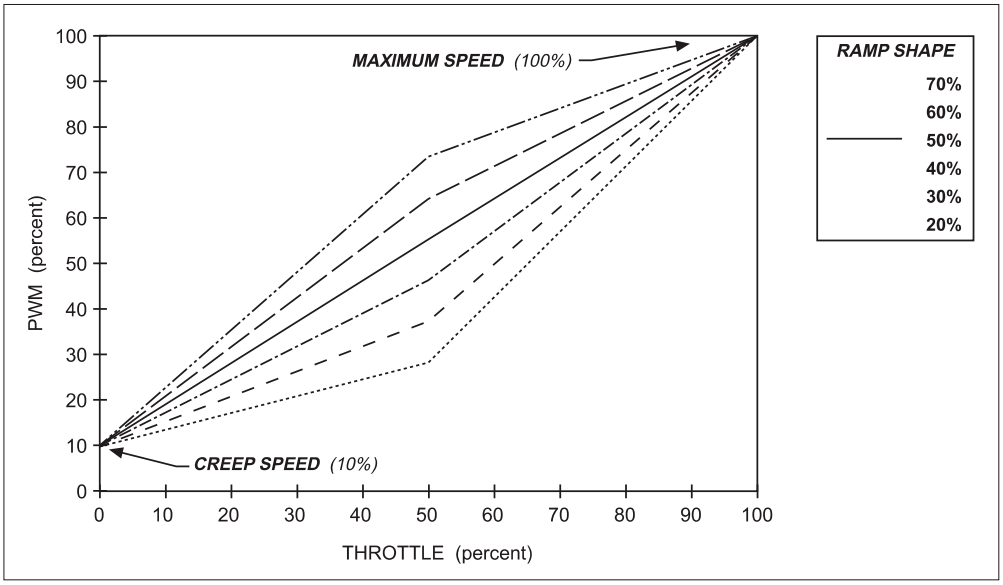
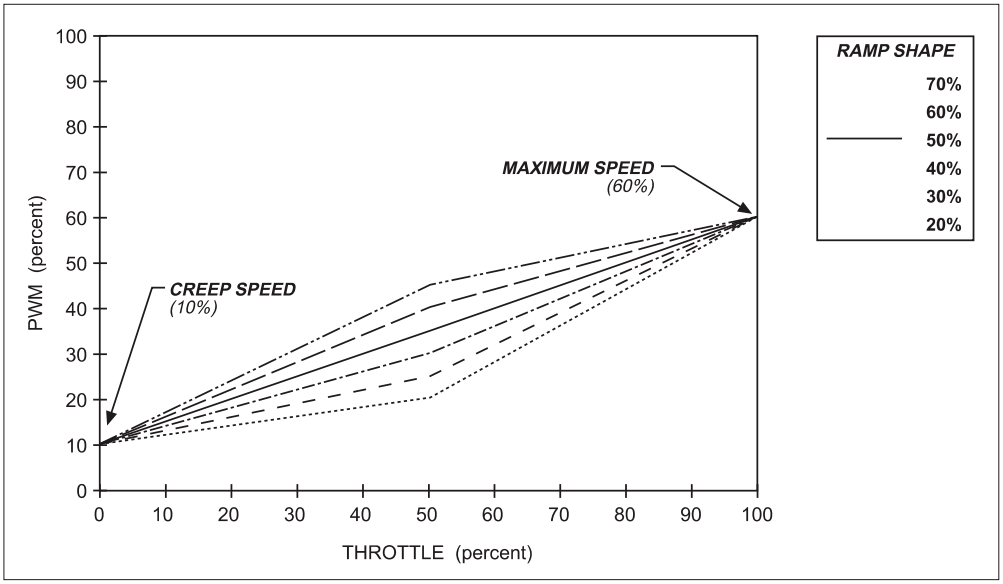


Fig. A-3 *Ramp shape (throttle map) for controller with maximum speed set at 60% and creep speed set at 10%.*



In all cases, the ramp shape number is the PWM output at half throttle, as a percentage of its full range. So, for example, in Figure A-3, a 50% ramp shape gives 35% PWM output at half throttle (halfway between 10% and 60%). A 30% ramp shape gives 25% PWM at half throttle (30% of the range {which is 50%, from 10% to 60%}, starting at 10% output, or {[.30 x 50%] + 10%} = 25%).

