# MANUAL

**CURTIS**PMC

# 1207&
# 1207A

**MultiMode™**
**MOTOR CONTROLLERS**

**CURTIS**

**CURTIS PMC**

1207 / 1207A Manual
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This electronic version of the 1207/1207A manual is offered as a convenience to our customers. You may download any or all of it.

If you would like a hard copy of the published manual, please order it by part number from the Curtis office nearest you.

The electronic version of the manual is identical to the printed version published in August 1999 and revised March 2000. The revisions are in Figures 4, 4A, and 9A (on pages 8, 24, and 28).

Bookmarks have been added to the electronic version to speed the process of going directly to a particular part of the document.

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# **1**

# OVERVIEW

Curtis PMC 1207/1207A programmable motor speed controllers provide efficient, cost-effective, and simple-to-install control for a variety of small electric vehicles. Typical applications include walkie fork/pallet trucks, mini personnel carriers, and sweepers. The microprocessor-based logic section combined with a proven MOSFET power section gives the 1207/1207A controllers high power and advanced features in a simple, compact package. The optional handheld programmer enables the user to set parameters, conduct tests, and obtain diagnostic information quickly and easily.

**Fig. 1** *Curtis PMC 1207 and 1207A electronic motor controllers and handheld programmer.*



Like all Curtis PMC motor controllers, the 1207 and 1207A models offer superior operator control of the vehicle's motor drive speed. **Features include:**

✓  Power MOSFET design, providing
- infinitely variable drive and plug brake control
- silent high-frequency operation
- high efficiency (for reduced motor and battery losses)

✓  Compact size

✓  Overvoltage and undervoltage protection

✓  Thermal protection and compensation circuitry provides undertemperature cutback, constant current limit, and linear rollback in overtemperature—thus preventing sudden power loss regardless of thermal conditions

*More Features*  ☞

✓  Intelligent handheld programmer (optional) provides a full set of parameter and function settings

✓  Diagnostic and test information for the controller—and other system components—readily available both on-board and through the programmer

✓  On-board potentiometers allow direct manual adjustment of acceleration rate, creep speed, maximum speed, plug current, and main current limit *(1207 single-mode models only)*

✓  Circuitry and software detects faults in the throttle circuit, MOSFET drive circuit, MOSFET transistors, contactor drivers, and contactors—ensuring that the controller meets EEC fault detect requirements

✓  Input sequencing options include neutral start and static return to off (SRO)

✓  Microprocessor-controlled contactor sequencing provides true arcless contactor switching

✓  Smooth, controlled plug braking—with either variable (throttle-dependent) or fixed plug current limit

✓  Neutral braking option provides automatic plug braking in neutral

✓  MultiMode™ input selects between two different operating modes, thus allowing optimization of vehicle characteristics for different driving conditions

✓  Emergency reverse (belly button switch) with a single input

✓  Ramp-start feature provides full power for starting on ramps

✓  Simple contactor and switch wiring, with coil drivers monitored for faults— thus ensuring fail-safe operation

✓  Flexible throttle circuitry accommodates a variety of throttle types

✓  Programmable "ramp shape" (static throttle map) provides flexibility in selecting throttle response feel

✓  Connections made by solid copper power busses with a polarized Molex connector for control signals

✓  Solid, well-protected construction—with an aluminum mounting plate and injection-molded cover.

Familiarity with your Curtis PMC controller will help you install and operate it properly. We encourage you to read this manual carefully. If you have questions, please contact the Curtis office nearest you.

# 2

# INSTALLATION AND WIRING: 1207

## MOUNTING

The 1207 controller can be oriented in any position, but **the location should be carefully chosen to keep the controller as clean and dry as possible. If a clean mounting location cannot be found, a cover must be used to shield the controller from water and contaminants.**

To ensure full rated output power, the controller should be fastened to a clean, flat metal surface with three screws. The case outline and mounting hole dimensions are shown in Figure 2. The controller should be mounted with sufficient clearance to allow the sliding cover to be opened, providing access to

**Fig. 2** *Mounting dimensions, Curtis PMC 1207 controller.*



SLIDING
COVER

165 (6.50)
127 (5.00)
22 (0.85)
28 (1.10)
122 (4.80)
66 (2.60)
6.6 (0.26) dia., 3 plcs
152 (6.00)
6.5 (0.25)
21 × 16 × 1.5 (0.83 × 0.63 × 0.06); 8.4 (0.33) dia. hole thru
60 (2.35)
4.8 (0.19)

*Dimensions in millimeters and (inches)*
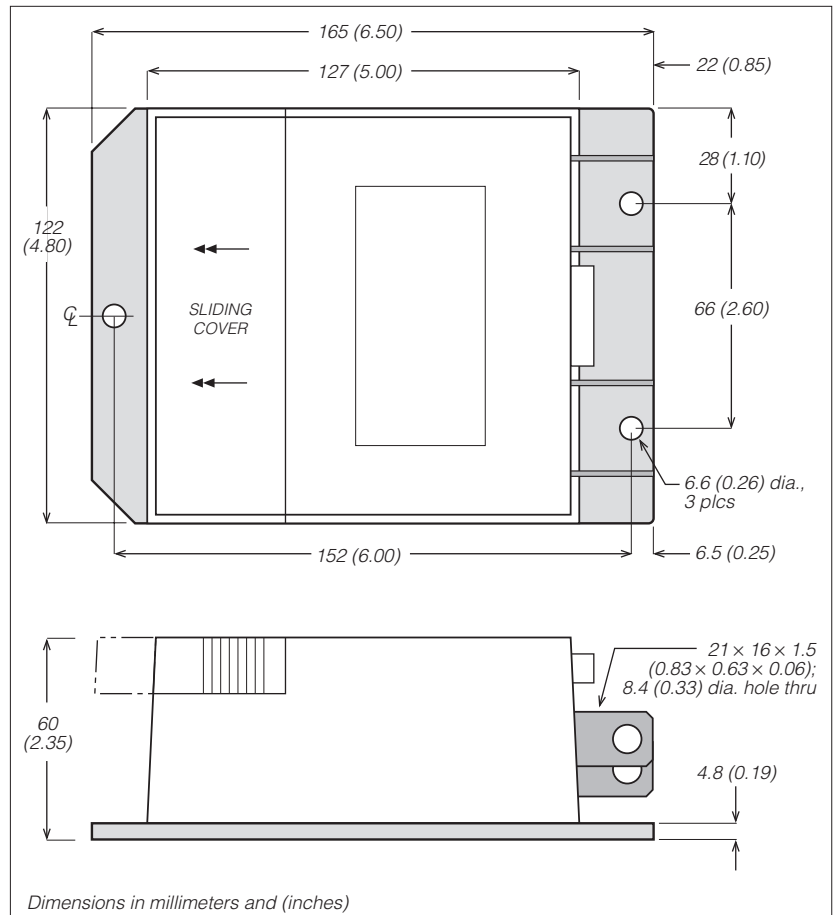
the user-adjustable potentiometers. Access is also needed to plug the programmer into the connector beneath the sliding cover, and to view the Status LED.

Although not usually necessary, a thermal joint compound can be used to improve heat conduction from the case to the mounting surface.

## CONNECTIONS: Low Current

An integrated 16-pin low power connector molded into the front of the controller provides the low power logic control connections (see pin list below). The mating connector is Molex Mini-Fit Jr., part number (5557) 39-01-2165. Contact Molex regarding compatible pins for various wire sizes.

| 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 |
|----|----|----|----|----|----|----|---|
| 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1 |

| | |
|---|---|
| **Pin 1**  | shunt field driver output; n/c for series motors |
| **Pin 2**  | reverse contactor driver output |
| **Pin 3**  | forward contactor driver output |
| **Pin 4**  | main contactor driver output |
| **Pin 5**  | throttle: 3-wire pot high |
| **Pin 6**  | throttle: 3-wire pot wiper or 0–5V |
| **Pin 7**  | throttle: pot low |
| **Pin 8**  | throttle: 2-wire 5kΩ–0 or 0–5kΩ input |
| **Pin 9**  | throttle: 0–10V |
| **Pin 10** | emergency reverse (BB) check output [optional] |
| **Pin 11** | reverse input |
| **Pin 12** | forward input |
| **Pin 13** | emergency reverse input |
| **Pin 14** | mode selection input |
| **Pin 15** | brake input |
| **Pin 16** | keyswitch input (KSI) |

### CONNECTIONS: High Current

Four tin-plated copper bus bars are provided for the high current connections to the battery and motor:
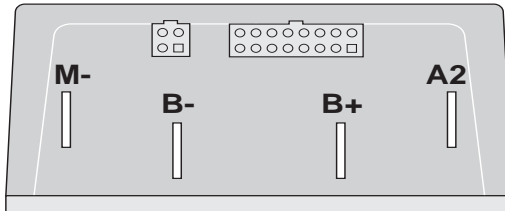
M-  output to motor armature
B-  negative connection to battery
B+  positive connection to battery/field
A2  plug diode to motor armature

Cables are fastened to the bus bars by M8 (⁵⁄₁₆") bolts. When tightening the bolts, two opposing wrenches should be used to prevent bending the bus bars and putting undue strain on the internal connections.

### ADJUSTMENT PANEL

The adjustment panel is located on top of the 1207 controller, under a sliding protective cover. The panel provides access to a set of adjustable potentiometers, and also contains the Status LED and a connector for the handheld programmer.
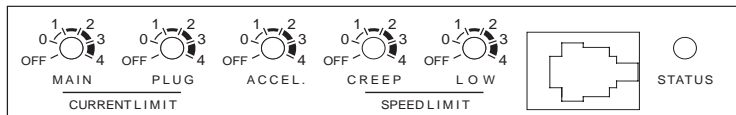
*Manually Adjustable Potentiometers*
Five screwdriver-adjustable potentiometers ("trimpots") allow manual adjustment of the main and plug current limits, acceleration rate, maximum creep speed, and maximum speed (labeled "LOW"), as described in Section 3. The trimpots can be enabled or disabled at the factory; if they are enabled, MultiMode™ operation is not available. NOTE: To adjust any of these parameters electronically with the programmer, its potentiometer must be set to "OFF."

*Programmer Connector*
An RJ11 modular connector is provided for the handheld programmer. The mating cable is supplied with the programmer.

*Status LED*
The LED displays flashing codes to indicate controller status; the codes are listed in Section 5.

### WIRING:  Standard Configuration (Series Motor)

The basic wiring for series motors with field reversing is shown in Figure 3.

**Fig. 3** *Standard wiring diagram (series motor), Curtis PMC 1207 controller.*
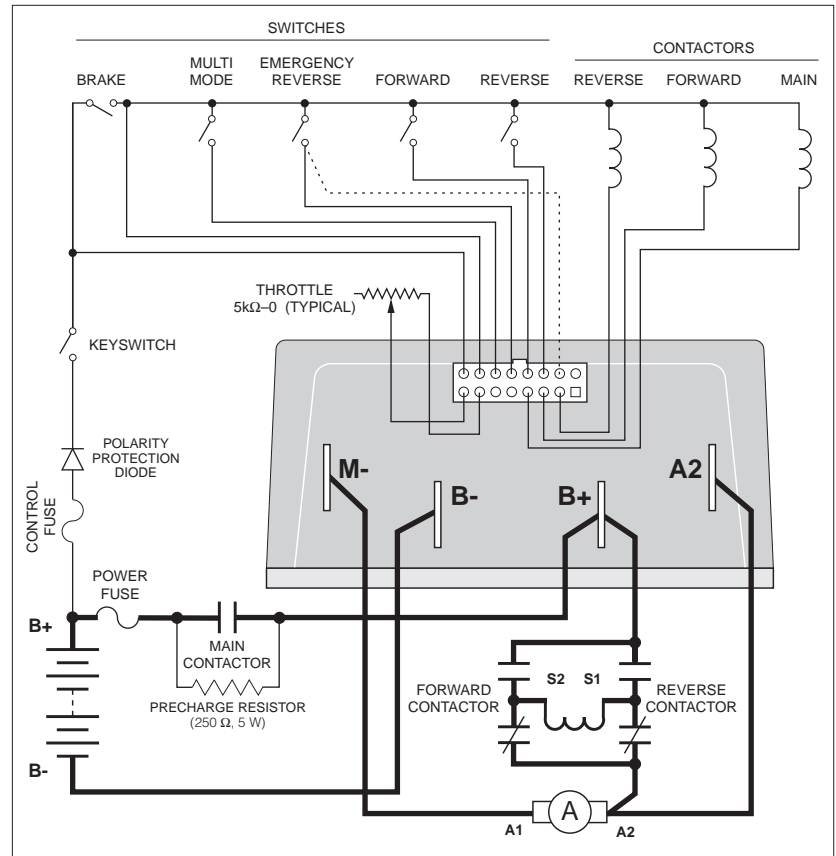


The configuration shown in Figure 3 is a typical arrangement for a series motor. Curtis PMC controllers are designed for use in a wide range of applications, and accordingly can be installed in a variety of ways to best meet customer needs.

