MANUAL

MODEL **1213**

MOTOR CONTROLLER

Printed on Recycled Paper

CURTIS PMC

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FIGURES

1 OVERVIEW

Curtis PMC Model 1213 electronic DC motor speed controllers are designed for permanent magnet motor applications in sweeper/scrubbers, large mobility aids, personnel carriers, lawn tractors, AGVs, etc. They offer smooth, silent, cost-effective control of motor speed and torque.

The 1213 controller adds extended features and higher power capabilities to Curtis PMC's line of permanent magnet motor controllers. The four-quadrant, full bridge design provides direction control and regenerative braking for down-hill and deceleration control without the need for external reversing contactors. Both wigwag and single-ended throttle options are available.

Fig. 1 *Curtis PMC 1213 motor speed controller.*

[PHOTO]

Like all Curtis PMC 1200 series controllers, the 1213 offers superior operator control of the vehicle's motor drive speed. Other key features include:

✓ Infinitely variable drive and brake control

✓ Full bridge power MOSFET design providing high efficiency (for reduced motor and battery losses) and silent operation

✓ Optional IR compensation (motor speed feedback) to stabilize speed on ramps and over obstacles

✓ Circuitry is protected by precision current-limit setting—rated to 200 amps (24 volt controllers)

More Features ☞

✓ Potentiometer-adjustable acceleration rate, deceleration rate, and maximum reverse speed

✓ Anti-rollback circuitry sets brake delay according to speed and direction—this improves the braking response and minimizes rollback on hills, etc.

✓ High pedal disable feature (HPD) monitors status of throttle during turn-on and prevents operation until throttle has been returned to neutral

✓ Window pot fault circuit shuts off controllers with restrictive range throttles if pot signal goes out of range for any reason; an ISO 7176 compliant pot fault option is also available

✓ Missing brake detector disables controller in the event of an open brake circuit

✓ Current-limited brake driver protects the controller from shorts in the brake or its wiring (24 and 36 volt controllers only)

✓ Undervoltage cutback function protects against low battery voltage, including those caused by external loads

✓ Polarity protected battery input (when main contactor is used)

✓ Neutral throttle (default braking) brakes motor during hands off or power off

✓ Optional brake light driver turns on brake light during deceleration (24 volt controllers only)

✓ Push function allows vehicle to be pushed with key off; pushing too fast causes motor to be shorted, thus limiting push speed

✓ Simple installation with no adjustments required

✓ Solid copper busses for power connections, with polarized Molex connector for control signals

Familiarity with your Curtis PMC controller will help you to install and operate it properly. We encourage you to read this manual carefully. If you have questions, please contact the service center nearest you *(see list on back cover)*.

2 INSTALLATION AND WIRING

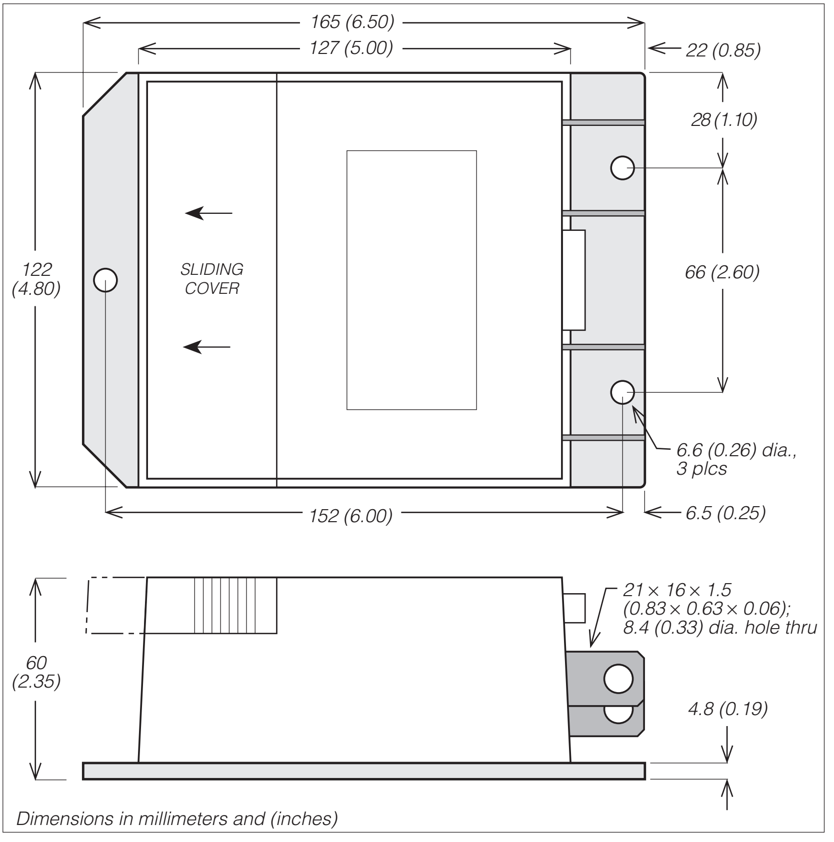
MOUNTING

The 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, dry 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 the user-adjustable potentiometers.

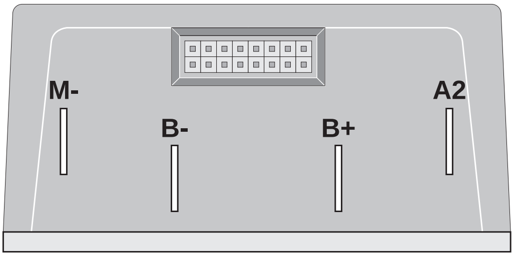
Although not usually necessary, a thermal joint compound can be used to improve heat conduction from the case to the mounting surface.

Fig. 2 *Mounting dimensions for the Curtis PMC 1213 controller.*



CONNECTIONS: High Current

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

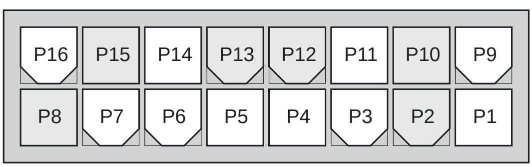


M-	output to motor armature (-)
B-	negative connection to battery
B+	positive connection to battery
A2	output to motor armature (+)

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.

CONNECTIONS: Low Current

An integrated 16-pin low power connector molded into the front of the controller provides the low power logic control connections.



The mating connector is Molex Mini-Fit Jr., part number (5557) 39-01-2165. Contact Molex for information regarding compatible pins for various wire sizes.

P1:	electromechanical brake high
P2:	n/c
P3:	electromechanical brake driver output
P4:	main contactor driver output
P5:	throttle: pot high
P6:	throttle: 3-wire pot wiper or 0–5V
P7:	throttle: pot low
P8:	n/c
P9:	optional brake light driver output
P10:	n/c
P11:	direction input: single-ended throttles
P12:	n/c
P13:	n/c
P14:	inhibit
P15:	n/c
P16:	keyswitch input (KSI)

AUXILIARY HARDWARE

Main Contactor

A main contactor allows the 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 Instruments).*

Electromagnetic Brake

The 1213 controller provides connections for command of the motor's electromagnetic brake. The electromagnetic brake must be connected in order for the controller to implement the anti-roll-forward, anti-rollback, and brake delay functions. If the application does not require an electromagnetic brake, a 10 kΩ, 0.25 W resistor — or equivalent — must be connected between the brake high and brake driver pins (**P1** and **P3**) to allow controller operation.

Direction Switch

Single-ended potentiometer throttles and 0–5V throttles require a direction switch. It can be any type of single-pole, double-throw (SPDT) switch capable of switching the battery voltage at 10 mA.

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 controller, and coil current for the main contactor. The keyswitch must be capable of carrying these currents.

Circuitry Protection Devices

Circuit breakers or fuses are recommended for use in the main power line and keyswitch signal line to protect the controller against external wiring shorts.

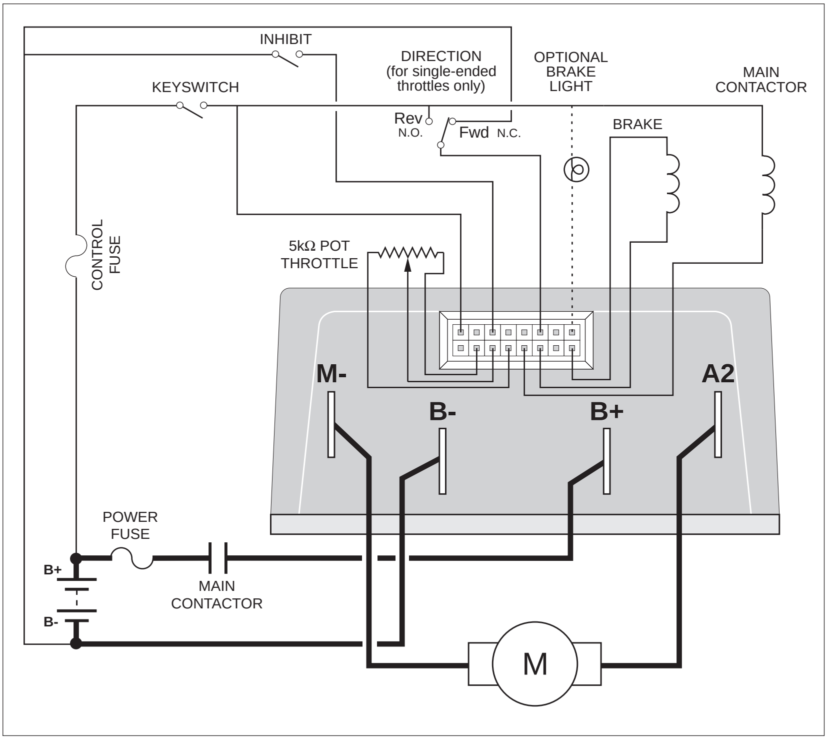
A power diode can be connected across the main contactor and circuit breaker or fuse in the main power line (see Appendix B). The power diode allows regenerative braking to flow back into the battery, providing controlled deceleration in the event the main contactor drops out or the circuit breaker or fuse becomes open. This configuration is called "key-off deceleration." Note that using the power diode eliminates the controller's reverse polarity protection. Using a PTC resistor with the diode allows key-off deceleration without compromising the controller's reverse polarity protection; see Appendix B for details.