Ramp start (anti-rollback)

The ramp start feature allows the vehicle to be started with a higher plug current limit to prevent rolling downhill. Ramp start increases the plug current limit for the selected direction only. When the opposite direction is selected, ramp start will be canceled and a 3-step sequence must be followed to re-activate it:

STEP 1. select a direction for more than 1 second
STEP 2. return to neutral
STEP 3. re-select the same direction.

Once the vehicle is operating in ramp start mode, it will continue to do so until the opposite direction is selected for more than one second. The new direction then becomes the decision direction, and the 3-step ramp start sequence is required to regain the ramp start current limit level.

The handheld programmer can be used to adjust the maximum ramp start current limit value. The instantaneous ramp start current limit when the brake is first released depends on throttle position and increases to the maximum programmed value as the throttle is increased.

Reset

Almost all faults require a cycling of the KSI or brake/seat switch input to reset the controller and enable operation; *see "Fault recovery" for exceptions*.

Sequencing delay

Sequencing delay allows the brake/seat switch to be momentarily opened within a set time (the sequencing delay), thus preventing inadvertent activation of HPD or SRO. This feature is useful in applications where the brake/seat switch may bounce or be momentarily cycled during operation. The delay can be set with the handheld programmer from 0 to 3 seconds, where 0 corresponds to no delay.

Speed settings

The maximum speed setting defines the upper-limit speed as a percentage of PWM output at full throttle. The maximum speed settings in Mode 1 and in Mode 2 are independently adjustable via the handheld programmer.

The maximum creep speed setting (see *Creep speed)* and the maximum emergency reverse speed setting (see *Emergency reverse)* are also adjustable via the handheld programmer.

Static-return-to-off (SRO)

The SRO feature prevents the vehicle from being started when "in gear." SRO checks the sequencing of brake/seat switch input—or of KSI and brake input—relative to a direction input. The brake/seat switch input must come on before a direction is selected. If a direction is selected before or simultaneously (within 50 msec) with the brake input, the controller is disabled. There are three types of SRO: SRO relative to brake/seat switch input alone (Type "1" in the programming menu); SRO relative to brake/seat switch input plus KSI (Type "2"); and SRO relative to brake/seat switch input plus KSI plus forward only (Type "3"). The handheld programmer can be used to set the controller to operate with one of these types of SRO, or with no SRO (SRO Type "0").

If your controller is wired so that both KSI and brake/seat switch input are required (SRO Type "2"), the following sequence must be followed to enable the controller: STEP 1, KSI on; STEP 2, brake/seat switch closed; and STEP 3, direction selected. The interval between steps 1 and 2 is the same as between steps 2 and 3; that is, KSI input must precede brake/seat switch input by at least 50 msec. Once the controller is operational, turning off either KSI or the brake/seat switch input causes the controller to turn off; re-enabling the controller requires the 3-step sequence.

Similarly, if your controller is wired so that KSI, brake/seat switch, and forward inputs are all required (SRO Type "3"), they must be provided in that sequence in order to enable the controller. However, operation is allowed if a reverse input precedes the brake/seat switch input; this can be useful when operating a walkie on ramps.

Sequencing delay, which can be set with the handheld programmer, provides a variable delay before disabling the controller. If the brake/seat switch is opened while direction is selected, SRO is not activated if the brake/seat switch is then closed before the delay time elapses.

Temperature compensation for current limits

Full temperature compensation provides constant current limits throughout the normal operating range (heatsink temperatures of -25°C to +85°C). The temperature sensor is also used to calculate and display the heatsink temperature on the handheld programmer.

Temperature extreme current-limit cutback *(see Overtemperature, Undertemperature)*

Temperature extreme data storage

The maximum and minimum temperatures read at the heatsink at any time during powering of the controller are stored in the controller's memory. These values (which can be accessed via the programmer's Test Menu) are cleared each time the controller's diagnostic history file is cleared. Each time the controller's power is cycled, the initially recorded maximum and minimum temperatures will be accurate only to within 10°C.

Throttle map

The throttle map (duty factor as a function of throttle position) is adjustable, so that you can provide the proper feel for the many types of vehicles that use the 1214-/15-/19-8 controller. The throttle map parameter is called "ramp shape"; see the entry under *Ramp shape* for more information.