NOTE:  The emergency reverse check feature (wiring shown by dashed line) is a factory option.

<u>Power Wiring for Series Motor</u>

In every wiring configuration, it is imperative that the field be wired between the controller's **B+** and **A2** terminals and that the armature be wired between the **M-** and **A2** terminals. The internal plug diode used in the 1207 is connected between **M-** and **A2**. Therefore, the armature and field positions cannot be interchanged. Reversing contactors can be used to switch either the armature or the field.

<u>Control Wiring for Series Motor</u>

Wiring for the input switches and contactors is shown in Figure 3 (see detail below). The main contactor, if one is used, is normally connected directly to the controller. Optionally, the main contactor can be switched directly by the keyswitch or brake, leaving Pin 4 unconnected.

*16-pin detail  (see Fig. 3):*
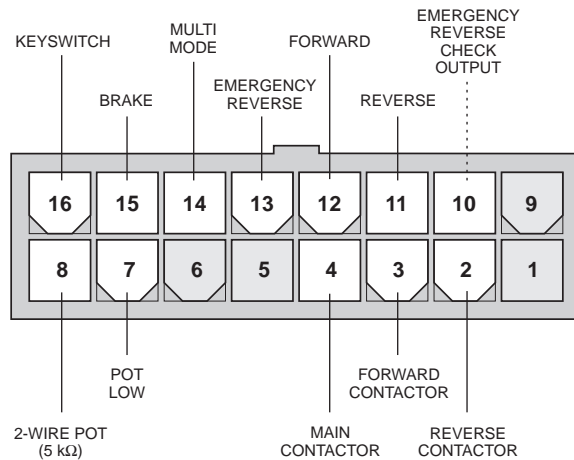


The throttle shown in Figure 3 is a 5kΩ–0 type. Various other throttles can also be accommodated, and are discussed in the throttle wiring section.

## WIRING:  Compound Motor Configuration

A specially configured controller is available for compound motor applications. The wiring for a compound wound motor with armature reversing is shown in Figure 4.

**Fig. 4** *Compound motor wiring diagram, Curtis PMC 1207 controller.*
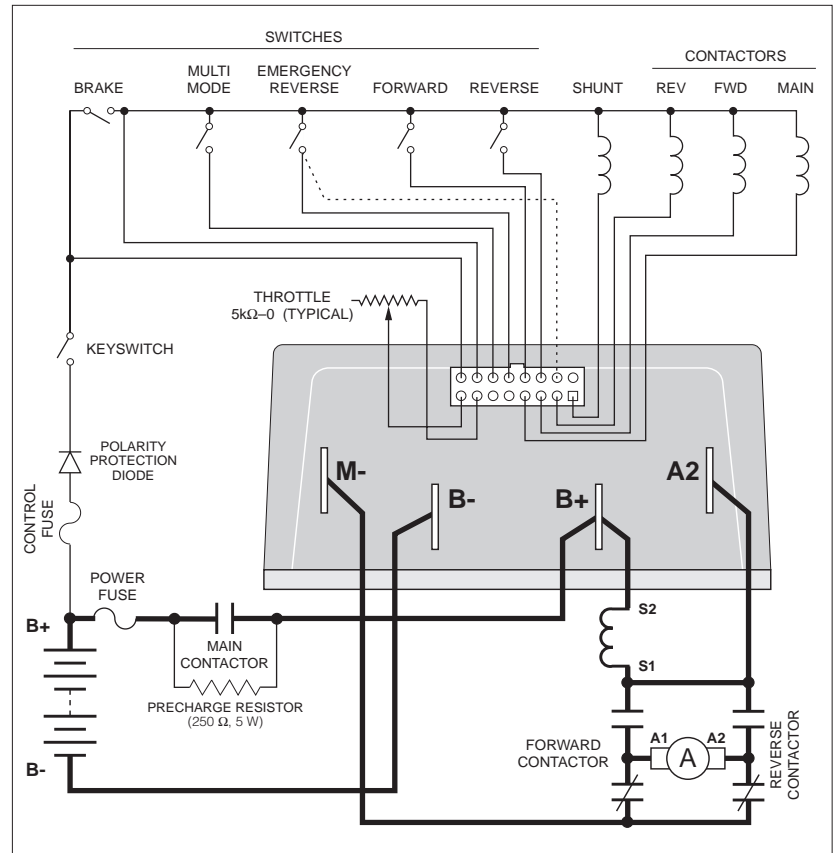


The configuration shown in Figure 4 requires the use of a compound wound motor. **Pure shunt motors cannot be used with 1207 controllers.** Although the configuration shown is typical, various other configurations are possible.

NOTE:  The emergency reverse check feature (wiring shown by dashed line) is a factory option.

Power Wiring for Compound Motor

The field must be wired between **B+** and **A2** and the armature between **M-** and **A2**. The internal plug diode in the 1207 is connected between **M-** and **A2**; therefore, the armature and field positions cannot be interchanged.

If the shunt is rated for under 2 amperes, it can be connected directly to the controller as shown in Figure 4. If the shunt is rated for higher than 2 amperes, a contactor must be used to control the shunt field.

Control Wiring for Compound Motor

Control wiring for the compound motor application is like that for the standard (series motor) wiring. The main contactor, if one is used, is normally connected directly to the controller. Optionally, the main contactor can be switched directly by the keyswitch or brake, leaving pig Pin 4 unconnected.

*16-pin detail  (see Fig. 4):*



The throttle shown in Figure 4 is a 5kΩ–0 type. Various other throttles can also be accommodated, and are discussed in the throttle wiring section.

Polarity protection diodes and control fuses must be sized appropriately to handle the increased current from the shunt field.

## WIRING: Throttle

Wiring for various throttles is described below. They are characterized as Type 1, Type 2, and Type 3 throttles in the programming menu of the handheld programmer. NOTE: In the text, throttles are identified by their nominal range and not by their actual active range.

If the throttle you are planning to use is not covered, please contact the Curtis office nearest you.

### 5kΩ–0 Throttle ("Type 1")

The 5kΩ–0 throttle (called a "Type 1" throttle in the programming menu of the handheld programmer) is a 2-wire resistive throttle that connects between the 5kΩ–0/0–5kΩ pin (Pin 8) and the Pot Low pin (Pin 7), as shown in Figure 5. It doesn't matter which wire goes on which pin. Zero speed corresponds to 5kΩ measured between the two pins and full speed corresponds to 0Ω.
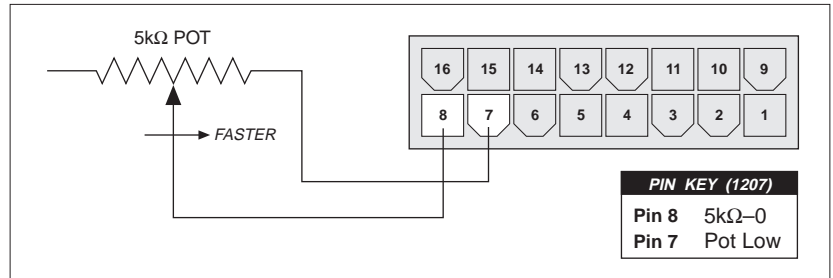
**Fig. 5** *Wiring for 5kΩ–0 throttle ("Type 1").*



In addition to accommodating the basic 5kΩ–0 throttle, the Type 1 throttle is the easiest with which to implement a wigwag-style throttle. Using a 20kΩ potentiometer wired as shown in Figure 6, the pot wiper can be set such that the controller has 5kΩ between Pins 7 and 8 when the throttle is in the neutral position (i.e., at the center of the pot). The throttle mechanism can then be designed such that rotating it either forward or back decreases the resistance between Pins 7 and 8, which increases the controller output. The throttle

**Fig. 6** *Wiring for 20kΩ potentiometer used as a wigwag-style throttle ("Type 1").*
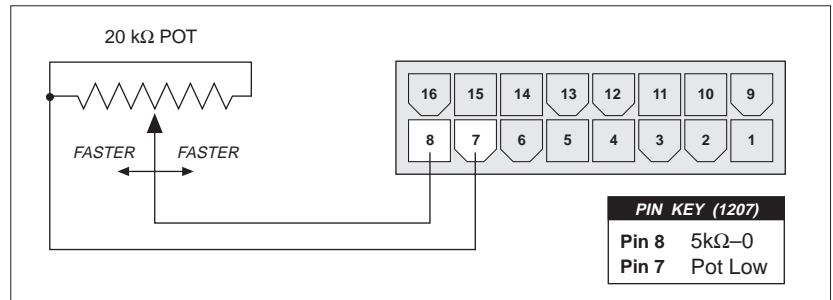
mechanism must provide signals to the controller's forward and reverse inputs independent of the throttle pot resistance. The controller will not sense direction from the pot resistance.

Broken wire protection for Type 1 throttles is provided by the controller sensing the current flow from the 5kΩ–0 input through the pot and into the Pot Low pin. If the Pot Low input current falls below 0.1 mA, a throttle fault is generated and the controller is disabled. NOTE: The Pot Low pin (Pin 7) must not be tied to ground.

### 0–5V, 0–10V, 3-Wire Potentiometer, and Electronic Throttles ("Type 2")

With these throttles ("Type 2" in the programming menu), the controller looks for a voltage signal at either the pot wiper/0–5V input of the controller (Pin 6) or the 0–10V input (Pin 9). Zero speed corresponds to 0V and full speed corresponds to either 5V or 10V, measured relative to B-. Pot Low is the current return path for all Type 2 throttles.

A voltage source, 3-wire pot, or electronic throttle can be used with this throttle type. The wiring for each is slightly different and each has varying levels of throttle fault detection associated with it.

*0–5V Throttle*
Two ways of wiring the 0–5V throttle are shown in Figure 7. Broken wire protection is provided by the controller looking for a minimum current into the

**Fig. 7** *Wiring for 0–5V throttle ("Type 2").*
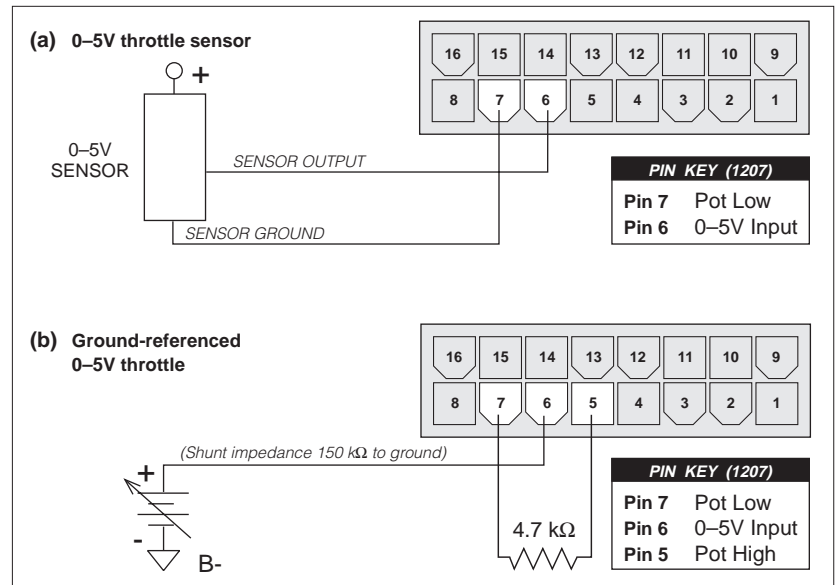
Pot Low pin. If the Pot Low input current falls below 0.1 mA, a throttle fault is generated and controller shuts down. If a throttle sensor is used, the sensor's ground return current must be less than 10 mA. If the 0–5V throttle input (Pin 7) exceeds 8 volts, controller output will shut down. NOTE: In Figure 7(b), the throttle's voltage input signal is in reference to Pot Low.

*0–10V Throttle*
Two ways of wiring the 0–10V throttle are shown in Figure 8. Broken wire protection is provided by the controller looking for a minimum current into the Pot Low pin. If the Pot Low input current falls below 0.1 mA, a throttle fault is generated and the controller shuts down. If a throttle sensor is used, the sensor's ground return current must be less than 10 mA. If the 0–10V throttle input (Pin 9) exceeds 16 volts, the controller will shut down. NOTE: In Figure 8(b), the throttle's voltage input signal is in reference to Pot Low.

