MANUAL

CURTIS PMC

MODEL **1297**

INTEGRATED TRACTION & HYDRAULIC SYSTEM CONTROLLER

DESIGN OF CURTIS PMC 1200 SERIES CONTROLLERS PROTECTED BY U.S. PATENT NO. 4626750.

CURTIS

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1297 Manual, p/n 36411
Rev. A: February 2001

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CONTENTS

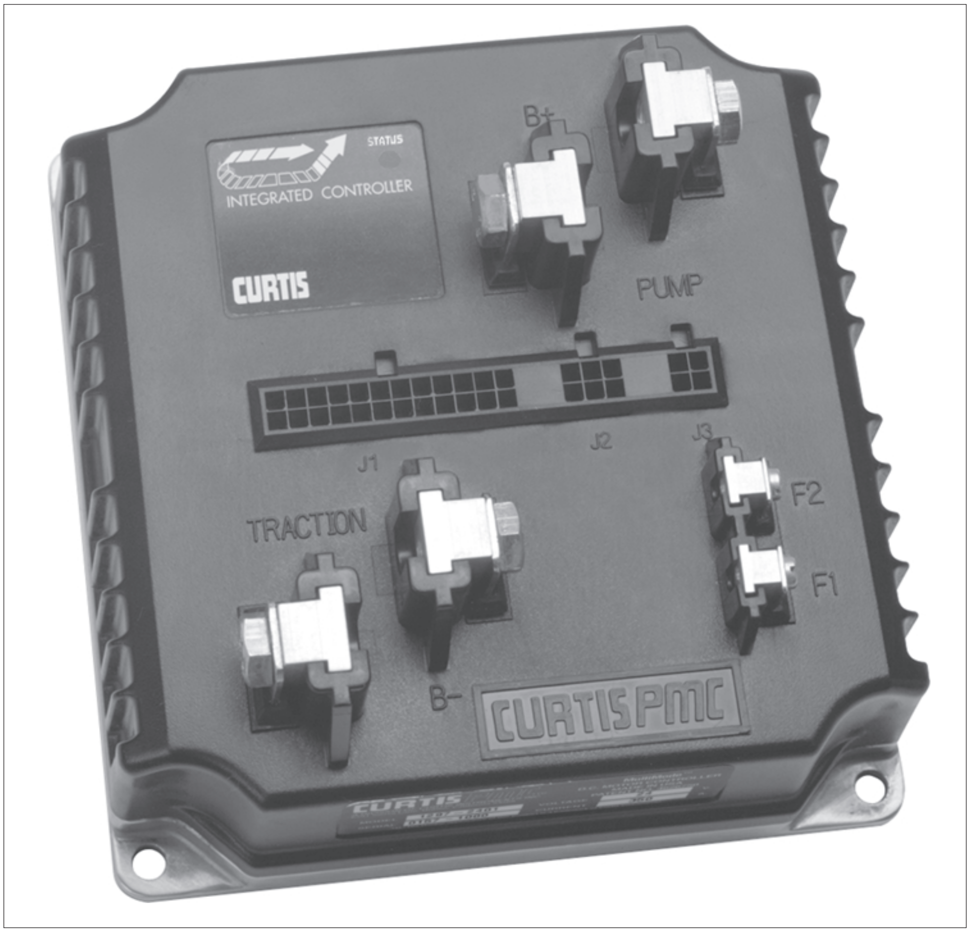
FIGURES

TABLES

1 OVERVIEW

The Curtis PMC 1297 motor controller is an integrated controller that combines two motor controllers in one: it controls both a separately-excited traction motor and a series pump motor. Typical applications include walkie/rider pallet trucks, low lifts, stackers, small order-pickers, small reach trucks, and other small industrial vehicles.

Fig. 1 *Curtis PMC 1297 integrated traction and hydraulic system controller.*



The 1297 controller offers smooth, silent, cost effective control of motor speed and torque. The traction section includes a full-bridge field control and a half-bridge armature control to provide full solid-state regenerative braking. The pump section contains a half-bridge drive designed to provide smooth and efficient control of a series pump motor. In addition to controlling the pump motor, the 1297 controls the valves on the Lift cylinder's hydraulic line and thus controls the hydraulic path for Lift and Lower operations.