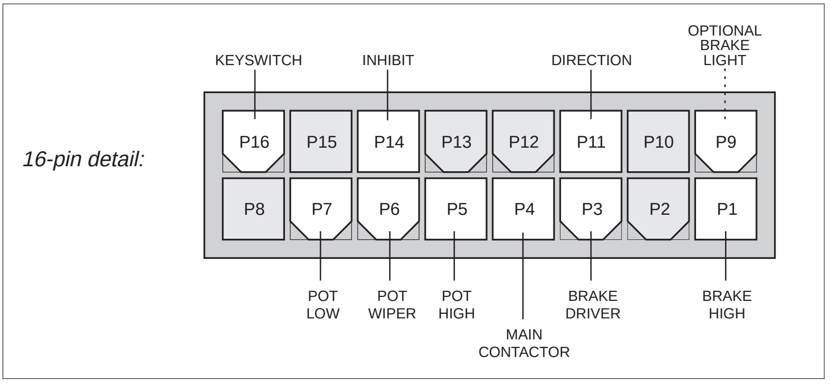
WIRING

Potentiometer Throttle

A complete wiring diagram using a standard 3-wire, single-ended 5kΩ throttle potentiometer is shown in Figure 3. The 1213 controller is available in models

Fig. 3 *Basic wiring diagram for the Curtis PMC 1213 controller, using a potentiometer throttle.*





designed specifically for single-ended or for wigwag potentiometer throttles, as well as for several other types of throttles.

Single-ended potentiometer throttle With the single-ended throttle option, a direction switch must be added to the control circuit. A single-pole, double-throw (SPDT) switch, as shown in Figure 3, is recommended.

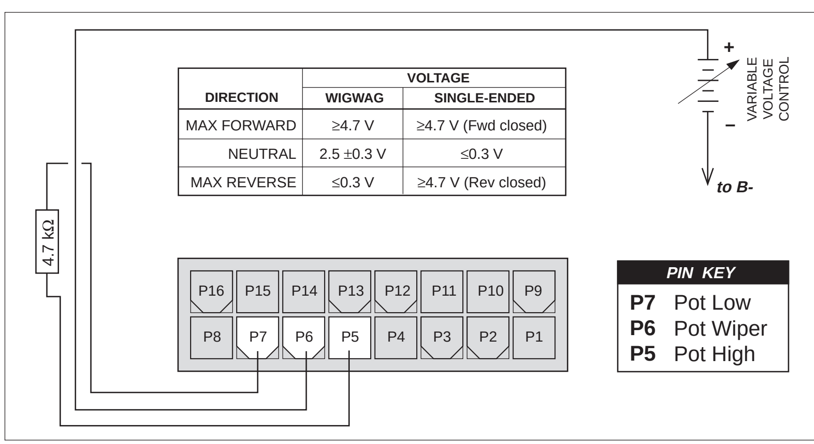
Wigwag potentiometer throttle With the wigwag throttle option, no direction switch is required. The controller automatically selects forward, reverse, or neutral depending on the throttle potentiometer position. The potentiometer provides a neutral window in the center of its travel range, from approximately 2.2 kΩ to 2.8 kΩ. This neutral deadband range allows for variations in the centering of the throttle potentiometer. Throttle inputs greater than 2.8 kΩ select the forward direction, with increasing forward speed corresponding to increasing resistance. Throttle inputs less than 2.2 kΩ select the reverse direction, with increasing reverse speed corresponding to decreasing resistance.

Voltage Throttle

A 0–5V variable voltage may also be used as a throttle input to the 1213, as shown in Figure 4. This 0–5V signal is in reference to B-. When using a voltage input, a 4.7 kΩ resistor must be connected between the Pot High and Pot Low pins (**P5** and **P7**) to simulate a throttle potentiometer and prevent the pot fault circuitry from disabling the controller.

The 1213 is factory-configured for either single-ended or wigwag operation with the 0–5V input. Just as with the potentiometer throttles described above, a direction switch is required with the single-ended voltage throttle but not with the wigwag voltage throttle.

Fig. 4 *Variable voltage throttle input (wigwag configuration shown).*



DIRECTION	VOLTAGE	
	WIGWAG	SINGLE-ENDED
MAX FORWARD	≥4.7 V	≥4.7 V (Fwd closed)
NEUTRAL	2.5 ±0.3 V	≤0.3 V
MAX REVERSE	≤0.3 V	≥4.7 V (Rev closed)

Electronic Throttle

Curtis offers two bi-directional wigwag electronic throttles, manufactured by Hardellet: the ET series and the CH series. They can be used only with 24V and 36 V controllers.

The ET-XXX throttle provides a 0–5V output and forward/reverse relay coil drivers; wiring is shown in Figure 5. The CH-XXX is a complete control head, consisting of an ET-XXX throttle integrated into a molded steel and plastic assembly designed for mounting directly to a tiller stem. For more information about ET-series and CH-series products, contact your Curtis office. The 1213 controller's 0–5V input must be factory-configured specifically for interface with the electronic throttles.

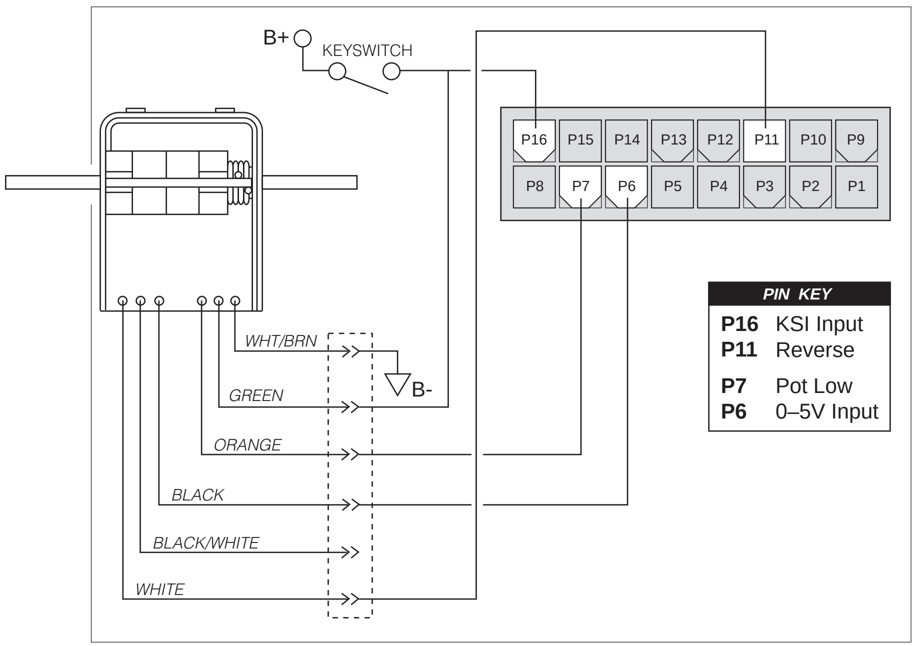


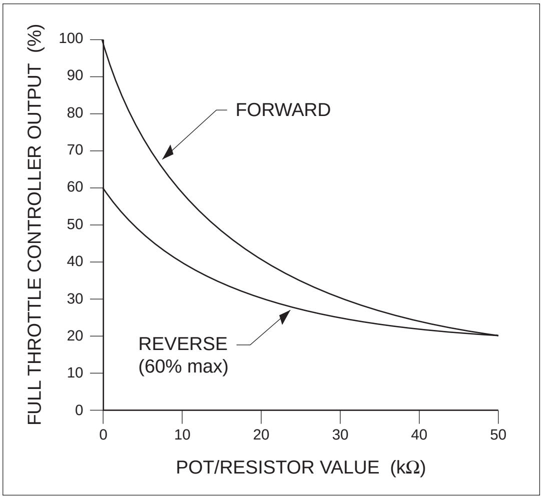
Fig. 5 *Wiring for Curtis ET-XXX electronic throttle.*

Maximum Speed Limiting

If desired, an optional maximum speed potentiometer/resistor in series with the throttle wiper wire can be used to limit maximum speed. This pot/resistor can be used with both 0–5V variable voltage throttles and 5 kΩ potentiometer throttles, and will affect both forward and reverse speed. The 1213 full throttle output vs. the maximum speed pot/resistor value is shown on the graph in Figure 6.