**Fig. 8** *Wiring for 0–10V throttle ("Type 2").*
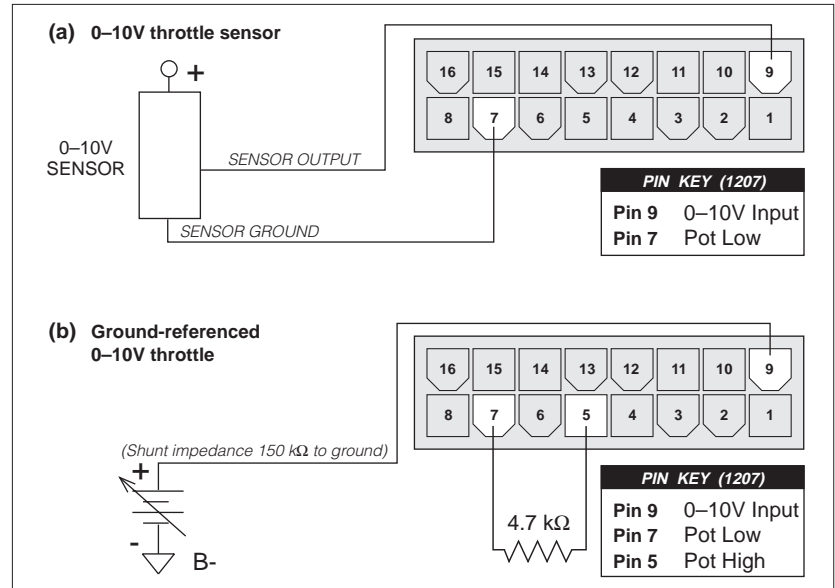
*3-Wire Potentiometer (500Ω–10kΩ) Throttle*

A 3-wire potentiometer with a total resistance value anywhere between 500Ω and 10kΩ can be used, wired as shown in Figure 9. The pot is used in its voltage divider mode—with the voltage source and return being provided by the 1207 controller. Pot High provides a current-limited 5V source to the potentiometer, and Pot Low provides the return path.

**Fig. 9** *Wiring for 3-wire potentiometer throttle ("Type 2").*
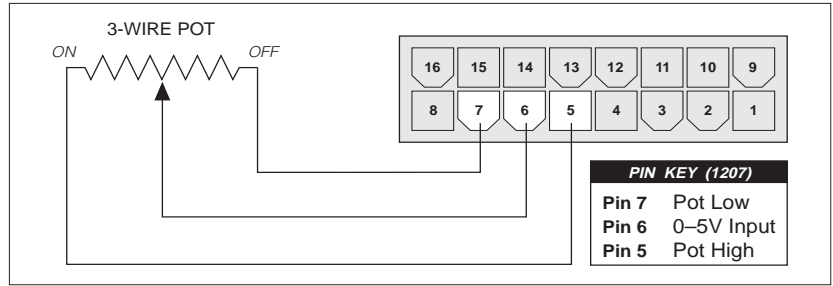


As with the 2-wire throttles, broken wire protection is provided by the controller looking for a minimum current into the Pot Low pin. If the Pot Low input current falls below 0.1 mA, a throttle fault is generated and the controller shuts down. NOTE: The Pot Low pin (Pin 7) must not be tied to ground.

*Curtis ET-XXX Electronic Throttle*

The Curtis ET-XXX provides throttle and forward/reverse inputs to the 1207. Wiring for the Curtis ET-XXX is shown in Figure 10.

**Fig. 10** *Wiring for Curtis ET-XXX electronic throttle ("Type 2").*
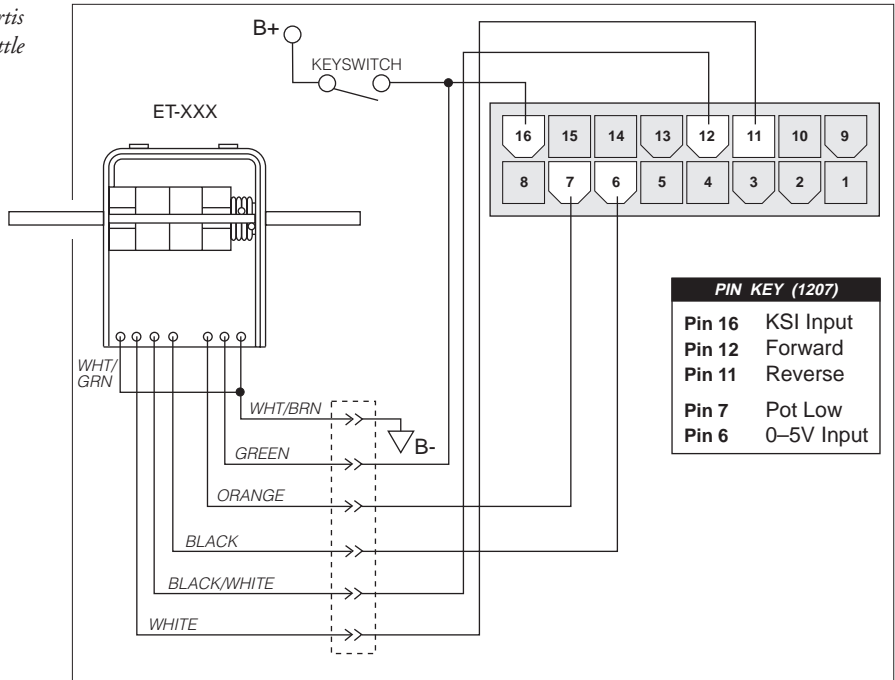


There is no fault detection built into the ET-XXX, and the controller will detect only open wiper faults. It is the responsibility of the vehicle manufacturer to provide any additional throttle fault detection necessary for the application.

The ET-XXX can be integrated into a control head to provide wigwag-style throttle control. Alternatively, a complete control head assembly is available from Curtis. This control head assembly—the CH series—combines the ET-XXX throttle with a variety of standard control head switch functions for use in walkie and lift truck applications.

<u>0–5kΩ Throttle ("Type 3")</u>

The 0–5kΩ throttle ("Type 3" in the programming menu) is a 2-wire resistive throttle that connects between the 5kΩ–0/0–5kΩ pin (Pin 8) and the Pot Low pin (Pin 7), as shown in Figure 11. It doesn't matter which wire goes on which pin. For Type 3 throttles, zero speed corresponds to 0Ω and full speed corresponds to 5kΩ.

**Fig. 11** *Wiring for 0–5Ω throttle ("Type 3").*
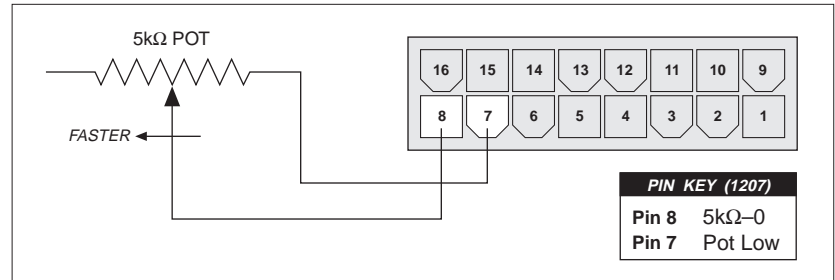


Broken wire protection is provided by the controller sensing the current flow from the 0–5kΩ input through the pot and into the Pot Low pin. If the Pot Low input current falls below 0.1 mA, a throttle fault is generated and the controller shuts down. NOTE: The Pot Low pin (Pin 7) must not be tied to ground.

## WIRING:  Emergency Reverse Check

An optional wire connected directly to the emergency reverse (belly button) switch provides for broken wire detection **when that option is enabled at the factory.** The emergency reverse check output wire periodically pulses the emergency reverse circuit to check for continuity. If there is no continuity in the circuit, the controller shuts down and a fault code is indicated.

This feature must be enabled at Curtis PMC. If the option is selected and the check wire is not connected, the vehicle will not operate. If the option is not selected and the check wire is connected, no harm will occur—but continuity will not be checked.

The emergency reverse check output wire is connected to Pin 10, as shown by the dashed lines in the two basic wiring diagrams (Figures 3 and 4).

## SWITCHES AND OTHER HARDWARE

### Keyswitch

The vehicle should have a master on/off switch to turn the system off when not in use. The keyswitch provides logic power for the 1207 controller, coil current for the contactors, and shunt current (in compound motor applications). The keyswitch must be capable of carrying these currents.

### Main Contactor

A main contactor allows the 1207 controller to be disconnected from the battery. In 24V applications a main contactor is optional, but **in 36V applications a main contactor is required.** A heavy-duty single-pole, single-throw (SPST) contactor with silver-alloy contacts is recommended, such as an Albright SW80 or SW180 *(available from Curtis)*.

After initial closing of the contacts, inrush currents flow as the controller's internal filter capacitors are charged. A 250Ω, 5W resistor (such as Curtis PMC p/n MP-2) can be used across the contactor to precharge the capacitors and reduce the inrush current through the contacts.

### Forward/Reverse Contactors

For forward/reverse, a paired single-pole, double-throw (2×SPDT) contactor is recommended, such as an Albright DC88 or DC182 *(available from Curtis)*. With 4-terminal split field motors, two single-pole, single-throw (SPST) contactors are typically used. The coil voltage should match the vehicle voltage. The maximum allowed coil current is 1 ampere.

### Forward/Reverse, Emergency Reverse, and Mode Switches

The direction input switches can be any type of single-pole, single-throw (SPST) switch capable of switching the battery voltage at 10 mA.

### Circuitry Protection Devices

For reverse polarity protection, a diode should be added to the control circuit. It must be sized appropriately for the maximum contactor coil currents (and shunt current, in compound motor applications). To protect the control wiring from accidental shorts, a low current fuse (appropriate for the maximum current draw) should be connected in series with the battery feed. These devices are both shown in the wiring diagrams.

### 1207 INSTALLATION CHECKOUT

Before operating the vehicle, carefully complete the following checkout procedure. If you find a problem during the checkout, refer to the diagnostics and troubleshooting section (Section 5) for further information.

The installation checkout can be conducted with or without the handheld programmer. The checkout procedure is easier with a programmer. Otherwise, observe the Status LED for codes.

**CAUTION** ☞

> **Put the vehicle up on blocks to get the drive wheel(s) off the ground before beginning these tests.**
>
> **Turn the keyswitch off and make sure that the brake is applied (brake switch open), the throttle is in neutral, and the forward/reverse switches are open.**
>
> **Do not stand, or allow anyone else to stand, directly in front of or behind the vehicle during the tests.**

1. Slide open the cover on the top of the controller. The cover is not removable; be careful not to force it. If a programmer is available, connect it to the programmer connector.

2. Turn the keyswitch on. The programmer should "power up" with an initial display, and the controller's Status LED should begin steadily blinking a single flash. If neither happens, check for continuity in the keyswitch circuit and controller ground.

3. If you are using a programmer, put it into the diagnostic mode by pressing the DIAGNOSTICS key. The display should indicate "No Faults Found."

    Release the brake (close the brake switch). To do this on a walkie, pull the tiller down to the operating position. The LED should continue blinking a single flash and the programmer should continue to indicate no faults. If there is a problem, the LED will flash a diagnostic code and the programmer will display a diagnostic message. If you are conducting the checkout without a programmer, look up the LED diagnostic code in Section 5: Diagnostics and Troubleshooting.

    When the problem has been corrected, it may be necessary to cycle the brake in order to clear the fault code.

4. With the brake released, 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 forward/reverse switches, forward/reverse contactors, and motor. The motor should run proportionally faster with increasing throttle. If not, refer to Section 5.

5. If you are using a programmer, put it into the test mode by pressing the TEST key. Scroll down to observe the status of the forward, reverse, brake, emergency reverse, and mode switches. Cycle each switch in turn, observing the programmer. Each input should show the correct state on the programmer.

6. Specific material handling directives, such as prEN1175, require testing of the controller's fault detection circuitry. This can be done as follows:
   a) Disconnect the battery and make sure the keyswitch is off.
   b) Using an inline fuse holder fitted with a 10-amp fuse and alligator clips, connect the controller's M- and B- terminals.
   c) Turn the keyswitch on, release the brake, and apply the throttle. The motor should not operate, and the direction contactors should not pull in.
   d) Leave the keyswitch on and remove the inline fuse wire. The vehicle status should continue to remain off.
   e) Cycle the keyswitch off and on, release the brake, and apply the throttle. The vehicle should now operate normally.

7. Take the vehicle off the blocks and drive it in a clear area. It should have smooth acceleration and good top speed.

8. Test the plug braking of the vehicle. Verify that the plug braking option is as desired (variable or fixed).

9. Verify that all options, such as high pedal disable (HPD), static return to off (SRO), and anti-tiedown, are as desired.

10. Check to see whether the emergency reverse (belly button) feature is working correctly. If you have the optional emergency reverse check wiring, verify that the circuit is operational by momentarily disconnecting one of the emergency reverse wires. The vehicle should be disabled and a fault indicated.

11. When you have completed the checkout procedure, be sure to close the protective sliding cover.

# 2A

## INSTALLATION AND WIRING: 1207A

### MOUNTING

The 1207A controller can be oriented in any position, but **the location should be carefully chosen to keep the controller as clean and dry as possible. If a clean mounting location cannot be found, a cover must be used to shield the controller from water and contaminants.**

To ensure full rated output power, the controller should be fastened to a clean, flat metal surface with three screws. The case outline and mounting hole dimensions are shown in Figure 2A.