The 1297 controller is fully programmable through any of Curtis PMC's 13XX programmers. In addition to configuration flexibility, the programmer provides diagnostic and test capability.

The 1297 is also designed to work with the optional Curtis 840 Spyglass data display and the optional Curtis PMC 1312 tiller multiplexer.

Like all Curtis PMC motor controllers, the 1297 offers superior operator control of motor speed. **Features include:**

✓ 150–350 amp separately excited regenerative traction motor controller

✓ Field current standard at 25 amps on 150 and 250 amp controllers, and at 35 amps on 350 amp controllers

✓ MultiMode™ feature allows two distinct user-selectable operation modes

✓ 200–300 amp series pump motor controller, with choice of variable PWM or ramped on/off

✓ Proportional lowering valve is controlled by a variable-current driver, for precise control during lowering

✓ Lift and Lower operations start smoothly, because of hydraulic system pre-load function

✓ Programmability through the Curtis PMC 13XX programmer

✓ Complete diagnostics through the 13XX programmer and through the controller's built-in Status LED

✓ Throttle inputs for single-ended or wigwag 5kΩ pots or 0–5V throttles (both standard full stroke and restricted range); one throttle for the traction system and one for the hydraulic system

✓ Active precharge of controller capacitor bank extends life of main contactor tips

✓ Three hourmeters—total KSI-on hours, drive hours, pump hours—and their associated maintenance timers are built into the controller, with EEPROM storage (no battery)

✓ BDI calculations performed within controller

✓ Meets EEC fault detection requirements (standard M- PWM fault check)

✓ Fault detection circuitry on throttle inputs can be used to inhibit operation if traction or hydraulic throttle signal goes out of range for any reason

✓ Internal reverse polarity protection (no external diode required)

✓ Continuous diagnostics during operation, with microprocessor power-on self-test

✓ All output drivers are short-circuit protected and provide built-in coil spike protection

✓ Positive battery connections for all inputs

- ✓ Fully protected inputs
- ✓ Internal and external watchdog circuits ensure proper software operation
- ✓ High environmental protection rating (IP53)
- ✓ 3-wire serial interface for multifunction display—*see below*
- ✓ 4-wire serial interface for all tiller functions—*see below*

Curtis Model 840 Spyglass Display

- ✓ 3-wire serial interface
- ✓ Sequences between hourmeter, BDI, and error displays
- ✓ Single alphanumeric, non-backlit, 8 character, 5 mm LCD display for hourmeter, BDI, and fault messages
- ✓ Display updated by dedicated unidirectional serial port
- ✓ Available in 52 mm round case, DIN case, and as a bare board, each with an 8-pin Molex connector; cases feature front seal to IP65 and rear seal to IP40; shock and vibration protection to SAE J1378
- ✓ Operating temperature range -10°C to 70°C; models with lower temperature ratings available for freezer applications

Curtis PMC Model 1312 Tiller Multiplexer

- ✓ 4-wire serial interface increases reliability
- ✓ Multiplexes up to 12 signals, analog or digital
- ✓ All signals sampled 50 times per second
- ✓ Signal integrity checked 150 times per second
- ✓ Schematic drawing of the 1312 generic circuit board is available at no cost to OEMs who want to design their own tiller multiplexers.

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

MOUNTING THE CONTROLLER

The 1297 controller can be oriented in any position, and meets the IP53 ratings for environmental protection against dust and water. However, **the location should be carefully chosen to keep the controller clean and dry. If a clean, dry mounting location cannot be found, a cover must be used to shield the controller from water and contaminants.**

When selecting the mounting position, be sure to also take into consideration (1) that the built-in Status LED is visible only through the view port in the label on top of the controller, and (2) that convenient access is needed at the top of the controller to plug the programmer into its connector.