Throttle response

The dynamic throttle response (duty factor as a function of time) is shaped by the acceleration rate setting. Dynamic throttle response is linear. The newest throttle input is mapped to the throttle map, and the controller then automatically accelerates (or decelerates) through a straight line until the new throttle demand is obtained.

Throttle types

The 1214-/15-/19-8 controller accepts a variety of throttle inputs, through various combinations of its four throttle input pins. The most commonly used throttles (5kΩ–0 and 0–5kΩ pots, 3-wire pots, 0–5V, 0–10V, and the Curtis ET-XXX electronic throttle) can be hooked up simply by selecting the appropriate throttle type in the handheld programmer's Program Menu. Additional throttle types can also be accommodated; please contact the Curtis office nearest you.

Throttle full range produces 0–100% duty factor at the controller output (unless limited by other conditions). Throttle fault detect is performed on the throttle input signals and virtually eliminates the possibility of runaway operation. Adjustments and settings are independent of throttle type. However, throttle fault conditions will vary by throttle type.

Undertemperature

When the controller is operating at less than -25°C, the current limit is cut back to approximately one-half of the set current. The operating PWM frequency is shifted to 1.5 kHz when the controller is operating at undertemperature.

Undervoltage protection

Undervoltage protection automatically disables the controller output if battery voltage is detected below the undervoltage point at start-up, or when the battery voltage is pulled below the undervoltage point by an external load. The undervoltage cutback point is set in ROM, and is not adjustable.

During normal operation, the controller duty factor will be reduced when the batteries discharge down to less than the undervoltage level. If the motor current is such that the batteries are being pulled below the minimum point, the duty factor will be reduced until the battery voltage recovers to the minimum level. In this way the controller "servos" the duty factor around the point which maintains the minimum allowed battery voltage.

If the voltage continues to drop below the undervoltage level to a severe undervoltage condition (due to battery drain or external load), the controller continues to behave in a predictable fashion, with its output disabled.

Watchdog (external, internal)

The external watchdog timer guards against a complete failure of the microprocessor, which would incapacitate the internal watchdog timer. This independent system check on the microprocessor meets the EEC's requirement for backup fault detection.

The external watchdog timer safety circuit shuts down the controller (and the microprocessor) if the software fails to generate a periodic external pulse train. This pulse train can only be created if the microprocessor is operating. If not periodically reset, the watchdog timer times out after 150 msec and turns off the controller. The external watchdog also directly disengages all contactors and directly shuts down the PWM drive to the MOSFETs. It can only be reset by cycling KSI.

The internal watchdog timer must be reset periodically by correct sequential execution of the software. If not reset, the internal timer times out and the microprocessor is "warm booted." This causes the microprocessor to shut down its outputs (thus shutting down the controller) and attempt to restart.

6 PROGRAMMER MENUS

Items are listed for each menu in the order they appear in the actual menus displayed by the handheld programmer.

Program Menu *(not all items available on all controllers)*

EMR REV C/L	Emergency reverse current limit
THROTTLE TYPE	Throttle type*
RAMP SHAPE	Throttle map
CREEP SPEED	Creep speed, as percent PWM duty cycle
EMR REV SPEED	Emerg. reverse speed, as % PWM duty cycle
SEQUENCING DLY	Sequencing delay, in seconds
VARIABLE PLUG	Throttle-variable plug braking: on or off
HIGH PEDAL DIS	High pedal disable (HPD): type†
SRO	Static return to off (SRO): type‡
ANTI-TIEDOWN	Anti-tiedown: on or off
QUICK START	Quick-start throttle factor
M1 MAIN C/L	Mode 1 main current limit
M1 PLUG C/L	Mode 1 plug current limit
M1 RAMP C/L	Mode 1 ramp start current limit
M1 ACCEL RATE	Mode 1 acceleration rate, in seconds
M1 MAX SPEED	Mode 1 maximum speed, as % PWM output
M2 MAIN C/L	Mode 2 main current limit
M2 PLUG C/L	Mode 2 plug current limit
M2 RAMP C/L	Mode 2 ramp start current limit
M2 ACCEL RATE	Mode 2 acceleration rate, in seconds
M2 MAX SPEED	Mode 2 maximum speed, as % PWM output
NEUT BRAKE C/L	Neutral brake current limit
NEUTRAL BRAKE	Neutral brake: on or off

(Notes are on the next page.)

Program Menu Notes

(For more detail on these options, see Appendix A: Glossary of Features and Functions.)