**Fig. 2A** *Mounting dimensions, Curtis PMC 1207A controller.*



*Dimensions in millimeters and (inches)*

Although not usually necessary, a thermal joint compound can be used to improve heat conduction from the case to the mounting surface.

## CONNECTIONS: Low Current

An integrated 16-pin low power connector molded into the front of the controller provides the low power logic control connections (see pin list below). The mating connector is Molex Mini-Fit Jr., part number (5557) 39-01-2165. Contact Molex regarding compatible pins for various wire sizes.

| 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 |
|----|----|----|----|----|----|----|---|
| 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |

**Pin 1**  shunt field driver output; n/c for series motors
**Pin 2**  reverse contactor driver output
**Pin 3**  forward contactor driver output
**Pin 4**  main contactor driver output
**Pin 5**  throttle: 3-wire pot high
**Pin 6**  throttle: 3-wire pot wiper or 0–5V
**Pin 7**  throttle: pot low
**Pin 8**  throttle: 2-wire 5kΩ–0 or 0–5kΩ input

**Pin 9**  n/c
**Pin 10**  emergency reverse (BB) check output [optional]
**Pin 11**  reverse input
**Pin 12**  forward input
**Pin 13**  emergency reverse input
**Pin 14**  mode selection input
**Pin 15**  brake input
**Pin 16**  keyswitch input (KSI)
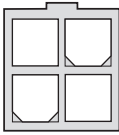
### Programmer Connector

A 4-pin Molex connector is provided for the handheld programmer. The mating cable is supplied with the programmer.

### Status LED

The Status LED, located on top of the controller, displays flashing codes to indicate controller status; the codes are listed in Section 5.

## CONNECTIONS: High Current

Four tin-plated copper bus bars are provided for the high current connections to the battery and motor:

**M-** output to motor armature
**B-** negative connection to battery
**B+** positive connection to battery/field
**A2** plug diode to motor armature

Cables are fastened to the bus bars by M8 (⁵⁄₁₆") bolts. When tightening the bolts, two opposing wrenches should be used to prevent bending the bus bars and putting undue strain on the internal connections.

### WIRING:  Standard Configuration (Series Motor)

The basic wiring for series motors with field reversing is shown in Figure 3A.

**Fig. 3A** *Standard wiring diagram (series motor), Curtis PMC 1207A controller.*



The configuration shown in Figure 3A is a typical arrangement for a series motor. Curtis PMC controllers are designed for use in a wide range of applications, and accordingly can be installed in a variety of ways to best meet customer needs.

NOTE:  The emergency reverse check feature (wiring shown by dashed line) is a factory option.

Power Wiring for Series Motor

In every wiring configuration, it is imperative that the field be wired between the controller's **B+** and **A2** terminals and that the armature be wired between the **M-** and **A2** terminals. The internal plug diode used in the 1207A is connected between **M-** and **A2**. Therefore, the armature and field positions cannot be interchanged. Reversing contactors can be used to switch either the armature or the field.

Control Wiring for Series Motor

Wiring for the input switches and contactors is shown in Figure 3A (see detail below). The main contactor, if one is used, is normally connected directly to the controller. Optionally, the main contactor can be switched directly by the keyswitch or brake, leaving Pin 4 unconnected.

*16-pin detail  (see Fig. 3A):*
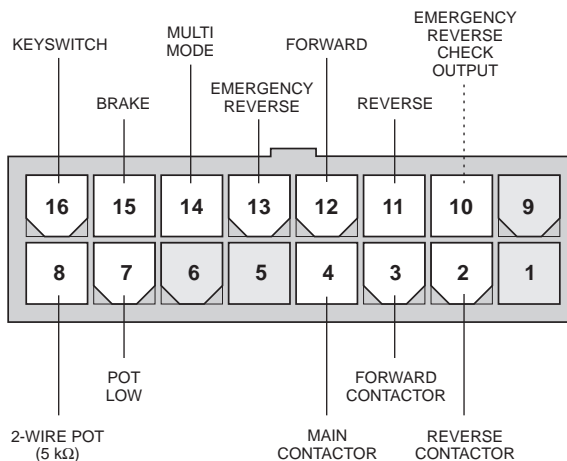


The throttle shown in Figure 3A is a 5kΩ–0 type. Various other throttles can also be accommodated, and are discussed in the throttle wiring section.

### WIRING:  Compound Motor Configuration

A specially configured controller is available for compound motor applications. In this controller, the MOSFET output driver is used to drive the shunt field. The wiring for a compound wound motor with armature reversing is shown in Figure 4A.

*Fig. 4A  Compound motor wiring diagram, Curtis PMC 1207A controller.*
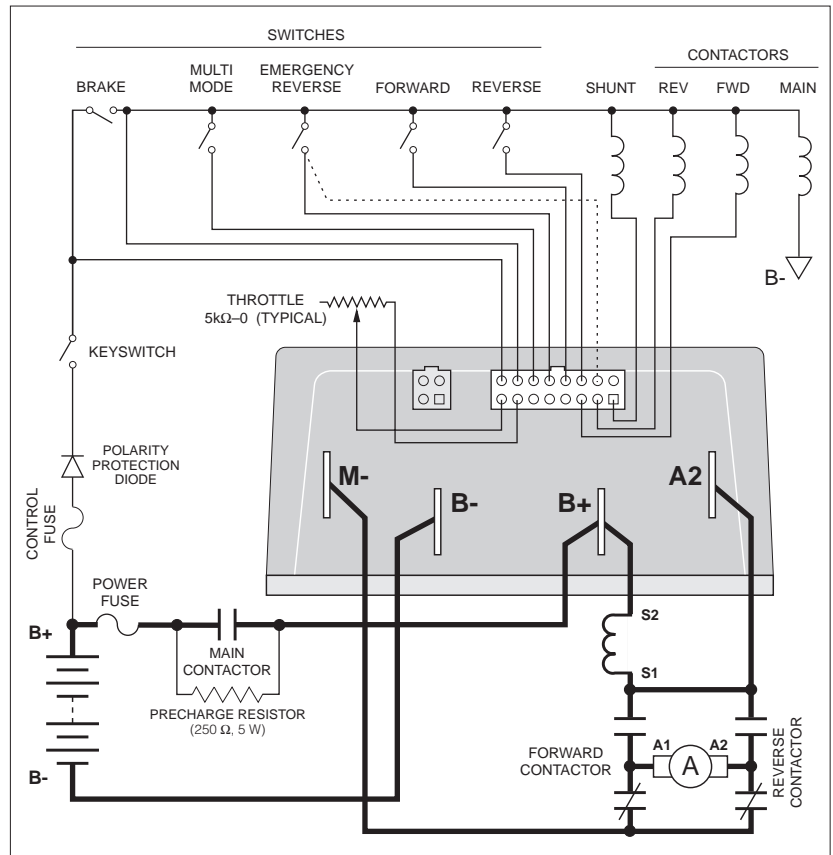


The configuration shown in Figure 4A requires the use of a compound wound motor. **Pure shunt motors cannot be used with 1207A controllers.** Although the configuration shown is typical, various other configurations are possible.

NOTE:  The emergency reverse check feature (wiring shown by dashed line) is a factory option.

Power Wiring for Compound Motor

The field must be wired between **B+** and **A2** and the armature between **M-** and **A2**. The internal plug diode in the 1207A is connected between **M-** and **A2**; therefore, the armature and field positions cannot be interchanged.

If the shunt is rated for under 2 amperes, it can be connected directly to the controller as shown in Figure 4A. If the shunt is rated for higher than 2 amperes, a contactor must be used to control the shunt field.

Control Wiring for Compound Motor

Control wiring for the compound motor application is like that for the standard (series motor) wiring. The main contactor, if one is used, is normally connected directly to B-.

*16-pin detail  (see Fig. 4A):*



The throttle shown in Figure 4A is a 5kΩ–0 type. Various other throttles can also be accommodated, and are discussed in the throttle wiring section.

Polarity protection diodes and control fuses must be sized appropriately to handle the increased current from the shunt field.

### WIRING: Throttle

Wiring for various throttles is described below. They are characterized as Type 1, Type 2, and Type 3 throttles in the programming menu of the handheld programmer. NOTE: In the text, throttles are identified by their nominal range and not by their actual active range.

If the throttle you are planning to use is not covered, please contact the Curtis office nearest you.

#### 5kΩ–0 Throttle ("Type 1")

The 5kΩ–0 throttle (called a "Type 1" throttle in the programming menu of the handheld programmer) is a 2-wire resistive throttle that connects between the

**Fig. 5A** *Wiring for 5kΩ–0 throttle ("Type 1").*
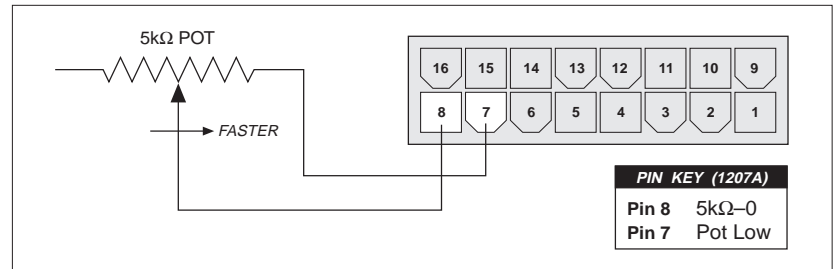


5kΩ–0/0–5kΩ pin (Pin 8) and the Pot Low pin (Pin 7), as shown in Figure 5A. It doesn't matter which wire goes on which pin. Zero speed corresponds to 5kΩ and full speed corresponds to 0Ω.

In addition to accommodating the basic 5kΩ–0 throttle, the Type 1 throttle is the easiest with which to implement a wigwag-style throttle. Using a 20kΩ potentiometer wired as shown in Figure 6A, the pot wiper can be set such that the controller has 5kΩ between Pins 7 and 8 when the throttle is in the neutral position (i.e., at the center of the pot). The throttle mechanism can then be designed such that rotating it either forward or back decreases the resistance

**Fig. 6A** *Wiring for 20kΩ potentiometer used as a wigwag-style throttle ("Type 1").*
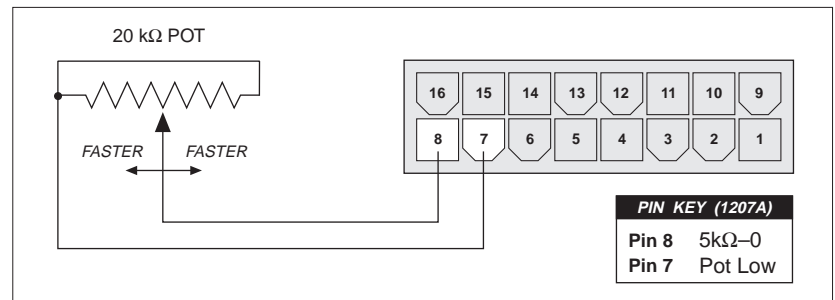
between Pins 7 and 8, which increases the controller output. The throttle mechanism must provide signals to the controller's forward and reverse inputs independent of the throttle pot resistance. The controller will not sense direction from the pot resistance.

### 0–5V, 3-Wire Potentiometer, and Electronic Throttles ("Type 2")

With these throttles ("Type 2" in the programming menu), the controller looks for a voltage signal at the pot wiper/0–5V input of the controller (Pin 6). Zero speed corresponds to 0V and full speed corresponds to 5V. Pot Low is the current return path for all Type 2 throttles.

#### 0–5V Throttle
Two ways of wiring the 0–5V throttle are shown in Figure 7A. If a throttle sensor is used, the sensor's ground return current must be less than 10 mA. If the 0–5V throttle input (Pin 6) exceeds 8 volts, the controller will shut down.

**Fig. 7A** *Wiring for 0–5V throttle ("Type 2").*
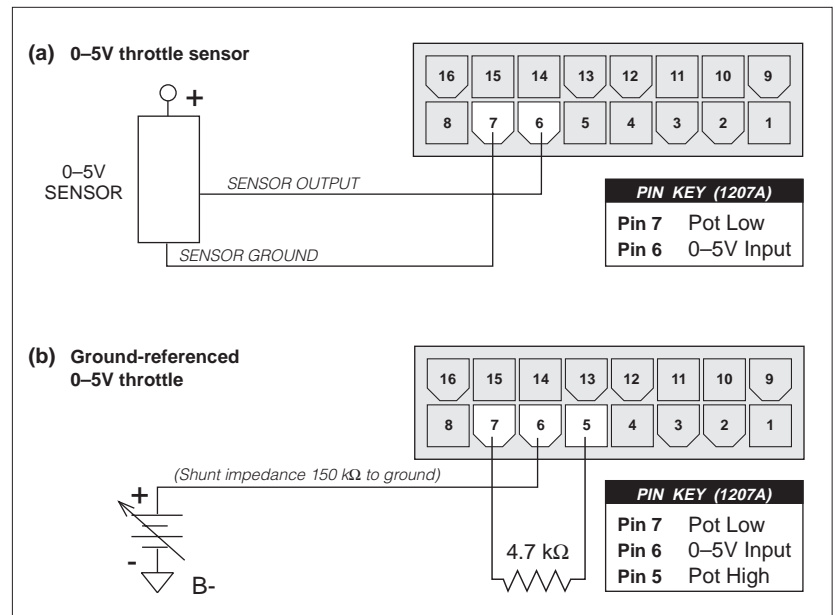
### 3-Wire Potentiometer (500Ω–10kΩ) Throttle

The 3-wire potentiometer is used in its voltage divider mode—with the voltage source and return being provided by the 1207A controller. Pot High provides a current-limited 5V source to the potentiometer, and Pot Low provides the return path. Wiring is shown in Figure 8A.