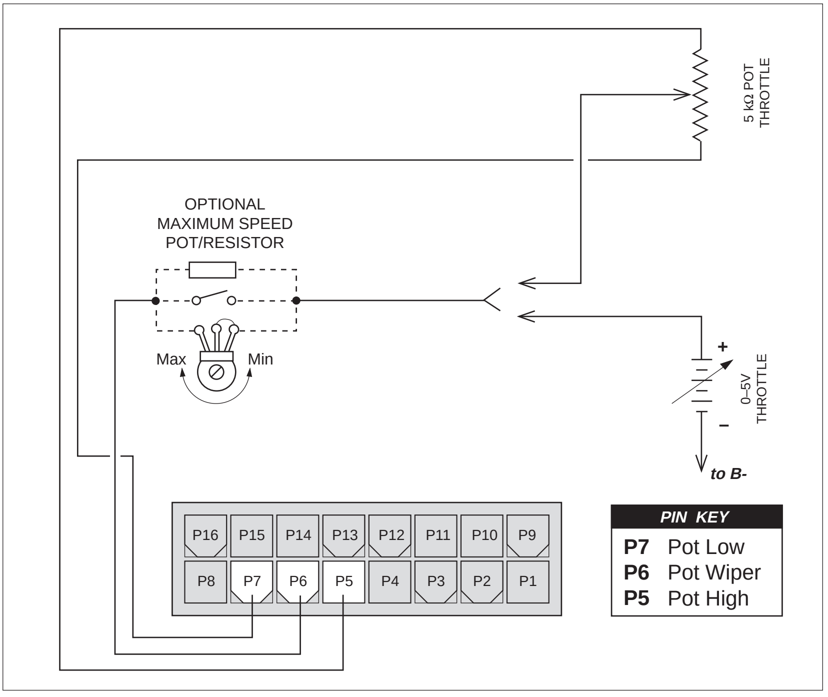
Wiring for implementing the maximum speed pot/resistor is shown in Figure 7. A 50 kΩ potentiometer used for maximum speed limiting allows

Fig. 6 *Maximum speed limiting.*



continuous adjustment of the output range down to 20%. It can be used to experimentally "dial in" the desired vehicle maximum speed and then be replaced by a fixed value resistor.

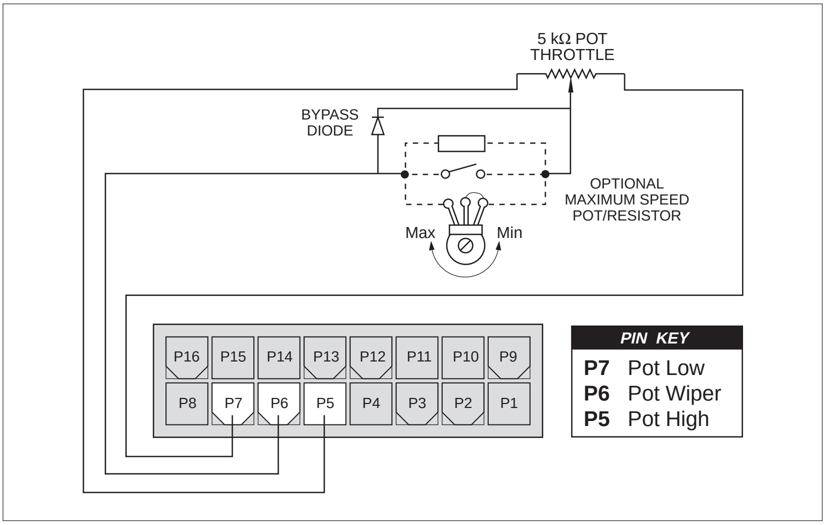
Fig. 7 *Wiring for maximum speed limiting potentiometer/resistor.*



A switch allows the speed limiting pot/resistor to be bypassed if a high speed mode is desired. This switch, which is often called a "rabbit switch," allows faster speeds for long distance, straight-line traveling.

The use of an external pot/resistor to limit speed will also further reduce reverse speed, if reverse speed has been set at less than 100%. To reduce the effect of a maximum speed limiting pot/resistor on reverse speed, a diode can be placed across it as shown in Figure 8.

Fig. 8 *Wiring to reduce effect of maximum speed potentiometer/resistor on reverse speed.*



INSTALLATION CHECKOUT

Carefully complete the following installation checkout procedure before operating the vehicle. If a step does not test correctly, use the troubleshooting guide (Section 7) to identify the problem.

CAUTION

Put the vehicle up on blocks to get the drive wheels off the ground before beginning these tests.

Don't let anyone stand in front of or behind the vehicle during the checkout.

Make sure the keyswitch is off and the vehicle is in neutral before beginning.

Wear safety glasses and use well-insulated tools.

A. Connect the battery. Use a voltmeter to verify that the proper voltage and polarity appears at the battery B+ and B- terminals. If a main contactor is being used, verify that there is no voltage between the B+ and B- terminals of the controller.

B. With the throttle in neutral, turn on the keyswitch. Check the voltage between the controller B+ and B- bus bars. It should be equal to the full battery voltage.

C. If "A" and "B" do not check out, troubleshoot the wiring connections. Do not continue until the trouble is corrected and "A" and "B" check out.

D. With the throttle in neutral, turn on the keyswitch. If the motor runs without the throttle being applied, turn the keyswitch off and recheck the wiring. If the motor does **not** run without the throttle applied, proceed with the checkout. Select a direction and slowly apply the throttle; the motor should now respond.

E. Look to see which direction the wheels are turning. If the wheels are going the wrong way, turn everything off and interchange the motor connections.

F. If you have HPD, check it next. Turn off the keyswitch and direction switch. Apply the throttle, turn the keyswitch on, and then select a direction. The motor should not run. Release the throttle and re-apply it — the motor should now run. If the motor runs before you release the throttle, recheck the wiring.

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

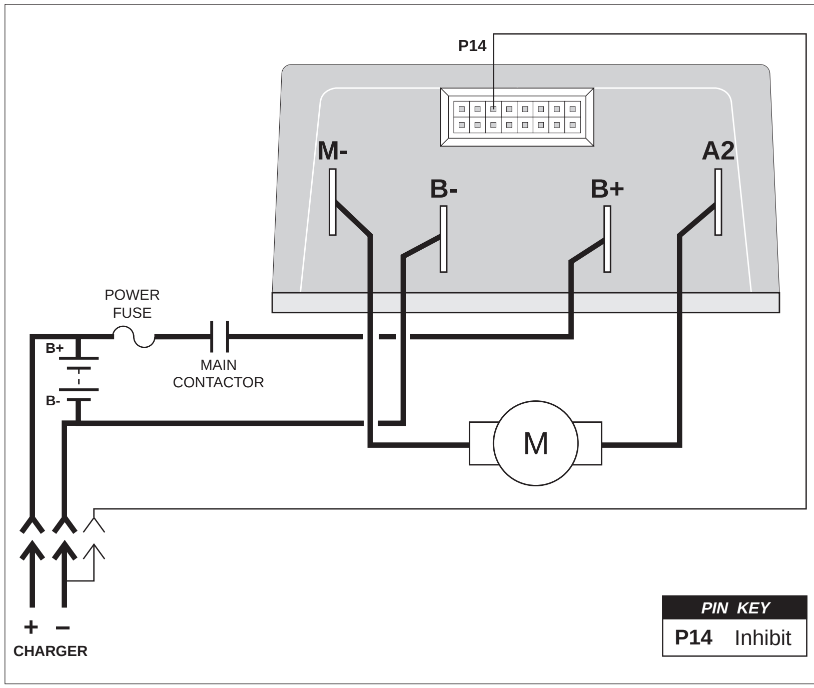
H. Check the regenerative braking by driving forward at moderate speed and releasing the throttle. The vehicle should smoothly brake to a stop.

3 STANDARD FEATURES

Inhibit

All 1213 models offer the inhibit feature. This input is commonly used to inhibit operation during battery charging, as shown in Figure 9. The inhibit input overrides all other controller inputs and is active when low. The input can be left floating when not engaged; it does not need to be pulled high.

Fig. 9 *Wiring to inhibit operation during battery charging.*



Brake Output / Anti-Roll-Forward, Anti-Rollback

The electromagnetic brake output immediately applies battery power (rated output 1 amp) to the brake when going from neutral to forward or reverse. Brake power is removed (i.e., the brake is applied), with a delay, when the throttle is returned to neutral. This is the anti-roll-forward feature. The length of the delay is a function of the amount of throttle applied. That is, the brake delay will be shorter when the throttle has been slow and longer when the throttle has been fast.

The brake is applied without delay when the controller senses a change of direction after returning to neutral; this is the anti-rollback feature. For example, if the vehicle is moving up a ramp and the throttle is released, the brake will be applied as soon as the vehicle begins to roll back.