* Throttle types

Type 1: 5kΩ–0
Type 2: 0–5V, 0–10V, 3-wire pot, and electronic throttles
Type 3: 0–5kΩ

† HPD types

Type 0: no HPD
Type 1: HPD fault unless KSI input and brake input before throttle input
Type 2: HPD fault unless KSI input before throttle input

‡ SRO types

Type 0: no SRO
Type 1: SRO fault unless brake input before direction input
Type 2: SRO fault unless KSI before brake input before direction input
Type 3: SRO fault unless KSI before brake input before forward input

Test Menu *(not all items available on all controllers)*

FORWARD SWITCH	Forward switch: on/off
REVERSE SWITCH	Reverse switch: on/off
BRAKE SWITCH	Brake switch: on/off
THROTTLE %	Throttle reading, in percent of full
SPEED SWITCH	Speed switch: on/off
EMR REV SWITCH	Emergency reverse switch: on/off
FWD CONTACTOR	Forward contactor: on/off
REV CONTACTOR	Reverse contactor: on/off
BATT VOLTAGE	Battery voltage
HEAT SINK °C	Heatsink temperature
MAX TEMP °C	Maximum temperature seen *
MIN TEMP °C	Minimum temperature seen *

* Maximum/minimum temperatures recorded while controller active. After controller power is cycled, the initially recorded temperatures will be accurate only to within 10°C.

Special Program Menu

RESET ALL SETTINGS	Revert to original settings
CONT SETTINGS→ PROG	Save controller settings in programmer
PROG SETTINGS→ CONT	Load programmer settings in controller
CLEAR DIAG HISTORY	Clear diagnostic history memory
CONTRAST ADJUSTMENT	Adjust display contrast
LANGUAGE SELECTION	Select displayed language
PROGRAMMER INFO	Display programmer information
CONTROLLER INFO	Display controller information

Diagnostics and Special Diagnostics "Menu"

This is not a menu as such, but simply a list of the possible messages you may see displayed when the programmer is operating in either of the Diagnostics modes. The messages are listed in alphabetical order for easy reference.

BB WIRING CHECK	BB wiring check failed
CONT DRVR OC	Contactor driver overcurrent
DIR CONT WELDED	Direction contactor welded
HPD	High-pedal-disable activated
HW FAILSAFE	Hardware failsafe activated
LOW BATTERY VOLTAGE	Battery voltage too low*
M- FAULT	M- output fault
MISSING CONTACTOR	Missing contactor
NO KNOWN FAULTS	No known faults
OVERVOLTAGE	Battery voltage too high†
SRO	Static-return-to-off activated
THERMAL CUTBACK	Thermal cutback due to temperature
THROTTLE FAULT1	Throttle input fault
THROTTLE FAULT2	Throttle low input fault

* <16 volts (24–36V models); <21 volts (36–48V models)

† >46 volts (24–36V models); >60 volts (36–48V models)

5 DIAGNOSTICS AND TROUBLESHOOTING

PROGRAMMER DIAGNOSTICS

With a programmer, the diagnostics and troubleshooting process is more direct than with the LED alone. The programmer presents complete diagnostic information in plain language—no codes to decipher. Faults are displayed in the Diagnostic Menu, and the status of the controller inputs/outputs is displayed in the Test Menu.

The following 4-step process is generally used for diagnosing and troubleshooting an inoperative vehicle: (1) visually inspect the vehicle for obvious problems; (2) diagnose the problem, using the programmer; (3) test the circuitry with the programmer; and (4) correct the problem. Repeat the last three steps as necessary until the vehicle is operational.

> **Example:** A vehicle that does not operate in "forward" is brought in for repair.
>
> STEP 1: Examine the vehicle and its wiring for any obvious problems, such as broken wires or loose connections.
>
> STEP 2: Connect the programmer, put it in diagnostic mode, and read the displayed fault information. In this example, the display shows "No Faults Present," indicating that the controller has not detected anything out of the norm.
>
> STEP 3: Put the programmer in test mode, and observe the status of the inputs and outputs in the forward direction. In this example, the display shows that the forward switch did not close when "forward" was selected, which means the problem is either in the forward switch or the switch wiring.
>
> STEP 4: Check or replace the forward switch and wiring and repeat the test. If the programmer shows the forward switch closing and the vehicle now drives normally, the problem has been corrected.