**Fig. 8A** *Wiring for 3-wire potentiometer throttle ("Type 2").*
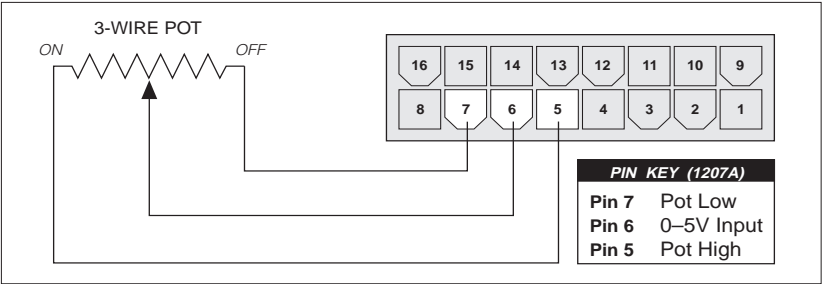


### Curtis ET-XXX Electronic Throttle

The Curtis ET-XXX (manufactured by Hardellet) provides throttle and forward/reverse inputs to the 1207A controller. Wiring for the Curtis ET-XXX is shown in Figure 9A.

**Fig. 9A** *Wiring for Curtis ET-XXX electronic throttle ("Type 2").*
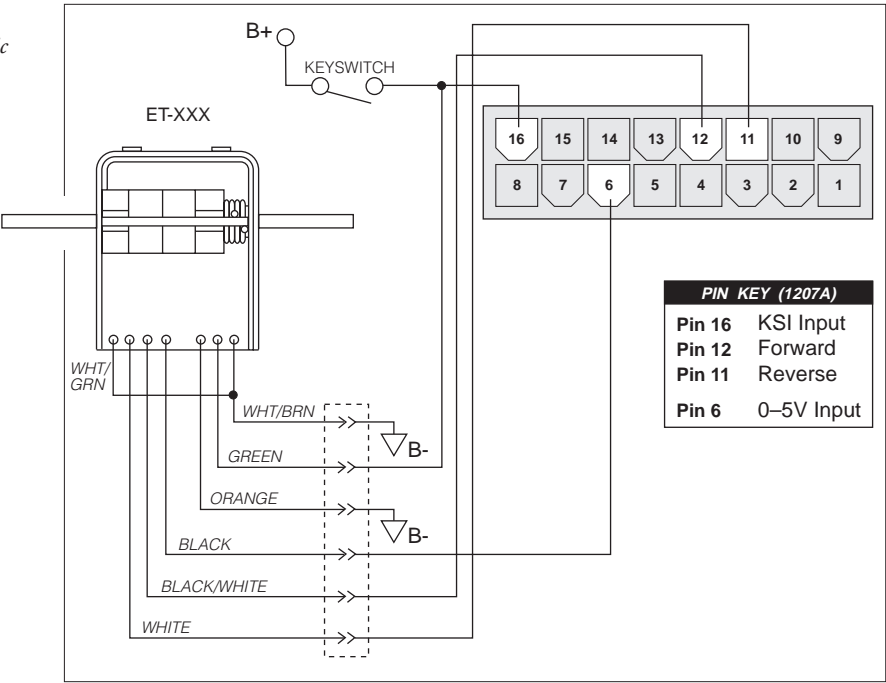


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### 0–5kΩ Throttle ("Type 3")

The 0–5kΩ throttle ("Type 3" in the programming menu) is a 2-wire resistive throttle that connects between the 5kΩ–0/0–5kΩ pin (Pin 8) and the Pot Low pin (Pin 7), as shown in Figure 10A. It doesn't matter which wire goes on which pin. Zero speed corresponds to 0Ω and full speed corresponds to 5kΩ.

**Fig. 10A** *Wiring for 0–5Ω throttle ("Type 3").*
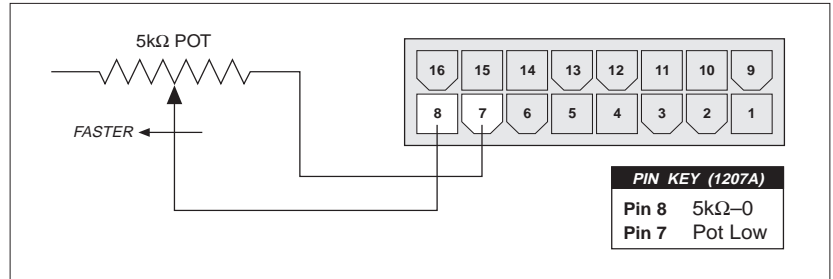


### WIRING: Emergency Reverse Check

An optional wire connected directly to the emergency reverse (belly button) switch provides for broken wire detection **when that option is enabled at the factory.** The emergency reverse check output wire provides a dc bias to the emergency reverse circuit to check for continuity. If there is no continuity in the circuit, the controller shuts down and a fault code is indicated.

**Fig. 11A** *Alternative wiring for 1207A emergency reverse check.*
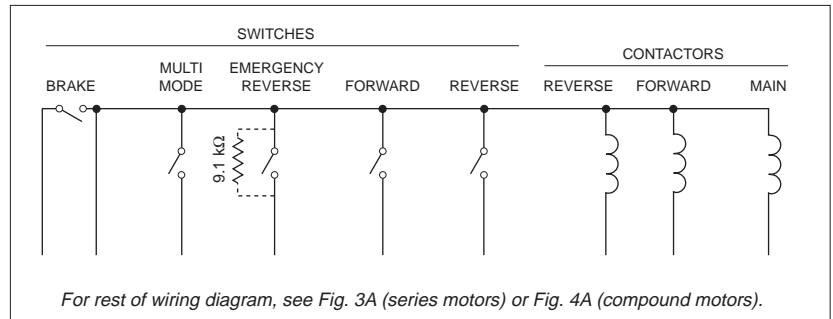


This feature must be enabled at Curtis PMC. If the option is selected and the check wire is not connected, the vehicle will not operate. If the option is not selected and the check wire is connected, no harm will occur—but continuity will not be checked.

The emergency reverse check output wire is connected to Pin 10, as shown by the dashed lines in the two basic wiring diagrams (Figures 3A and 4A).

Alternatively, a 9.1kΩ resistor can be wired directly across the emergency reverse switch to provide the dc bias, as shown by the dashed line in Figure 10A.

## SWITCHES AND OTHER HARDWARE

### Keyswitch

The vehicle should have a master on/off switch to turn the system off when not in use. The keyswitch provides logic power for the 1207A controller, coil current for the contactors, and shunt current (in compound motor applications). The keyswitch must be capable of carrying these currents.

### Main Contactor

A main contactor allows the 1207A controller to be disconnected from the battery. A heavy-duty single-pole, single-throw (SPST) contactor with silver-alloy contacts is recommended, such as an Albright SW80 or SW180 *(available from Curtis)*.

After initial closing of the contacts, inrush currents flow as the controller's internal filter capacitors are charged. A 250Ω, 5W resistor (such as Curtis PMC p/n MP-2) can be used across the contactor to precharge the capacitors and reduce the inrush current through the contacts.

In compound motor applications, the main contactor driver is used to drive the shunt field. The main contactor—if one is used—is normally connected directly to B- in this configuration.

### Forward/Reverse Contactors

For forward/reverse, a paired single-pole, double-throw (2×SPDT) contactor is recommended, such as an Albright DC88 or DC182 *(available from Curtis)*. With 4-terminal split field motors, two single-pole, single-throw (SPST) contactors are typically used. The coil voltage should match the vehicle voltage. The maximum allowed coil current is 1 ampere.

### Forward/Reverse, Emergency Reverse, and Mode Switches

The direction input switches can be any type of single-pole, single-throw (SPST) switch capable of switching the battery voltage at 10 mA.

### Circuitry Protection Devices

For reverse polarity protection, a diode should be added to the control circuit. It must be sized appropriately for the maximum contactor coil currents (and shunt current, in compound motor applications). To protect the control wiring from accidental shorts, a low current fuse (appropriate for the maximum current draw) should be connected in series with the battery feed. These devices are both shown in the wiring diagrams.

## 1207A INSTALLATION CHECKOUT

Before operating the vehicle, carefully complete the following checkout procedure. If you find a problem during the checkout, refer to the diagnostics and troubleshooting section (Section 5) for further information.

The installation checkout can be conducted with or without the handheld programmer. The checkout procedure is easier with a programmer. Otherwise, observe the Status LED for codes.

**CAUTION** 👉

> **Put the vehicle up on blocks to get the drive wheel(s) off the ground before beginning these tests.**
>
> **Turn the keyswitch off and make sure that the brake is applied (brake switch open), the throttle is in neutral, and the forward/reverse switches are open.**
>
> **Do not stand, or allow anyone else to stand, directly in front of or behind the vehicle during the tests.**

1. If a programmer is available, connect it to the programmer connector.

2. Turn the keyswitch on. The programmer should "power up" with an initial display, and the controller's Status LED should begin steadily blinking a single flash. If neither happens, check for continuity in the keyswitch circuit and controller ground.

3. If you are using a programmer, put it into the diagnostic mode by pressing the DIAGNOSTICS key. The display should indicate "No Faults Found."

    Release the brake (close the brake switch). To do this on a walkie, pull the tiller down to the operating position. The LED should continue blinking a single flash and the programmer should continue to indicate no faults. If there is a problem, the LED will flash a diagnostic code and the programmer will display a diagnostic message. If you are conducting the checkout without a programmer, look up the LED diagnostic code in Section 5: Diagnostics and Troubleshooting.

    When the problem has been corrected, it may be necessary to cycle the brake in order to clear the fault code.

4. With the brake released, 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 forward/reverse switches, forward/reverse con-
tactors, and motor. The motor should run proportionally faster with
increasing throttle. If not, refer to Section 5.

5.  If you are using a programmer, put it into the test mode by pressing
    the TEST key. Scroll down to observe the status of the forward, reverse,
    brake, emergency reverse, and mode switches. Cycle each switch in
    turn, observing the programmer. Each input should show the correct
    state on the programmer.

6.  Specific material handling directives, such as prEN1175, require testing
    of the controller's fault detection circuitry. This can be done as follows:
    a)  Disconnect the battery and make sure the keyswitch is off.
    b)  Using an inline fuse holder fitted with a 10-amp fuse and
        alligator clips, connect the controller's M- and B- terminals.
    c)  Turn the keyswitch on, release the brake, and apply the throttle.
        The motor should not operate, and the direction contactors
        should not pull in.
    d)  Leave the keyswitch on and remove the inline fuse wire. The
        vehicle status should continue to remain off.
    e)  Cycle the keyswitch off and on, release the brake, and apply the
        throttle. The vehicle should now operate normally.

7.  Take the vehicle off the blocks and drive it in a clear area. It should have
    smooth acceleration and good top speed.

8.  Test the plug braking of the vehicle. Verify that the plug braking option
    is as desired (variable or fixed).

9.  Verify that all options, such as high pedal disable (HPD), static return
    to off (SRO), and anti-tiedown, are as desired.

10. Check to see whether the emergency reverse (belly button) feature is
    working correctly. If you have the optional emergency reverse check
    wiring, verify that the circuit is operational by momentarily disconnect-
    ing one of the emergency reverse wires. The vehicle should be disabled
    and a fault indicated.

# 3

# ADJUSTMENT OF PARAMETERS

A number of controller parameters can be adjusted electronically via the optional handheld programmer; for a complete list of the adjustments that can be made, see Section 6: Programmer Operation. On some 1207 models, it is also possible to adjust the main current limit, plug current limit, acceleration rate, maximum creep speed, and maximum speed mechanically, by means of the built-in screwdriver-adjustable potentiometers.

## ADJUSTMENT VIA THE PROGRAMMER

To change a parameter using the programmer, press the PROGRAM key, and scroll down the Program Menu until the desired parameter is the top line of the display. Press the appropriate CHANGE VALUE key ("up" or "down") until the desired number is reached. The parameter is now set at the desired value. All programming occurs in real time. That is, the parameters can be changed while the vehicle is in operation.