The electromagnetic brake driver is short circuit protected against inadvertent shorts in the brake coil or wiring. Likewise, the fault logic protects against "missing brake" conditions by disabling the controller's output. Normal controller operation will resume when the fault is repaired.

Temperature Compensation

The 1213 controller provides internal temperature compensation to prevent controller damage in high temperature operating conditions. This feature compensates for temperature induced component variations up to 85°C (185°F) in order to maintain specified operating parameter limits. Above 85°C (185°F), the main current limit is gradually cut back until it is reduced to zero at 95°C (203°F).

To prevent the loss of braking effort, regenerative current limit is not cut back in overtemperature conditions.

Push Too Fast

The 1213 will allow a vehicle to be pushed without the controller being powered. This is convenient when, for example, a vehicle without batteries needs to be moved. It is not necessary to disconnect the controller from the motor; however, the electromagnetic brake must be released. If the vehicle is pushed too fast, indicating a runaway or other abnormal condition, the controller will automatically turn on and short the motor, limiting the vehicle speed to a slow walk.

4

OEM-SPECIFIED PARAMETERS

The following items specify various operating characteristics of the 1213 controller that can be defined by the OEM. These parameters should be determined by working with Curtis PMC application engineers.

Anti-Roll-Forward Time Delay

The anti-roll-forward function varies the time delay of the electromagnetic brake to minimize the distance the vehicle can roll. The time delay is dependent on the throttle position just prior to its return to neutral. Therefore, the brake delay time is shorter for slow vehicle speeds and longer at higher speeds. The specified brake delay time occurs when the throttle is returned to neutral from 100% output, and is the maximum delay time available. If the throttle is returned to neutral from less than full throttle, the brake delay is proportionately shorter. The standard specified brake delay is 3 seconds; a different delay time can be factory set if so desired.

IR Compensation *[OPTIONAL FEATURE]*

The IR compensation feature provides a level of constant speed control when the vehicle negotiates inclines and declines. It accomplishes this by compensating for voltage losses within the motor that do not provide a driving force to the vehicle wheels.

IR compensation is dependent on the characteristics of the specific motor used in each application. If this feature is desired, the manufacturer must provide the internal motor resistance or motor terminal resistance value to Curtis PMC application engineers, who will then define a unique controller for that particular motor. IR compensation in this controller will be set at the factory to match the motor. A dedicated model number will be assigned to the controller to facilitate future orders for controllers to be used with that motor.

If the optional IR compensation feature is selected, the manufacturer has a further choice: the IR compensation can be potentiometer adjustable or it can be fixed at the factory setting. There are some concerns regarding adjustable IR compensation. These concerns are presented in Section 5, where the IR compensation adjustment effects are discussed.

High Pedal Disable (HPD) *[OPTIONAL FEATURE]*

High Pedal Disable (HPD) is an optional safety feature to prevent inadvertent vehicle operation. If the keyswitch is turned on with greater than ≈25% throttle applied, the controller will be inhibited until the throttle is returned to neutral.

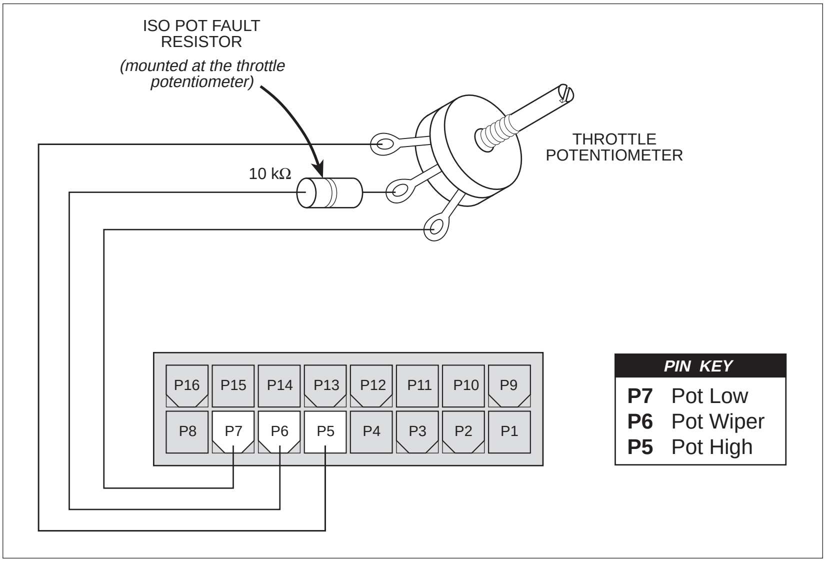
At this point, throttle can be re-applied and the vehicle will operate normally. The HPD feature operates with either potentiometer or voltage throttles. The 1213 controller is available with and without the HPD feature.

ISO Pot Fault *[OPTIONAL FEATURE]*

The 1213 controller is available with a throttle option that meets International Standard ISO 7176 requirements for control systems. This option detects any combination of open or shorted throttle wires and shuts down the controller. The standard pot fault circuitry protects against an open condition in the throttle wires.

The ISO pot fault option requires an external 10 kΩ resistor, in addition to specifying the ISO pot fault option for the controller. This resistor **must** be added at the throttle control source in the wiper lead in order to meet the ISO 7176 requirements. (NOTE: Placing the resistor in the wiring harness or at the controller input **will not** meet the ISO 7176 requirements.) The proper wiring configuration for the ISO pot fault option is shown in Figure 10.

Fig. 10 *Wiring for ISO pot fault option.*



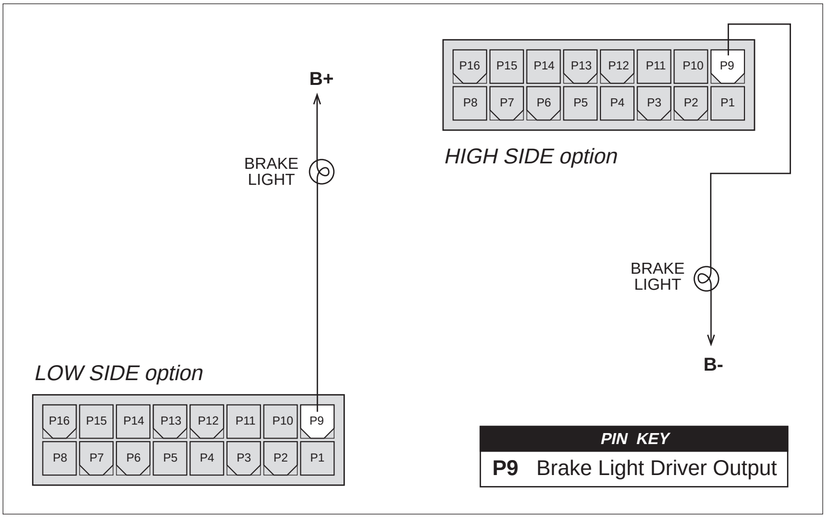
Brake Light Driver *[OPTIONAL FEATURE; 24V models only]*

The 1213 is also available with a brake light driver option on 24V models. This circuitry is capable of powering a brake light during vehicle deceleration and for a timed period after the electromagnetic brake is engaged. The brake light remains on for 1 second after the electromagnetic brake engages.

The standard brake light driver option pulls the brake light to ground (low side) with the light hardwired to B+. Contact Curtis PMC for availability of models that pull the brake light to B+ (high side) and hardwire the light to ground. A maximum current of 2.0 amperes can be drawn through the brake light driver circuit in either the high side or low side configuration. A fuse is recommended in series with the brake light to prevent damage to the brake light driver circuitry due to wiring or brake light faults.

The two brake light wiring options are shown in Figure 11.

Fig. 11 *Wiring for optional brake light.*



Overvoltage Protection

The 1213 controller contains circuitry to protect itself from operating in potentially damaging overvoltage conditions. These conditions may exist if the batteries become disconnected or any circuit protection devices open. Two overvoltage protection options are available: short and coast.

With the overvoltage <u>short</u> option, the controller shorts the motor when it senses an overvoltage condition. This brakes the motor to a stop so that the vehicle can no longer travel while the overvoltage condition exists. Because the motor is actually shorted, the braking effect may be significant. The overvoltage short option is recommended for manned vehicles because the controller cannot influence the vehicle's travel while freewheeling.

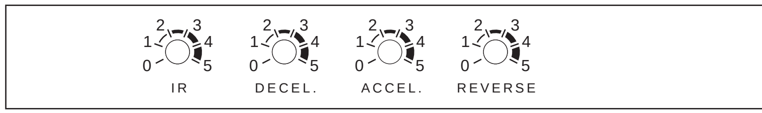
The overvoltage <u>coast</u> option allows the vehicle to coast or "freewheel" if there is an overvoltage condition.

The 1213 overvoltage threshold is set at 42 volts for 24V controllers, 48 volts for 36V controllers, and 64 volts for 48V controllers.

5

OEM ADJUSTMENTS

The 1213 provides manual adjustment potentiometers to allow the OEM to set acceleration/deceleration rates and maximum reverse speed. There may also be a manual adjustment potentiometer for the optional IR compensation feature. These potentiometers are located on the adjustment panel under the sliding protective cover on top of the controller:



The pot's relative position indicates the approximate value over the allowable range. For example, the reverse speed adjustment range is 40% to 100%, where position "0" corresponds to 40% and position "5" to 100%. Setting the pot at position "2" corresponds to approximately 64% reverse speed.