Refer to the troubleshooting chart (Table 1) for suggestions covering a wide range of possible faults.

Table 1 TROUBLESHOOTING CHART

LED CODE	PROGRAMMER LCD DISPLAY	EXPLANATION	POSSIBLE CAUSE
1,2	HW FAILSAFE	hardware fail-safe error	1. Controller defective.
1,3	M- FAULT	M- output shorted	1. M- output shorted to ground. 2. Internal motor short to ground.
1,4	SRO	SRO fault	1. Improper sequence of KSI, brake, and direction inputs. 2. Wrong SRO type selected. 3. Brake or direction switch circuit open. 4. Sequencing delay too short.
2,1	THROTTLE FAULT 1	5kΩ–0 or wiper fault	1. Throttle input wire open. 2. Throttle input wire shorted to ground or B+. 3. Throttle pot defective. 4. Wrong throttle type selected.
2,2	BB WIRING CHECK	emerg. reverse wiring fault	1. BB wire open. 2. BB check wire open.
2,3	HPD	HPD sequencing fault	1. Improper seq. of KSI, brake, throttle inputs. 2. Wrong HPD type selected. 3. Misadjusted throttle pot. 4. Sequencing delay too short.
2,4	THROTTLE FAULT 2	Pot Low broken or shorted	1. Pot Low wire open. 2. Pot Low wire shorted. 3. Wrong throttle type selected.
3,1	CONT DRVR OC	driver output overcurrent	1. Direction contactor coil shorted.
3,2	DIR CONT WELDED	welded direction contactor	1. Direction contactor stuck closed.
3,4	MISSING CONTACTOR	missing contactor	1. Direction contactor coil open. 2. Direction contactor missing. 3. Wire to direction contactor open.
4,1	LOW BATTERY VOLTAGE	low battery voltage	1. Battery voltage <16 volts (24–36V models) or <21 volts (36–48V models). 2. Corroded or loose battery terminal. 3. Loose controller terminal.
4,2	OVERVOLTAGE	overvoltage	1. Battery voltage >46 volts (24–36V models) or >60 volts (36–48V models). 2. Vehicle operating with charger attached.
4,3	THERMAL CUTBACK	over-/under-temp. cutback	1. Temperature >85°C or <-25°C. 2. Excessive load on vehicle. 3. Improper mounting of controller. 4. Operation in extreme environments.

LED DIAGNOSTICS

During normal operation, with no faults present, the LED on the controller's front face flashes a single flash at approximately 1 flash/second. If the controller detects a fault, a 2-digit code (see Table 2) is flashed continuously until the fault is corrected. For example, code "3,2"—welded direction contactor—appears as:

¤ ¤ ¤ ¤ ¤	¤ ¤ ¤ ¤ ¤	¤ ¤ ¤ ¤ ¤
(3 , 2)	(3 , 2)	(3 , 2)

Table 2 LED CODES

LED CODE		EXPLANATION
LED off	▬▬▬	no power or defective controller
solid on	▭	defective controller
single flash	¤	controller operational; no faults
1,2	¤ ¤¤	hardware fail-safe error
1,3	¤ ¤¤¤	M- fault or motor output short
1,4	¤ ¤¤¤¤	sequencing fault (SRO)
2,1	¤¤ ¤	5kΩ–0 or throttle wiper input fault
2,2	¤¤ ¤¤	emerg. rev. circuit check fault (BB wiring)
2,3	¤¤ ¤¤¤	high-pedal-disable fault (HPD)
2,4	¤¤ ¤¤¤¤	throttle pot low open or shorted to B+ or B-
3,1	¤¤¤ ¤	contactor driver overcurrent
3,2	¤¤¤ ¤¤	welded direction contactor
3,3	¤¤¤ ¤¤¤	[reserved for future use]
3,4	¤¤¤ ¤¤¤¤	missing contactor
4,1	¤¤¤¤ ¤	low battery voltage
4,2	¤¤¤¤ ¤¤	overvoltage
4,3	¤¤¤¤ ¤¤¤	thermal cutback
4,4	¤¤¤¤ ¤¤¤¤	[reserved for future use]

NOTE: Only one fault is indicated at a time, and faults are not queued up. Operational faults—such as a fault in SRO sequencing—are cleared by cycling the brake/seat switch or keyswitch. *(See "Fault recovery" in Appendix A for more information.)*