The upper and lower limits of parameters are set at the factory. Some parameters have dependencies on other parameters. When the programmer is being used to adjust a parameter and a limit is reached, the display will stop changing. To see why the display has stopped changing, press the MORE INFO key. If the limit is related to another parameter, that information will be displayed; changing the value of the related parameter may allow the original parameter to be adjusted further. Otherwise, the display simply says "Max Limit" or "Min Limit."

Use of the programmer is described more fully in Section 6.

> ### *1207 single-mode controllers only*
>
> If a programmer is connected when a parameter is adjusted mechanically (see next page), the effect of the change can be seen in the programmer display. To adjust one of these five parameters with the programmer, its potentiometer must be set to the "OFF" position on the adjustment panel. If you attempt to use the programmer to adjust a parameter whose potentiometer is <u>not</u> set to the "OFF" position, its value will not change. You will also note that the LEDs in the corners of both the CHANGE VALUE keys do not light up— another indication the parameter cannot be adjusted electronically. If you press the MORE INFO key, the programmer will display the following message: "Protected by controller, can't program."

## MECHANICAL ADJUSTMENT   *[1207 single-mode controllers only]*

Five screwdriver-adjustable potentiometers ("trimpots") allow mechanical adjustment of the main current limit, plug current limit, acceleration rate, maximum creep speed, and maximum speed (labeled "LOW"). The five trimpots are accessed through holes on the adjustment panel, located under the sliding protective cover on top of the controller. Adjustments are made with a small insulated screwdriver.
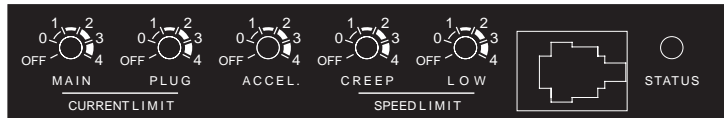


The trimpot's relative position indicates the approximate value over the allowable range. For example: if the main current limit range is 20–250 amps, position "0" corresponds to 20 amps, and position "4" to 250 amps. Setting the pot halfway (at position "2") corresponds to approximately 135 amps.

If you wish to adjust any of these parameters electronically, using the programmer, its trimpot must be set to "OFF."

NOTE:  On 1207 controllers with the MultiMode™ feature, the trimpots are disabled at the factory.

# 4

# MAINTENANCE

There are no user-serviceable parts inside Curtis PMC 1207 and 1207A controllers. **No attempt should be made to open the controller.** Opening the controller may damage it and will void the warranty.

However, it is recommended that the controller exterior be cleaned periodically, and—if a handheld programmer is available—this periodic cleaning provides a good opportunity to check the controller's diagnostic history file. It is also recommended that the controller's fault detection circuitry be checked whenever the vehicle is serviced.

**C A U T I O N** 👉

The 1207/1207A controller is inherently a high power device. **When working around any battery powered vehicle, proper safety precautions should be taken.** These include, but are not limited to: proper training, wearing eye protection, avoiding loose clothing and jewelry, and using insulated wrenches.

## CLEANING

Although the 1207/1207A controller requires virtually no maintenance if properly installed, the following minor maintenance is recommended in certain applications.

1.  Remove power by disconnecting the battery.

2.  Discharge the capacitors in the controller by connecting a load (such as a contactor coil or a horn) across the controller's B+ and B- terminals.

3.  Remove and dirt or corrosion from the bus bar area. The controller should be wiped clean with a moist rag. Allow it to dry before reconnecting the battery.

4.  Make sure the connections to the bus bars are tight. Use two well insulated wrenches for this task in order to avoid stressing the bus bars.

## DIAGNOSTIC HISTORY

The handheld programmer can be used to access the controller's diagnostic history file. Connect the programmer, press the [MORE INFO] key, and then—while

continuing to hold the MORE INFO key—press the DIAGNOSTICS key. The programmer will read out all the faults that the controller has experienced since the last time the diagnostic history file was cleared. The faults may be intermittent faults, faults caused by loose wires, or faults caused by operator errors. Faults such as contactor faults may be the result of loose wires; contactor wiring should be carefully checked out. 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 diagnostic history file is advisable. This allows the controller to accumulate a new file of faults. By checking the new diagnostic history file at a later date, you can readily determine whether the problem was indeed completely fixed.

To clear the diagnostic history file, go to the Special Program Menu (by pressing and holding the MORE INFO key, and then pressing the PROGRAM key), scroll through the menu until "Clear Diagnostic History" is the top line in the display, and then press MORE INFO again. The programmer will prompt you to acknowledge or cancel. See Section 6 of this manual for more detail on programmer operation.

## TESTING THE FAULT DETECTION CIRCUITRY

Specific material handling directives, such as prEN1175, require periodic testing of the controller's fault detection circuitry. It is recommended that each time the vehicle is serviced, the M- fault detection circuitry be checked as follows:

1. Put the vehicle up on blocks to get the drive wheel(s) off the ground, disconnect the battery, and make sure the keyswitch is off.

2. Using an inline fuse holder fitted with a 10-amp fuse and alligator clips, connect the controller's M- and B- terminals.

3. Turn the keyswitch on, release the brake, and apply the throttle. The motor should not operate, and the direction contactors should not pull in.

4. Leave the keyswitch on and remove the inline fuse wire. The vehicle status should continue to remain off.

5. Cycle the keyswitch off and on, release the brake, and apply the throttle. The vehicle should now operate normally.

# 5

# DIAGNOSTICS AND TROUBLESHOOTING

The 1207/1207A controllers provide diagnostics information to assist techni-
cians in troubleshooting drive system problems. The diagnostics information can
be obtained in two ways: reading the appropriate display on the programmer or
observing the fault codes issued by the Status LED. The Status LED is located on
top of the controller. On 1207 models, it is under the sliding protective cover.

## LED DIAGNOSTICS

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

| ¤ ¤ ¤  ¤ ¤ | ¤ ¤ ¤  ¤ ¤ | ¤ ¤ ¤  ¤ ¤ |
|:---:|:---:|:---:|
| ( 3 , 2 ) | ( 3 , 2 ) | ( 3 , 2 ) |

The codes are listed in Table 1. For suggestions about possible causes of the
various faults, refer to the troubleshooting chart (Table 2).

| Table 1   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 or shunt driver overcurrent |
| 3,2 | ¤¤¤  ¤¤ | welded direction contactor |
| 3,3 | ¤¤¤  ¤¤¤ | [reserved for future use] |
| 3,4 | ¤¤¤  ¤¤¤¤ | missing contactor or shunt |
| 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 overtemperature—are cleared as soon as operation is brought within range. Non-operational faults—such as a throttle fault—usually require the brake or keyswitch to be cycled after the problem is remedied.

## PROGRAMMER DIAGNOSTICS

With a programmer, diagnostics and troubleshooting 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 2) for suggestions covering a wide range of possible faults.

<table>
<tr><td colspan="4" align="center"><strong>Table 2   TROUBLESHOOTING CHART</strong></td></tr>
<tr><td>LED<br>CODE</td><td>PROGRAMMER<br>LCD DISPLAY</td><td>EXPLANATION</td><td>POSSIBLE CAUSE</td></tr>
<tr><td>1,2</td><td>HW FAILSAFE</td><td>hardware fail-safe error</td><td>1. Controller defective.</td></tr>
<tr><td>1,3</td><td>M- SHORTED</td><td>M- output shorted</td><td>1. M- output shorted to ground.<br>2. Direction contactor not closing.<br>3. Direction contactor not closing fast enough.<br>4. Internal motor short to ground.</td></tr>
<tr><td>1,4</td><td>SRO</td><td>SRO fault</td><td>1. Improper sequence of KSI, brake, and direction inputs.<br>2. Wrong SRO type selected.<br>3. Brake or direction switch circuit open.<br>4. Sequencing delay too short.</td></tr>
<tr><td>2,1</td><td>THROTTLE FAULT 1</td><td>5kΩ–0 or wiper fault</td><td>1. Throttle input wire open.<br>2. Throttle input wire shorted to ground or B+.<br>3. Throttle pot defective.<br>4. Wrong throttle type selected.</td></tr>
<tr><td>2,2</td><td>BB WIRING CHECK</td><td>emerg. reverse wiring fault</td><td>1. BB wire open.<br>2. BB check wire open.</td></tr>
<tr><td>2,3</td><td>HPD</td><td>HPD sequencing fault</td><td>1. Improper seq. of KSI, brake, throttle inputs.<br>2. Wrong HPD type selected.<br>3. Misadjusted throttle pot.</td></tr>
<tr><td>2,4</td><td>THROTTLE FAULT 2</td><td>Pot Low broken or shorted</td><td>1. Pot Low wire open.<br>2. Pot Low wire shorted.<br>3. Wrong throttle type selected.</td></tr>
<tr><td>3,1</td><td>CONT DRVR OC</td><td>driver output overcurrent</td><td>1. Direction contactor coil shorted.<br>2. Shunt field shorted.</td></tr>
<tr><td>3,2</td><td>DIR CONT WELDED</td><td>welded direction contactor</td><td>1. Direction contactor stuck closed.</td></tr>
<tr><td>3,4</td><td>MISSING CONTACTOR</td><td>missing contactor or shunt</td><td>1. Direction contactor coil open.<br>2. Direction contactor missing.<br>3. Shunt field open.<br>4. Wire to shunt or direction contactor open.</td></tr>
<tr><td>4,1</td><td>LOW BATTERY VOLTAGE</td><td>low battery voltage</td><td>1. Battery voltage <16 volts.<br>2. Corroded battery terminal.<br>3. Loose battery or controller terminal.</td></tr>
<tr><td>4,2</td><td>OVERVOLTAGE</td><td>overvoltage</td><td>1. Battery voltage >48V (1207); >33V (1207A).<br>2. Vehicle operating with charger attached.</td></tr>
<tr><td>4,3</td><td>THERMAL CUTBACK</td><td>over-/under-temp. cutback</td><td>1. Temperature >85°C or <-25°C.<br>2. Excessive load on vehicle.<br>3. Improper mounting of controller.<br>4. Operation in extreme environments.</td></tr>
</table>

**6**

# PROGRAMMER OPERATION

The universal Curtis PMC handheld programmer (optional) allows you to program, test, and diagnose Curtis PMC programmable controllers. The programmer is powered by the host controller, via an RJ11 modular connector located in the adjustment panel on top of the controller (1207 models) or via a 4-pin Molex connector on the front panel (1207A models).

When the programmer is first plugged into the controller, it displays the controller's model number, date of manufacture, and software revision code. Following this initial display, the programmer displays a prompt for further instructions.

```
+    C U R T I S   P M C    +
+                           +
+                           +
+++++++++++++++++++++
```

*A 4-line LCD display is presented in this window*

*The LED in the corner of the key lights up to identify the mode of operation*

**PROGRAM    TEST    DIAGNOSTICS**

*Choose the Program, Test, or Diagnostics Mode with one of these three keys*

*Scroll the 4-line display (up and down) with these two keys*

**SCROLL DISPLAY    CHANGE VALUE**

*Change the selected item's value (up or down) with these two keys*

**✳ MORE INFO**

*Get more information about selected items with this key. Also, use this key in combination with other keys to put the programmer in Special modes.*

**CURTIS PMC**
A DIVISION OF CURTIS INSTRUMENTS INC.

The programmer is operated via an 8-key keypad. Three keys select operating modes (Program, Test, Diagnostics), two scroll the display up and down, and two change the values of selected parameters. The eighth key, the MORE INFO key, is used to display further information about selected items within any of the three standard modes. In addition, when pressed together with the PROGRAM or the DIAGNOSTICS key, the MORE INFO key selects the Special Program mode or the Special Diagnostics mode.

The display window presents a 4-line LCD display. The display is visible even in bright sunlight. You can adjust the display contrast in the Special Program mode.

When one of the menu keys is pressed, the LED at the corner of the key lights up, identifying the mode of programmer operation. For example, if the TEST key is pressed, the LED at the corner of the key indicates that the programmer is now in the Test mode, and the Test Menu is displayed.

Four lines of a menu are displayed at a time. The item at the top of the display window is the selected item. To select an item, scroll within the menu until the desired item is positioned at the top of the display window. The selected item is always the top line. (In the Program mode, the selected item is highlighted by a flashing arrow.) To modify a parameter or obtain more information about it, it must be scrolled to the top position in the display window.

SCROLL
DISPLAY

To scroll up and down within a menu, use the two SCROLL DISPLAY arrow keys. The SCROLL DISPLAY arrow keys can be pressed repeatedly or be held down. When a key is held down, the scrolling speed increases the longer the key is held.