Acceleration/Deceleration Rate

The acceleration rate is the time required for the controller to increase from 0% to 100% duty factor when full throttle is applied. The deceleration rate is the time required for the controller to decrease from 100% to 0% duty factor when the throttle is returned to neutral from the full on position. A symmetrical acceleration/deceleration rate has the same rate—or time—for both acceleration and deceleration. An asymmetrical rate typically has a shorter time for deceleration than for acceleration.

The acceleration and deceleration rate adjustment range is 0.5 to 3 seconds. The actual time for a particular vehicle to accelerate or decelerate is a function of the vehicle load, gearing, and vehicle dynamics. The deceleration pot must be adjusted so as to guarantee that the vehicle will stop within the maximum distance specified by applicable requirements.

Turning the adjustment pots clockwise makes the vehicle accelerate or decelerate faster.

Reduced Reverse Speed (% of maximum speed)

Reduced reverse speed is a safety feature designed to prevent full speed in reverse where vehicle control may be restricted. 60% maximum reverse speed has been determined to be a good compromise between performance and control in reverse. The reverse speed adjustment range is from 40% to 100%.

Turning the adjustment pot counterclockwise reduces the maximum allowed reverse speed.

IR Compensation

The IR compensation adjustment pot allows the manufacturer to fine-tune the "feel" of the IR compensation over a limited range. Note that even if the adjustment pot is specified, the motor resistance must still be provided.

Turning the adjustment pot counterclockwise reduces the effect of the IR compensation, and turning it clockwise increases the effect. If the vehicle displays a tendency to speed up when going uphill or slow down when going downhill, the controller is overcompensated and the IR adjustment pot should be turned counterclockwise. Surging is another indication that the IR compensation is set too high, as is jerky response to throttle settings. The IR compensation is adjusted to the optimum setting at the factory, based on the motor resistance value provided by the manufacturer. It should not require additional adjustment unless there are wide variations in motor resistance or special requirements on the compensation characteristics for a particular application.

The IR compensation feature can cause undesirable operating characteristics if improperly adjusted. Because IR compensation is a type of feedback system, misadjustment can cause unstable operation. In extreme cases, this could lead to harsh or jerky throttle response. Adjustment of the IR compensation pot should only be performed by experienced technicians. Precautions should be taken by the manufacturer to ensure there is no operator access to the IR compensation adjustment potentiometer; this can be accomplished by enclosing the entire controller in an inaccessible case or by covering the pot opening with a "seal" label after installation and adjustment.

6 MAINTENANCE

There are no user-serviceable parts inside the Curtis PMC 1213 controller. **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.

SAFETY

CAUTION

The 1213 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 1213 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 all 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.

7 TROUBLESHOOTING AND BENCH TESTING

Some behaviors that may seem to suggest controller malfunction do not, in fact, indicate a problem but rather are typical of normal operation. Before undertaking the diagnostic tests, check to see whether your problem is addressed in the first section, "Operational Notes."

The diagnostic tests are designed to enable you to determine whether the trouble is in the controller or in some other part of the motor control circuitry. ***The controllers themselves are not field serviceable; contact your local Curtis PMC service center if the problem is in the controller.*** *The diagnostic section provides enough detail to enable you to track circuitry problems to their source and repair them.*

Finally, the bench tests will allow you to confirm controller operation in a simple, low-power test configuration. Bench testing is primarily intended for checking out a number of controllers on a regular basis.

OPERATIONAL NOTES

Sluggish vehicle behavior

Loss of power will be noticeable when the batteries become overly discharged. This is a normal response to low battery voltage. Curtis PMC 1213 controllers are designed to protect against damage caused by low batteries. On 24 volt controllers, for example, power to the motor is cut back when the voltage goes below 16 volts. Refer to the specifications (Appendix A) for other models.

Hot controller

If the controller gets hot, it does not necessarily indicate a serious problem. Curtis PMC 1213 controllers protect themselves by reducing power to the motor if their internal temperature exceeds 85°C (185°F). Power output will be reduced for as long as the overheat condition remains, and full power will return when the unit cools.

In typical applications, overheating will rarely be a problem. However, operation with oversized motors and vehicle overloading may cause overheating, particularly if the controller is mounted so that heat cannot be conducted away from its case or if other heat-generating devices are nearby. If thermal cutback occurs often during normal operation, the controller is probably undersized and should be replaced with a higher current model if one exists.

IN-VEHICLE DIAGNOSTIC TESTS

These tests require a general purpose volt ohmmeter; you can use either a conventional “V-O-M” or an inexpensive digital voltmeter.

The troubleshooting chart (Figure 12) serves as a guide to the procedures that follow. Before starting these tests, refer to the appropriate wiring diagrams and make sure your controller is hooked up properly.

CAUTION

Working on electric vehicles is potentially dangerous. Protect yourself while performing the diagnostic tests:

Jack up the vehicle to get the drive wheels off the ground

Open the battery circuit before working on the motor control circuit

Wear safety glasses

Use properly insulated tools.

Fig. 12 *Guide to troubleshooting procedures.*

[To use this guide, refer to the specified **PROCEDURES** .]

TEST 1 Check for power to the controller

Check voltage at CONTROLLER B- and BATTERY B+ terminals. **1-A, B, C**

It should read full voltage for system.

if NO → Bad, discharged, or miswired batteries, or corroded connections. **1-C**

TEST 2 Check for main contactor operation and KSI

Check voltage at contactor coil and at KSI terminal. **2-A, B, C**

Contactor coil and KSI should read full rated voltage.

if NO → Trace flow to locate problem. **2-D**

if YES ↓

Check voltage across contactor power terminals. **2-D**

There should be no measurable voltage drop.

if YES → If voltage drop occurs, contactor is defective. **2-E**

TEST 3 Check the inhibit input (if applicable)

Check voltage between B- and the inhibit input pin (**P14**). **3-A**

Voltage should be greater than 1 volt.

if NO → Trace wiring to locate the short. **3-B**

TEST 4 Check electromagnectic brake connections

Check voltage at pins **P1** and **P3** with respect to B-. **4-A**

Both pins should be getting full battery voltage.

if NO → If **P1** is not getting full voltage, controller is defective.

If **P1** reads full voltage but **P3** is shorted to B-, remove connector and check the resistance between **P3** and B-.

If the resistance between **P3** and B- is less than 1 MΩ, the controller is defective. If it is greater than 1 MΩ, check the brake coil wiring. **4-B, C, D**

if YES ↓

Check the voltage at **P3** while rotating the throttle from neutral to a direction. **4-E**

Voltage should drop less than 1 volt. If the drop is greater than 1 volt, the controller is defective.

Fig. 12, *continued*

TEST 5 Check throttle circuitry (wigwag 5kΩ throttles)

Check resistance between pins **P6–P7**, **P6–P5**, and **P5–P7** while applying throttle. **5-A, B, C**

*Resistance between **P6** and **P7** should be 0–300 ohms (full reverse), 2200–2800 (neutral), and 4700–5500 (full forward).*

*Resistance between **P6** and **P5** should be 4700–5500 ohms (full reverse), 2200–2800 (neutral), and 0–300 (full forward).*

*Resistance between **P5** and **P7** should be 4250–6000 ohms, regardless of throttle position.*

if NO → Defective throttle pot, broken wires to potbox, or improper mechanical operation. **5-D**

if YES ↓

Check power to the motor. **5-E**

If throttle assembly is working properly and the resistances are OK, there should be power to the motor.

if NO → Controller or wiring is defective. **5-E**

TEST 6 Check for controller output

Check voltage output (B+ to M-) while applying throttle. **6-A, B, C**

Voltage should be zero with no throttle applied, and full battery voltage with throttle full on.

if NO → Controller is defective. **6-C**

if YES ↓

Check current in the controller's M- lead while applying throttle. **6-D, E**

Current should be high, and motor should turn.

if NO → If no current, look for open circuit. If current is high but motor won't turn, check motor, wiring & plug diode. **6-F, G, H, I**

CAUTION

Jack up vehicle

Open the battery circuit

Wear safety glasses

Use insulated tools

TEST 1 Check for power to the controller

1-A Leave the keyswitch off for these tests.

1-B Verify that battery (-) connects to the B- terminal of the controller. Connect voltmeter (-) lead to this point.

1-C Connect voltmeter (+) to the battery side of the main contactor. Check for full battery voltage. If it is not there, the trouble is in the battery pack, the cables to it, or the power fuse.

TEST 2 Check for main contactor operation and KSI

2-A Turn the key on and place the forward/reverse switch in forward or reverse. This should cause the main contactor to operate with an audible click.

2-B Connect the voltmeter across the contactor coil terminals. You should see full battery voltage.

2-C The controller KSI terminal should also be getting full battery voltage. Verify this by connecting the voltmeter (-) to the controller's B- terminal, and the voltmeter (+) to the controller's KSI terminal.

2-D If the contactor coil and KSI terminal are not getting voltage, that's the problem. Use the voltmeter to find out where it is not getting through. Connect the voltmeter (-) to the controller's B- terminal and check the following points with the voltmeter (+) lead to trace the flow:

1. First, check both sides of the control wiring fuse.
2. Check both sides of the keyswitch.
3. Finally, check the contactor coil and controller KSI.