A small scroll bar at the left of the display window provides a rough indication of the position of the four displayed items within the entire menu. That is, when the bar is at the top of the window, the top of the menu is displayed. As you scroll through the menu, the bar moves downward. When the bar is at the very bottom of the window, you have reached the end of the menu. This sample display is from the Program Menu:

scroll bar ——

```
M1 MAIN C/L      →250
M1 PLUG C/L        70
M1 RAMP C/L       250
M1 ACCEL RATE     1.0
```
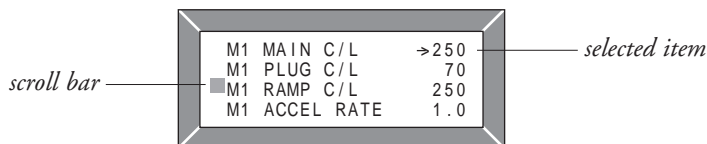
—— selected item

The two CHANGE VALUE arrow keys are used to increase or decrease the value of a selected menu item. Like the SCROLL DISPLAY arrow keys, the CHANGE VALUE arrow keys can be pressed repeatedly or be held down. The longer a key is held, the faster the parameter changes. This allows rapid changing of any parameter.

An LED on each CHANGE VALUE arrow key indicates whether the key is active and whether change is permissible. When the value of a parameter is being increased, the LED on the "up" CHANGE VALUE key is on until you reach the maximum value for that parameter. When the LED goes off, you cannot increase the value.

The MORE INFO key has three functions: (1) to display more information about the selected item, (2) to access the Special Program and Special Diagnostics modes (when used together with the PROGRAM and DIAGNOSTICS keys), and (3) to initiate certain commands (such as the Self Test).

"More information" is available in all of the programmer operating modes. After using the MORE INFO key to display additional information about the selected item, press the MORE INFO key again to return to the original list.

**CHANGE VALUE**

## OPERATING MODES:

PROGRAM, TEST, DIAGNOSTICS, SPECIAL PROGRAM, SPECIAL DIAGNOSTICS
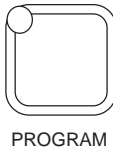
**PROGRAM**

In the **Program** mode, accessed by pressing the PROGRAM key, all the adjustable parameters and features of the controller are displayed (four at a time), along with their present settings. The setting of the selected item—the item at the top of the display, with the flashing arrow—can be changed, using the two CHANGE VALUE keys.

The LEDs on these keys indicate whether there is still room for change. That is, when the upper limit of a parameter's range is reached, the LED on the "up" key no longer lights up, indicating that the present value cannot be increased; when the lower limit is reached, the LED on the "down" key no longer lights up.

The MORE INFO key, when used in the Program mode, displays a bar graph along with the minimum and maximum values possible for the selected parameter. Parameters can be changed either from the main Program Menu or after the MORE INFO key has been pressed and the additional information is being displayed (see example below).



selected parameter — MODE 1 ACCELERATION RATE, SECS — set value
bar graph — 1.3
minimum value — MIN 0.2 / MAX 3.0 — maximum value
units
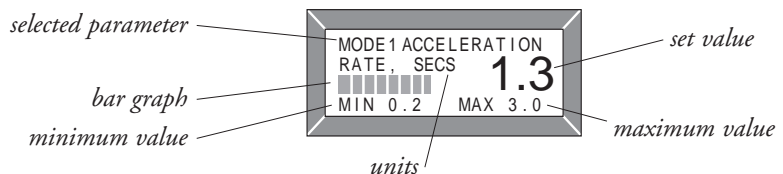
Some parameters on some controllers have dependencies on other parameters. This means that the available settings for one parameter may be dependent on the limits of another parameter. If you attempt to set a parameter (A) outside the limits imposed by another parameter (B), a message will be displayed indicating that parameter A is dependent on parameter B.

The Program Menu is presented at the end of this section. NOTE: Some items may not be available on all models.
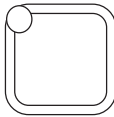
TEST

In the **Test** mode, accessed by pressing the [TEST] key, real-time information is displayed about the status of the inputs, outputs, and controller temperature. For example, when the status of the forward switch is displayed, it should read "On/Off/On/Off/On/Off" as the switch is repeatedly turned on and off. In the Test mode, the item of interest does not need to be the top item on the list; it only needs to be among the four items visible in the window. The Test mode is useful for checking out the operation of the controller during initial installation, and also for troubleshooting should problems occur.

The [MORE INFO] key, when used in the Test mode, causes additional information to be displayed about the selected item (top line in the window).

The Test Menu is presented at the end of this section. NOTE: Some items may not be available on all models.
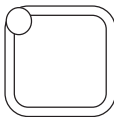
DIAGNOSTICS

In the **Diagnostics** mode, accessed by pressing the [DIAGNOSTICS] key, currently active faults detected by the controller are displayed.

The [MORE INFO] key, when used in the Diagnostics mode, causes additional information to be displayed about the selected item.

A list of the abbreviations used in the Diagnostics display is included at the end of this section.
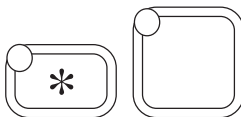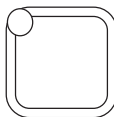
MORE INFO    PROGRAM

The **Special Program** mode allows you to perform a variety of tasks, most of which are self-explanatory. Through the Special Program Menu, you can revert to earlier settings, save controller settings into the programmer memory, load the controller settings from the programmer into a controller, clear the controller's diagnostic history, adjust the contrast of the programmer's LCD display, select the language to be displayed by the programmer, and display basic information (model number, etc.) about the controller and the programmer.

To access the Special Program mode, first press the [MORE INFO] key. Then, while continuing to hold the [MORE INFO] key, press the [PROGRAM] key. The LED on the [PROGRAM] key will light, just as when the programmer is in Program mode.

To distinguish between the Program and Special Program modes, look at the menu items in the display.

> ### CONTROLLER CLONING
>
> Two of the Special Program Menu items—"Save Controller Settings in Programmer" and "Load Programmer Settings into Controller"—allow you to "clone" controllers. To do this, simply program one controller to the desired settings, save these settings in the programmer, and then load them into other similar (same model number) controllers, thus creating a family of controllers with identical settings.

The MORE INFO key is used initially to access the Special Program mode, and once you are within the Special Program mode, it is used to perform the desired tasks. To adjust the contrast in the display window, for example, select "Contrast Adjustment" by scrolling until this item is at the top of the screen, and then press MORE INFO to find out how to make the adjustment.

The Special Program Menu is presented at the end of this section.
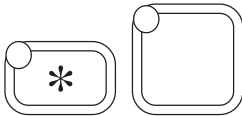
MORE INFO   DIAGNOSTICS

In the **Special Diagnostics** mode, the controller's diagnostic history file is displayed. This file includes a list of all faults observed and recorded by the controller since the history was last cleared. (NOTE: The maximum and minimum temperatures recorded by the controller are included in the Test Menu.) Each fault is listed in the diagnostic history file only once, regardless of the number of times it occurred.

To access Special Diagnostics, first press the MORE INFO key. Then, while continuing to hold the MORE INFO key, press the DIAGNOSTICS key. The LED on the DIAGNOSTICS key will light, just as when the programmer is in Diagnostics mode.

The MORE INFO key, when used within the Special Diagnostics mode, causes additional information to be displayed about the selected item.

To clear the diagnostic history file, put the programmer into the Special Program mode, select "Clear Diagnostic History," and press the MORE INFO key for instructions. Clearing the diagnostic history file also resets the maximum/minimum temperatures in the Test Menu.

**PEACE-OF-MIND PROGRAMMING**

Each time the programmer is connected to the controller, it acquires all the controller's parameters and stores them in its temporary memory. You can revert back to these original settings at any time during a programming session via the Special Program Menu. Select "Reset All Settings" by scrolling it to the top of the display window, press the MORE INFO key, and follow the instructions displayed. Any inadvertent changing of parameters can be "undone" using this procedure— even if you can't remember what the previous settings were—**as long as the programmer has not been unplugged and power has not been removed from the controller**.

*Programmer Self Test*

You can test the programmer by displaying two special test screens. Press the MORE INFO key while the programmer is powering up. During the Self Test, you can toggle between the two test screens by pressing the SCROLL DISPLAY keys. The first screen turns on every LCD element, and the second screen displays all the characters used in the various menus. As part of the Self Test, you can also test the keys be pressing each one and observing whether its corner LED lights up. To exit the Self Test, unplug the programmer or turn off the controller, and then re-power it without holding the MORE INFO key.
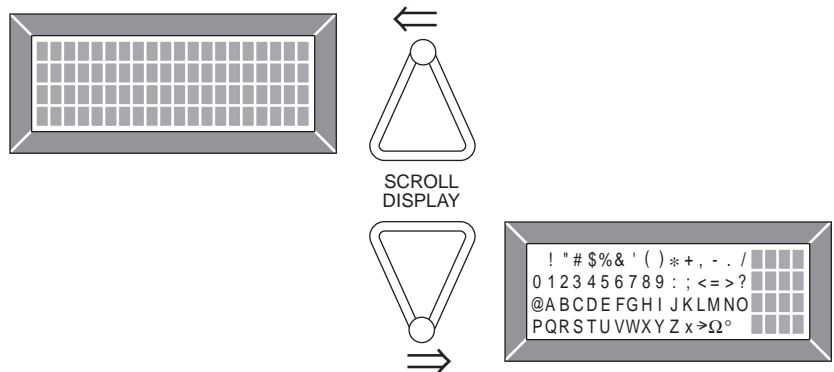
## PROGRAMMER MENUS

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 throttles

† HPD types
> *Type 0:* no HPD
> *Type 1:* HPD on brake input
> *Type 2:* HPD on KSI

‡ SRO types
> *Type 0:* no SRO
> *Type 1:* SRO on brake input
> *Type 2:* SRO on KSI plus brake input plus a direction input
> *Type 3:* SRO on KSI plus brake input plus <u>forward</u> input

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

| | |
|---|---|
| THROTTLE % | Throttle reading, as percent of full |
| BATT VOLTAGE | Battery voltage |
| HEAT SINK °C | Heatsink temperature |
| MAX TEMP °C | Maximum temperature seen * |
| MIN TEMP °C | Minimum temperature seen * |
| BRAKE INPUT | Brake switch: on/off |
| SPEED IN | Mode switch: on (Mode 1) / off (Mode 2) |
| EMR REV INPUT | Emergency reverse switch: on/off |
| FORWARD INPUT | Forward switch: on/off |
| REVERSE INPUT | Reverse switch: on/off |
| MAIN CONTACTOR | Main contactor: on/off |
| FWD CONT | Forward contactor: on/off |
| REV CONT | Reverse contactor: on/off |

\* Maximum/minimum temperatures recorded
   since Diagnostic History was last cleared.

### Special Program Menu

| | |
|---|---|
| R E S E T   A L L   S E T T I N G S | Revert to original settings |
| C O N T   S E T T I N G S ⇒   P R O G | Save controller settings in programmer |
| P R O G   S E T T I N G S ⇒   C O N T | Load programmer settings in controller |
| C L E A R   D I A G   H I S T O R Y | Clear diagnostic history memory |
| C O N T R A S T   A D J U S T M E N T | Adjust display contrast |
| L A N G U A G E   S E L E C T I O N | Select displayed language |
| P R O G R A M M E R   I N F O | Display programmer information |
| C O N T R O L L E R   I N F O | 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.

| | |
|---|---|
| B B   W I R I N G   C H E C K | BB wiring check failed |
| C O N T   D R V R   O C | Contactor driver overcurrent |
| D I R   C O N T   W E L D E D | Direction contactor welded |
| H P D | High-pedal-disable (HPD) activated |
| H W   F A I L S A F E | Hardware failsafe activated |
| L O W   B A T T E R Y   V O L T A G E | Low battery voltage (<16V) |
| M -   S H O R T E D | M- output fault |
| M I S S I N G   C O N T A C T O R | Missing contactor |
| N O   K N O W N   F A U L T S | No known faults |
| O V E R V O L T A G E | Overvoltage (1207: >48V; 1207A: >33V) |
| S R O | Static-return-to-off (SRO) activated |
| T H E R M A L   C U T B A C K | Cutback, due to over/under temp |
| T H R O T T L E   F A U L T 1 | Throttle input fault |
| T H R O T T L E   F A U L T 2 | Throttle low input fault |

# APPENDIX A

## GLOSSARY OF FEATURES AND FUNCTIONS

### Acceleration/deceleration 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-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.

### 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 <u>before</u> the direction contactor drops out.

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

### Brake

The brake must be released (brake input "high") for the controller to operate. This is a safety interlock used on most material handling vehicles.

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

### Contactor drivers and circuits

These controllers can accommodate up to four external contactors: forward, reverse, main, and shunt. 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.*

The shunt winding of a compound motor can be wired directly to the shunt driver, provided that the maximum current does not exceed the driver's current rating.

### 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; the adjustment can be made mechanically (via the appropriate trimpot on top of the 1207 controller) or electronically (via the handheld programmer).

### Current limiting

Curtis PMC 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, as well as on the ground on which the vehicle rides (an important consideration with golf courses and tennis courts, for example).

If you have a MultiMode™ controller, the main current limit, plug current limit, and ramp start current limit 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 main and plug current limits mechanically via the appropriate trimpots located on top of the controller.

In addition, the emergency reverse current limit can be set via the handheld programmer.

### Current multiplication

During acceleration and during reduced speed operation, the Curtis PMC 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 by a conventional controller (in which the battery current and motor current are always equal). The current multiplication feature gives vehicles using Curtis PMC 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.

### Emergency reverse

Emergency reverse is activated when the brake is 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, externally visible on top 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:

> contactor coil open / shorted driver (F/R and shunt contactors)
> contactor driver overcurrent / contactor coil short
> contactor welded
> emergency reverse circuit check
> M- output fault
> memory checks upon start-up
> overvoltage cutoff
> power supply out of range (internal)
> throttle fault
> undervoltage cutback
> watchdog (external and internal)
> 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 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 | BB re-applied <u>or</u> brake cycled |
| HPD | lower throttle to below HPD threshold |
| overvoltage | when battery voltage drops below overvoltage |
| SRO | when proper sequence is followed |
| thermal cutback | when temperature comes within range |
| throttle fault | clears when condition gone |
| undervoltage | when battery voltage rises above undervoltage |

### High-pedal-disable (HPD)

The HPD feature prevents the vehicle from being started while the throttle is applied. The controller can be programmed to have HPD based on either brake input or KSI.

#### Brake-type HPD

To start the vehicle, the controller must receive a brake input (brake released) 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 is released (brake input "high"). 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 is applied while the throttle is above the HPD threshold (25%), HPD is not activated if the brake is then released before the delay time elapses.

#### KSI-type HPD

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

### KSI

KSI (Key Switch Input) provides power to the 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

A Status LED located on top of the controller flashes a fault identification code if a fault is detected by the controller. The fault codes are listed in Table 1. The 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 for faults detected during operation. NOTE: In 1207 models, the Status LED is on the adjustment panel under the sliding protective cover.

**MOSFET**

A MOSFET (<u>M</u>etal <u>O</u>xide <u>S</u>emiconductor <u>F</u>ield <u>E</u>ffect <u>T</u>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. If Mode 1 is not selected, the controller operates by default in Mode 2. When the controller returns to Mode 2 from Mode 1, 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 Mode 2 values.

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 <u>not</u> 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 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 1207/1207A controls the <u>field</u> 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 on the 1207/1207A controls the <u>field</u> 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.

If you have a MultiMode™ controller, the plug current limits 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 plug current limit mechanically via the appropriate trimpot located on top of the controller.

### 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 PMC 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 1207/1207A 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.

**Fig. A-2** *Ramp shape (throttle map) for controller with maximum speed set at 100% and creep speed set at 10%.*
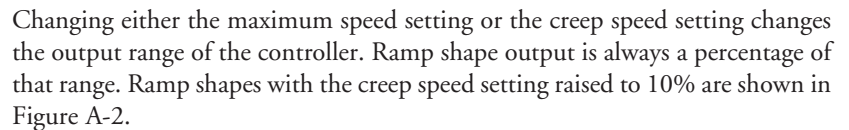
In Figure A-3, the creep speed is kept at 10% and the maximum speed setting dropped to 60%.

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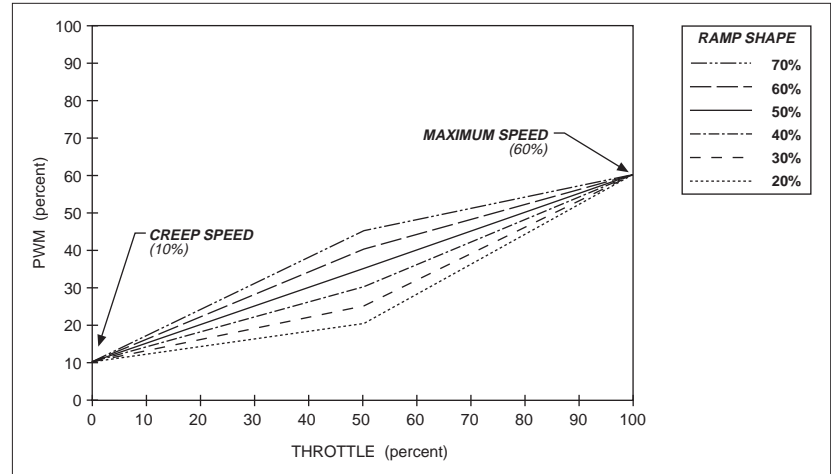


In all cases, the ramp shape number is the PWM output at half throttle, as a percentage of its full range. So, for example, in Figure A-3, a 50% ramp shape gives 35% PWM output at half throttle (halfway between 10% and 60%). A 30% ramp shape gives 25% PWM at half throttle (30% of the range {which is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

### Ramp start

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 <u>for the selected direction only</u>. 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, and
> 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.

When the brake is first released, the ramp start current limit level will be obtained when either direction is selected in plug braking mode. In ramp start mode, either direction selected will allow the ramp start current limit level. This condition remains until the other 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 in plug.

The ramp start current limit is adjustable via the handheld programmer. The Mode 1 and Mode 2 ramp start current limits can be set independently.

### Reset

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

### Sequencing delay

Sequencing delay allows the brake to be cycled within a set time (the sequencing delay), in order to prevent inadvertent activation of HPD or SRO. This feature is useful in applications where the brake 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.

### Shunt field control

The shunt field of a compound motor can be directly controlled by using the shunt winding driver (if the current requirement meets the contactor driver specifications). The shunt is activated while a direction is selected, as long as the controller is not in plug braking mode. A programmable delay is available for the shunt drive. This delays the shunt turn-on until some time after the reversing contactors have shuttled. The delay can be set with the handheld programmer from 0 to 0.5 seconds, where 0 corresponds to no delay.

### Smooth, stepless operation

Like all Curtis PMC 1200 Series controllers, the 1207 and 1207A models allow superior operator control of the vehicle's drive motor speed. The amount of current delivered to the motor is set by varying the "on" time (duty cycle) of the controller's power MOSFET transistors. This technique—pulse width modulation (PWM)—permits silent, stepless operation.

### Speed settings

The maximum speed setting defines the upper-limit speed as a percentage of PWM output at full throttle. If you have a MultiMode™ controller, the maximum speed settings 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 maximum speed mechanically via the trimpot labeled "LOW" on top of the controller.

The maximum creep speed setting is also adjustable via these two methods; see *Creep speed*. The maximum emergency reverse speed is adjustable only via the programmer.

### Static-return-to-off (SRO)

The SRO feature prevents the vehicle from being started when "in gear." SRO checks the sequencing of brake input—or of KSI <u>and</u> brake input—relative to a direction input. The brake 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 input alone (Type "1" in the programming menu); SRO relative to both KSI and brake input (Type "2"); and SRO relative to KSI, brake, and <u>forward</u> inputs (Type "3"). The handheld programmer can be used to set the controller to operate with any of these types of SRO, or with no SRO (SRO Type "0").

If your controller is programmed so that both KSI and brake input are required (SRO Type "2"), the following sequence must be followed to enable the controller: STEP 1, KSI on; STEP 2, brake released (brake input "high"); 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 input by at least 50 msec. Once the controller is operational, turning off either KSI or the brake causes the controller to turn off; re-enabling the controller requires the 3-step sequence.

Similarly, if your controller is programmed so that KSI, brake, and <u>forward</u> inputs are all required (SRO Type "3"), they must be provided in that sequence in order to enable the controller. Note, however, that operation is allowed if a <u>reverse</u> input precedes the brake 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 is applied while direction is selected, SRO is not activated if the brake is then released 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.

### 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 1207 controller. The throttle map parameter is called "ramp shape"; see *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 1207 and 1207A controllers accept a variety of throttle inputs, through various combinations of their four throttle input pins. The most commonly used throttles can all be hooked up directly: 5kΩ–0 and 0–5kΩ 2-wire rheostats, 3-wire pots, 0–5V throttles, 0–10V throttles (1207 only), and the Curtis ET-XXX electronic throttle.

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.

# APPENDIX B

## SPECIFICATIONS

| Table B-1    SPECIFICATIONS: 1207 CONTROLLERS | | |
|---|---|---|
| Nominal input voltage range | 24 – 36 V | |
| Maximum operating voltage | 45 V | |
| Overvoltage point | 48 V | |
| Minimum operating voltage | 16 V  (= undervoltage point) | |
| Electrical isolation to heatsink | 500 V ac  (minimum) | |
| PWM operating frequency | 15 kHz | |
| | | |
| Output current* | 1207-11XX | 1207-21XX |
| | 250 amps for 1 minute | 300 amps for 30 seconds |
| | 200 amps for 2 minutes | 210 amps for 2 minutes |
| | 150 amps for 5 minutes | 160 amps for 5 minutes |
| | 100 amps for 1 hour | 110 amps for 1 hour |
| | | |
| Contactor voltage | = battery voltage | |
| Contactor current (maximum) | 1 amp  (current limit at 2 amps) | |
| Contactor coil spike protection | internal diode to brake; internal diode from brake to KSI | |
| Shunt driver current (maximum) | 2 amps | |
| Shunt driver spike protection | active clamp at 47 V | |
| | | |
| KSI input voltage | 16 – 45 V | |
| KSI input current (typical) | 80 mA without programmer; 130 mA with programmer | |
| Logic input current (typical) | 10 mA at 24 V | |
| Logic input threshold | 8 V | |
| | | |
| Ambient operating temperature range | -25°C to 50°C | |
| Heatsink overtemperature cutback | 85°C | |
| Heatsink undertemperature cutback | -25°C | |
| | | |
| Package | splash resistant | |
| Weight | 1.1 kg   (2.5 lbs) | |
| Dimensions | 122 × 165 × 60 mm   (4.8" × 6.5" × 2.35") | |

* *Output current rating test conditions:*
     1. Controller cover installed
     2. Controller mounted to 230 × 305 × 3.2 mm (9" × 12" × 0.125") aluminum plate heatsink
     3. Airflow at 4.8 km/h (3 mph) perpendicular to bottom of aluminum plate
     4. Duty factor held at 60%
     5. Initial heatsink temperature at 20°C
     6. Ambient temperature at 20°C
     7. Current held at tested rating for 120% of time before thermal cutback

| Table B-2    SPECIFICATIONS: 1207A CONTROLLERS | | |
|---|---|---|
| Nominal input voltage | 24 V | |
| Maximum operating voltage | 30 V | |
| Overvoltage point | 33 V | |
| Minimum operating voltage | 16 V  (= undervoltage point) | |
| Electrical isolation to heatsink | 500 V ac  (minimum) | |
| PWM operating frequency | 15 kHz | |
| | | |
| Output current* | <u>1207A-41XX</u> | <u>1207A-51XX</u> |
| | 250 amps for 1 minute | 300 amps for 30 seconds |
| | 200 amps for 2 minutes | 210 amps for 2 minutes |
| | 150 amps for 5 minutes | 160 amps for 5 minutes |
| | 100 amps for 1 hour | 110 amps for 1 hour |
| | | |
| Contactor voltage | 24 V | |
| Contactor current (maximum) | 1 amp  (current limit at 2 amps) | |
| Contactor coil spike protection | internal diode to brake; internal diode from brake to KSI | |
| Shunt driver current (maximum) | 2 amps | |
| Shunt driver spike protection | active clamp at 47 V | |
| | | |
| KSI input voltage | 16 – 30 V | |
| KSI input current (typical) | 80 mA without programmer; 130 mA with programmer | |
| Logic input current (typical) | 10 mA at 24 V | |
| Logic input threshold | 8 V | |
| | | |
| Ambient operating temperature range | -25°C to 50°C | |
| Heatsink overtemperature cutback | 85°C | |
| Heatsink undertemperature cutback | -25°C | |
| | | |
| Package | splash resistant | |
| Weight | 1.1 kg  (2.5 lbs) | |
| Dimensions | 122 × 165 × 66 mm   (4.8" × 6.5" × 2.6") | |

\* *Output current rating test conditions:*
1. Controller cover installed
2. Controller mounted to 230 × 305 × 3.2 mm (9" × 12" × 0.125") aluminum plate heatsink
3. Airflow at 4.8 km/h (3 mph) perpendicular to bottom of aluminum plate
4. Duty factor held at 60%
5. Initial heatsink temperature at 20°C
6. Ambient temperature at 20°C
7. Current held at tested rating for 120% of time before thermal cutback

## 1207/1207A AUXILIARY PANELS

Auxiliary panels are available for the 1207 and 1207A controllers, consisting of a range of contactor and fuse assemblies mounted on small aluminum panels. These auxiliary panels are designed to let you install your controller in the minimum time, at minimum cost. The panels, manufactured by Curtis Instruments (UK) Ltd., are available through all Curtis offices.

All panels are flush rear mounting. Please contact the Curtis office nearest you for further configuration details.