2-E If the contactor coil and KSI are getting voltage, make sure the contactor is really working by connecting the voltmeter across its contacts (the big terminals). There should be no measurable voltage drop. If you see a drop, the contactor is defective.

TEST 3 Check the inhibit input

3-A The controller's inhibit input will disable the controller if it is less than 1 volt. With the keyswitch turned on and the inhibit switch turned off, measure the voltage between B- and the inhibit input pin (**P14**).

3-B If this voltage is less than 1 volt, the controller is being disabled by the input. Check the wiring to determine where the short is occurring.

TEST 4 Check the electromagnetic brake connections

The controller requires that a load be connected to the brake input pins (**P1** and **P3**). If an electromagnetic brake is not used, a 10 kΩ resistor can be substituted. In these procedures, we assume an electromagnetic brake is used.

4-A With the keyswitch on and full battery voltage at the controller's B+ terminal, measure the voltage at pins **P1** and **P3** with respect to B-. Both pins should be getting full battery voltage. If they are, proceed to Step 4-E.

4-B If pin **P1** does not read full battery voltage, there is something wrong with the controller.

4-C If pin **P1** reads full battery voltage but pin **P3** does not, there may be something wrong with the brake wiring. Check the brake coil and connections to ensure continuity.

4-D If the voltage between pin **P3** and B- is zero, the brake driver may be shorted. Remove the Molex connector and check the resistance between pin **P3** at the controller and B-. If **P3** is shorted to B-, the brake driver has shorted and the controller is defective. If the ohmmeter reads greater than 1 MΩ, the driver is good. Check the brake wiring for shorts to B-.

4-E If pins **P1** and **P3** are both reading full battery voltage in Step 4-A, select a direction and rotate the throttle out of the neutral range. The voltage at **P3** should drop to less than 1 volt. If it does not, the controller's brake driver is faulty and the controller is defective.

TEST 5 Check the throttle circuitry

The following procedure applies to the standard wigwag throttle input configuration: a 3-wire, 0–5kΩ pot in which the wiper resistance from pot high and pot low is 2.5 kΩ when in neutral. If your installation uses a controller with a throttle input other than the wigwag 0–5kΩ pot, find out what its range is and use a procedure comparable to the one below to make sure your throttle is working correctly.

5-A Disconnect the 16-pin Molex connector from the controller. Connect an ohmmeter to pins **P6** and **P7** and measure the resistance as you rotate the throttle from neutral to full reverse and full forward. The resistances should be within these ranges:

	RESISTANCE (in ohms)
Full Reverse	0 – 300
Neutral	2200 – 2800
Full Forward	4700 – 5500

5-B Connect an ohmmeter to pins **P6** and **P5** and measure the resistance as you rotate the throttle from neutral to full reverse and full forward. The resistances should be within these ranges:

	RESISTANCE (in ohms)
Full Reverse	4700 – 5500
Neutral	2200 – 2800
Full Forward	0 – 300

5-C Measure the resistance between pins **P5** and **P7**. Regardless of throttle position, it should be between 4.25 kΩ and 6.0 kΩ.

5-D If the resistances measured in Steps 5-A, 5-B, or 5-C are out of range, the pot itself is faulty, the wires to the pot are broken, or the throttle and its linkage are not moving the pot through its proper travel. Verify that the wires are intact and that the throttle linkage is performing properly.

5-E If the throttle assembly is working properly and the resistances are within the specified ranges but there is still no power to the motor, either the controller is defective or there is a problem somewhere else within the system.

CAUTION

Jack up vehicle

Open the battery circuit

Wear safety glasses

Use insulated tools

TEST 6 Check for controller output

6-A The first step is to measure the output drive voltage to the motor between the controller's M- and A2 terminals.

6-B Connect the voltmeter (+) lead to the controller's A2 terminal. Connect the voltmeter (-) lead to the controller's M- terminal.

6-C Turn on the keyswitch with the throttle in neutral, and then select forward and watch the voltmeter as you increase the throttle. The voltmeter should read zero (or close to zero) before you apply throttle, and should read full battery voltage with the throttle fully applied. If it does not, the controller is defective and must be replaced.

6-D The next step is to measure the current in the controller's M- lead. If you have a means of measuring this high dc current, such as a shunt/meter setup or a clamp-on dc ammeter, use it. If not, we recommend that you buy an inexpensive ammeter of the type that is simply held against the wire being tested. These are readily available at auto parts stores, and their accuracy is adequate for this test.

6-E Turn on the keyswitch with the throttle in neutral, and then select forward and watch the ammeter while applying the throttle.

6-F If you see no current flowing in the M- lead, the problem is an open circuit in the motor or the wiring between the motor and the controller. Check the motor for opens.

6-G If you do see a high current flowing in the M- lead, but the motor does not turn, the problem is a short in the motor circuit or a miswired motor.

BENCH TESTING

First, before starting any bench testing, pick up the controller and shake it. If anything rattles around inside, the unit should be returned. See warranty (inside back cover) for instructions.

CAUTION

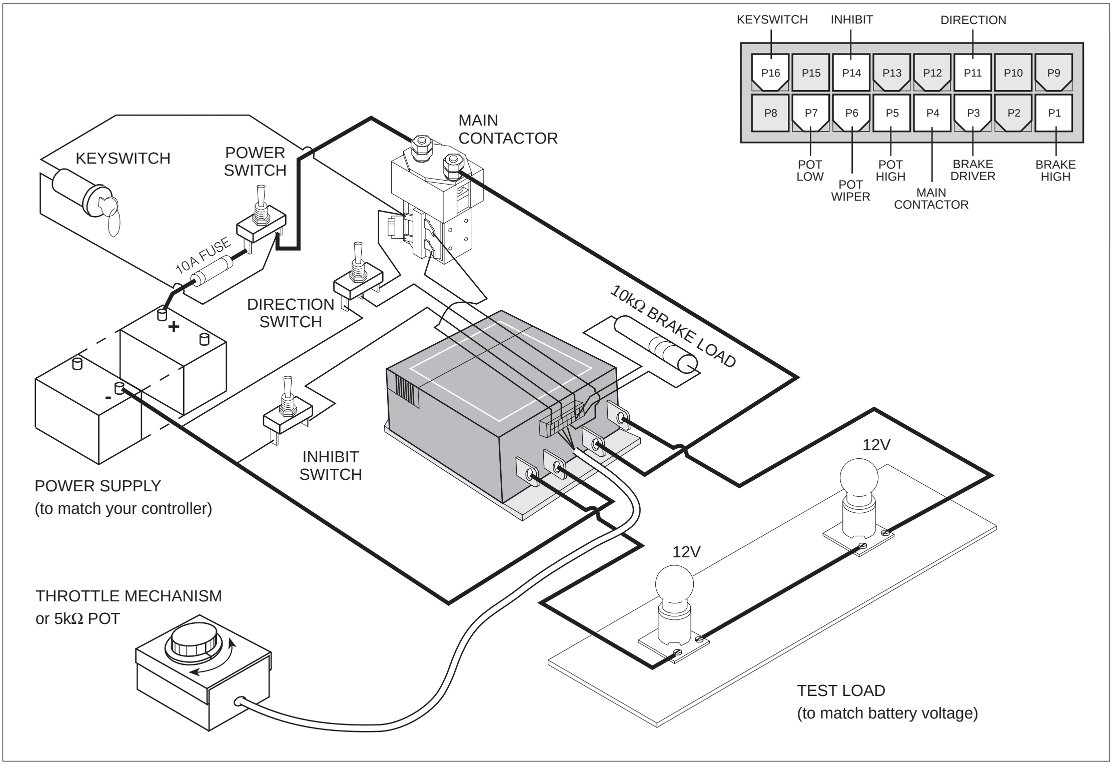
Protect yourself during bench testing. Wear safety glasses and use insulated tools.

Equipment Needed

The simple setup shown in Figure 13 is required for testing these controllers on the bench. You will need:

1. a POWER SUPPLY with a voltage equal to the rating of the controller you want to test. You can use either a string of batteries or a

Fig. 13 *Setup for bench testing.*



regulated line-operated power supply. Because only low power tests will be described, a 10 amp fuse should be wired in series with the batteries to protect both operator and controller against accidental shorts. A battery charger alone should not be used as a power supply, because without a battery load its output voltage may exceed the rating of the controller.

2. a THROTTLE. This can be either a throttle mechanism from the vehicle or a standard 5 kΩ potentiometer. For controllers with other input options, use whatever kind of throttle is used on the vehicle.

3. a POWER SWITCH to disconnect all power from the test setup.

4. a MAIN CONTACTOR with a KEYSWITCH to turn it on and off. Wiring the main contactor coil to the controller is optional.

5. a DIRECTION SWITCH, if required.

6. an INHIBIT SWITCH, if your application uses this feature.

7. a TEST LOAD consisting of incandescent light bulbs wired in series to get the same voltage as your power supply. (For example, with a 24 volt battery, use two 12 volt bulbs.)

8. a BRAKE LOAD to simulate the electromagnetic brake. A 10 kΩ resistor will suffice.

9. a general purpose VOLT OHMMETER or DIGITAL VOLTMETER.

Bench Test Procedure

A. Hook up the controller as shown. Connect the voltmeter leads to the controller's B+ and B- terminals.

B. Turn on the power switch and then the keyswitch. The main contactor should turn on and the voltage at the controller's B+ and B- terminals should equal the full battery voltage. Select the forward direction and move the throttle through its range. The lamps should go smoothly from full off to full on with the pot.

C. Select the reverse direction and move the throttle through its range. If reverse speed is limited by your controller, the lights will not shine as brightly at full reverse as at full forward.

D. If the controller has HPD, test this feature as follows:

1. Turn off the keyswitch.
2. Move the throttle input about halfway in either direction.
3. Turn the keyswitch switch on. Verify that the lamps do not come on until the throttle is returned to neutral and then reapplied.

E. Test the controller's throttle fault protection feature by disconnecting one of the throttle's connections to the controller's throttle input while the lamps are on (with the throttle applied). The lamps should turn off. With the throttle still applied, reconnect the wire. The lamps should smoothly increase in brightness to their previous level.

F. If your application uses the inhibit feature, test it as follows:

1. Turn on the inhibit switch so that the inhibit pin (**P14**) is pulled to ground.
2. Apply throttle in either direction. The lamps should not light.
3. Turn off the inhibit switch and apply the throttle in either direction. The lamps should now light.

G. Check the electromagnetic brake driver by monitoring the voltage at pin **P3** with respect to B-. The voltage should be at full battery voltage when the throttle is in the neutral position. It should pull down to less than 1 volt when the throttle is rotated out of the neutral range.

H. If your application uses a brake light driver, test it as follows:

1. Connect a brake light or a 10 kΩ resistor, using the option you have selected for your application from the two shown in Figure 11.
2. Turn on the keyswitch and apply full throttle in either direction. Once the test load lamps are fully lit, return the throttle to neutral.
3. If a brake light is being used, it should light as the other load lamps begin to dim and remain lit for a short time after the other lamps are fully off.

4. If a resistive load is used, measure the voltage between pin **P9** and B- as the lamps dim. The voltage should be approximately 1 volt if the controller is specified to have the low side brake light driver option.

8 GLOSSARY: FEATURES AND FUNCTIONS

Acceleration rate

The acceleration rate is the time required for the controller to increase from 0% to 100% duty factor. The acceleration and deceleration rates are adjustable via trimpots on the adjustment panel; see Section 5 for adjustment instructions. The shape of the acceleration/deceleration curves is controlled by the dynamic throttle response, which is linear.

Anti-rollback

The anti-rollback feature prevents a vehicle from rolling backwards when the throttle is released on a hill. It overrides the brake delay and engages the electromagnetic brake as soon as the vehicle begins to roll back down the hill, thus preventing undesired and uncontrolled downhill travel.

Anti-roll-forward

The anti-roll-forward feature modifies the brake delay time based on the throttle position just before the throttle is returned to neutral. It reduces the brake delay time when the vehicle is stopping from a low speed so that the vehicle will not coast after the controller output stops.

Brake delay time

The brake delay time specifies when the controller engages the electromagnetic brake after the throttle is returned to neutral. This time delay, specified for a throttle change from 100% to 0% duty factor, is set to be long enough to allow full deceleration without jerking the vehicle to a stop yet short enough so that the brake is engaged immediately after the vehicle comes to a stop.

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.

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 and service life are improved. 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).

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.

Environmental protection

The 1213 controller is housed in a rugged ABS plastic case that provides limited environmental protection. The controller must be kept clean and dry to ensure long life. Additional protection is required if the controller is mounted in a location exposed to dirt or water splash.

Full bridge

The 1213 controller uses a full bridge design to accomplish power switching and direction selection. This eliminates the need for external or on-board forward/reverse contactors. The result is a higher reliability product that is simpler to install.

High pedal disable (HPD) *[OPTIONAL FEATURE]*

By preventing the vehicle from being turned on with the throttle applied, HPD ensures the vehicle starts smoothly and safely. If the operator attempts to start the vehicle when the throttle is already applied, the controller (and the vehicle) will remain off. For the vehicle to start, the controller must receive an input to KSI before receiving a throttle input. In addition to providing routine smooth starts, HPD also protects against accidental sudden starts if problems in the throttle linkage (e.g., bent parts, broken return spring) give a throttle input signal to the controller even with the throttle released.

The 1213 controller is available either with or without the HPD feature.

IR compensation *[OPTIONAL FEATURE]*

IR compensation is a technique used to provide near-constant speed control of a vehicle. Internal circuitry monitors the current in the motor relative to throttle position and adjusts the controller output to maintain a constant speed over varying terrain. Refer to Section 4 for a detailed discussion of this feature.

Key-off deceleration *[OPTIONAL FEATURE]*

The key-off deceleration feature provides smooth braking if the main contactor, circuit breaker, or power fuse becomes open for any reason. This feature is implemented by adding a diode from the controller B+ to the battery B+ as shown in Figure B-1. This feature prevents uncontrolled vehicle deceleration or coasting if any of the circuitry protection devices open. However, it also eliminates the inherent reverse polarity protection provided by the controller. Refer to Appendix B for a detailed discussion of this feature.

KSI

KSI (Key Switch Input) provides power to the controller's logic board. For non-vehicle applications (such as conveyor belts), KSI may simply be tied to B+.

Main contactor driver

The 1213 controller contains circuitry designed to drive the main contactor coil. This circuitry provides short circuit protection for the main contactor coil driver if the contactor coil is shorted. It is not necessary for the main contactor coil to be wired through the controller, but the short circuit protection is lost if it is not.

MOSFET

A MOSFET (Metal Oxide Semiconductor Field Effect Transistor) is a type of transistor characterized by its fast switching speeds and very low losses.

Overtemperature

See *Thermal protection*.

Overvoltage protection

The 1213 controller contains circuitry to protect itself from operating in potentially damaging overvoltage conditions. These conditions may exist if the batteries become disconnected or any circuit protection devices open.

Two overvoltage protection options are available: short and coast. With the overvoltage short option, the controller shorts the motor when it senses an overvoltage condition. This brakes the motor to a stop so that the vehicle can no longer travel while the overvoltage condition exists. Because the motor is actually shorted, the braking effect may be significant. The overvoltage short option is recommended for manned vehicles because the controller cannot influence the vehicle's travel while freewheeling. The overvoltage coast option allows the vehicle to coast or "freewheel" if there is an overvoltage condition.

The 1213 overvoltage threshold is set at 42 volts for 24V controllers, 48 volts for 36V controllers, and 64 volts for 48V controllers.

Pot fault

See *Throttle pot fault protection*.

PTC

A PTC (Positive Temperature Coefficient) resistor is a resistive element that changes value depending on its temperature. At low temperatures, it has a very low resistance value. As current flows through the PTC it heats up, and at a certain temperature it trips to a higher resistance value.

PWM

PWM (Pulse Width Modulation), 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.

Regenerative braking

The 1213 uses regenerative braking to slow the vehicle to a stop and reduce speed when traveling downhill. Regenerative braking means that the energy used to slow the vehicle is channeled back into the batteries; this results in longer vehicle range between charges.

Smooth, stepless operation

Like all Curtis PMC 1200 Series controllers, the 1213 model allows 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 factor) of the controller's power MOSFET transistors. This technique — pulse width modulation — permits silent, stepless operation.

Temperature compensation

Internal temperature compensation ensures that the controller's current limit remains constant over varying controller temperatures. This eliminates performance variations resulting from variations in controller or operating environment temperatures.

Thermal protection

Because of their efficiency and thermal design, Curtis PMC controllers should barely get warm in normal operation. Overheating can occur, however, if the controller is undersized for its application or otherwise overloaded. If the internal temperature of the controller exceeds 85°C, the current limit is gradually reduced until it is zero at 95°C.

Full current limit and performance return automatically after the controller cools down. Although this action is not damaging to the controller, it does suggest a mismatch. If thermal cutback occurs often in normal vehicle operation, the controller is probably undersized for the application and a higher current model should be used if available.

Throttle pot fault protection (runaway protection)

To prevent uncontrolled operation, the 1213 controller shuts off the motor in the event of an open circuit fault in the throttle or its wiring. The standard throttle configuration is a three-wire, 5 kΩ pot. Throttle fault protection is engaged when the resistance between the Pot High and Pot Low inputs exceeds approximately 7 kΩ. This would occur, for example, if one of the pot wires broke or became disconnected. Also, an open in the wiper wiring forces the controller to return to neutral. The controller returns to normal operation when the fault has been repaired. This controller is also available with a pot fault option that meets the ISO 7176 requirements; see ISO Pot Fault, Section 4).

Undervoltage protection

The control circuitry requires a minimum battery voltage to function properly. The controller is therefore designed so its output is gradually reduced if the battery voltage falls below a certain level. Cutback voltages for the various models are listed in the specifications (Appendix C). Reducing the output to the motor allows the battery voltage to recover, and an equilibrium is established in which the battery supplies as much current as it can without falling below the cutback voltage.

APPENDIX A

SPECIFICATIONS

NOMINAL INPUT VOLTAGE	24V, 36V, and 48V (by model)
MAXIMUM OPERATING VOLTAGE	125% of nominal voltage
TIME/CURRENT RATING	may be held at full current for 1 minute (continuous current rating depends on mounting)
PWM OPERATING FREQUENCY	15 kHz
SPEED CONTROL SIGNAL	5 kΩ, 3-wire pot; or 0–5V, single-ended or wigwag
STANDBY CURRENT	150 mA @ 24V
MAIN CONTACTOR DRIVER RATING	1 amp max
E-M BRAKE OUTPUT RATING	1 amp max
BRAKE LIGHT DRIVER RATING	2 amps max (available on 24V models only)
WEIGHT	1.13 kg (2.5 lbs)
DIMENSIONS (L ✕ W ✕ H)	165 mm ✕ 122 mm ✕ 60 mm (6.50" ✕ 4.80" ✕ 2.35")

MODEL NUMBER	NOMINAL BATTERY VOLTAGE (volts)	OPTIONAL BRAKE LIGHT OUTPUT	CURRENT LIMIT 1 MIN RATING (amps)	CURRENT LIMIT 1 HOUR RATING (amps)	MIN. ALLOW MOTOR RESISTANCE (mΩ)	TYP. FWD VOLTAGE DROP @ 60 A (volts)	UNDER VOLTAGE CUTBACK (volts)	OVER VOLTAGE CUTBACK (volts)
1213-2XXX	24	no	150	60	50	0.55	16	42
1213-5XXX	24	no	200*	70	40	0.45	16	42
1213-7XXX	24	yes	150	60	50	0.55	16	42
1213-8XXX	24	yes	200*	70	40	0.45	16	42
1213-3XXX	36	no	125	50	80	0.55	26	48
1213-6XXX	36	no	160*	60	65	0.45	26	48
1213-4XXX	48	no	100	40	150	1.2	35	64

** 30-second rating*

APPENDIX B

POWER CIRCUITRY PROTECTION

Three wiring configurations associated with power circuitry protection, each providing different performance characteristics, are discussed in this appendix. The simplest configurations allow the OEM to choose either (1) reverse polarity protection or (2) key-off deceleration. In some applications it may be possible to have both reverse polarity protection and key-off deceleration, through (3) the use of a PTC resistor.

Reverse Polarity Protection Configuration

The basic wiring configuration shown in Figure 3 provides reverse polarity protection. The 1213 controller senses when power has been applied backwards and prevents the main contactor from pulling in when the keyswitch is closed. The main contactor must be wired through pin **P4** for the controller to implement reverse polarity protection. If the main contactor, circuit breaker, or fuse is opened while the vehicle is moving, the motor regenerates energy into the controller's capacitors and may induce an overvoltage. If the controller does go into overvoltage and is specified with the overvoltage short option, the motor will be shorted and the vehicle will brake harshly to a stop. If the overvoltage coast option is specified, the vehicle will coast without any electrical braking. Coasting can be dangerous—for example, if the power circuit is opened while descending a hill.

Key-Off Deceleration Configuration

Adding a diode from the controller side of the main contactor to the battery B+ side of the power fuse or circuit breaker, as shown in Figure B-1, allows the vehicle to decelerate comfortably to a stop if the main contactor, circuit breaker, or fuse opens. This is the key-off deceleration configuration. Reverse polarity protection is lost, because the diode bypasses the main contactor and allows high current to flow through the power section. If the batteries are wired backwards in the key-off deceleration configuration, the power section of the controller will be destroyed. The recommended diode is a Motorola MR751 or equivalent.

PTC Resistor Configuration

Adding a PTC resistor in series with the key-off deceleration diode, as shown in Figure B-2, can provide controlled deceleration while maintaining reverse polarity protection. Raychem p/n RUE 800 is recommended for this configuration. It provides the necessary low impedance path during key-off deceleration while

Fig. B-1 *Wiring to implement key-off deceleration; in this configuration, reverse polarity protection in lost.*

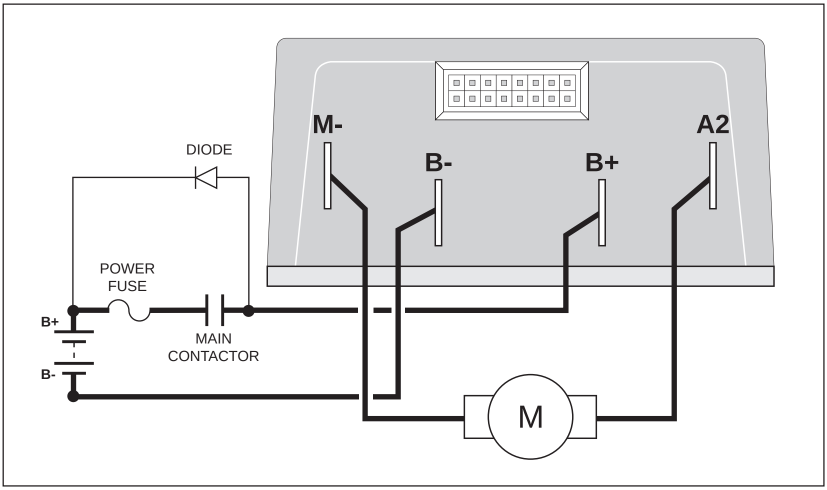
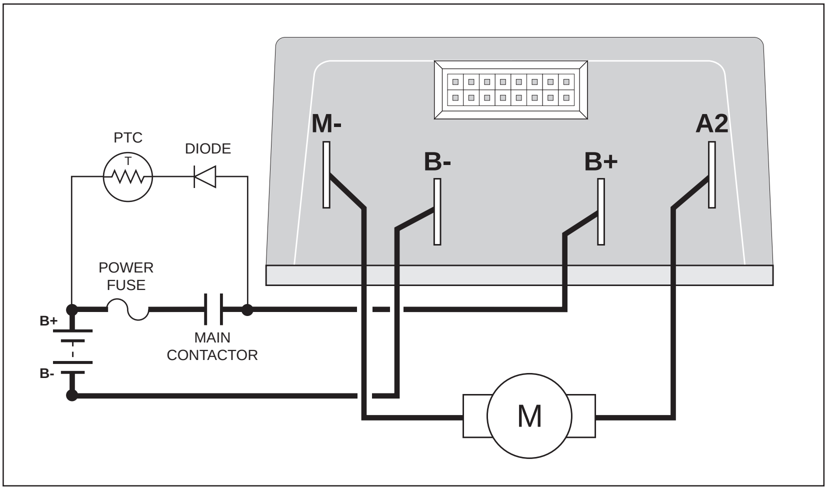


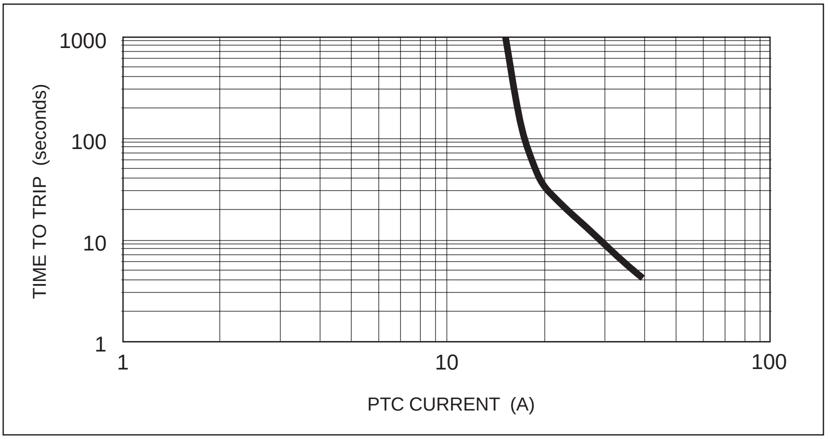
Fig. B-2 *Wiring a PTC resistor to implement key-off deceleration while maintaining reverse polarity protection.*



"tripping" to its high resistance mode quickly enough to limit the destructive currents in a reverse polarity condition. Current vs. time to trip for the Raychem RUE800 is shown in the graph in Figure B-3.

This configuration cannot be used in all cases. If the vehicle is large enough to cause the PTC to trip to its high resistance state before the vehicle has come to a stop, the key-off deceleration feature will not work. Using a PTC with a higher resistor value is not a viable option, because it would jeopardize the performance of the reverse polarity protection function.

Fig. B-3 *Ratings for the Raychem RUE800 PTC.*



The only way to determine whether the PTC will perform satisfactorily in a given application is through vehicle testing. The testing should consist of turning the keyswitch off while descending the maximum rated grade at full speed with the maximum specified load in the vehicle. If the PTC trips to its high resistance state during deceleration, the vehicle and load are too large for the PTC resistor configuration. In other words, the deceleration vs. time waveform through the PTC is above the rated high impedance trip threshold for the PTC.

If your application precludes the use of a PTC with the recommended resistor value (i.e., the Raychem RUE800 or equivalent) you will have to choose between wiring the controller to provide either (1) reverse polarity protection or (2) key-off deceleration.