The outline and mounting hole dimensions for the 1297 controller are shown in Figure 2. To ensure full rated power, the controller should be fastened

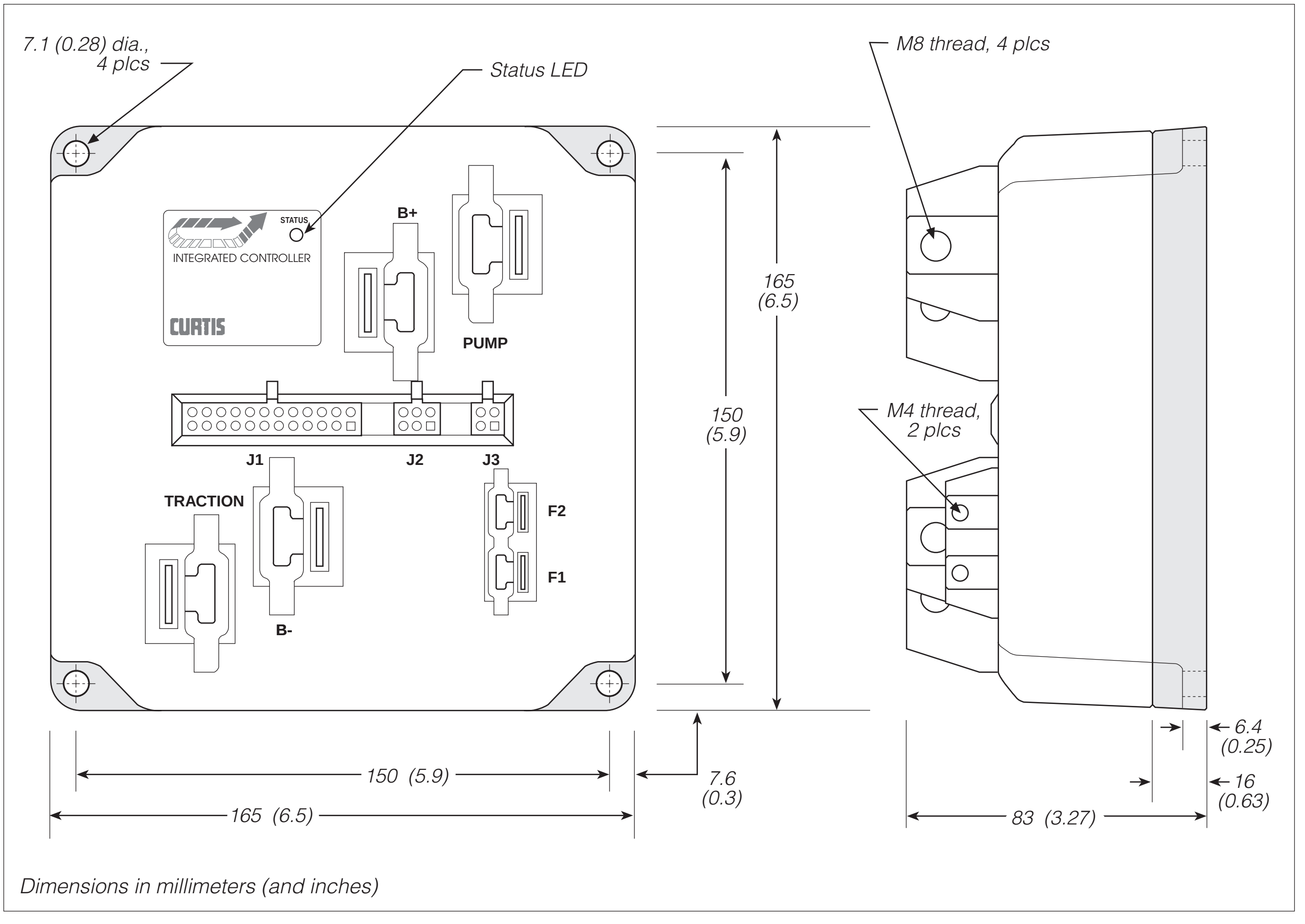


Fig. 2 *Mounting dimensions, Curtis PMC 1297controller.*

to a clean, flat metal surface with four 6 mm (1/4") diameter screws, using the holes provided. Although not usually necessary, a thermal joint compound can be used to improve heat conduction from the controller heatsink to the mounting surface.

You will need to take steps during the design and development of your end product to ensure that its EMC performance complies with applicable regulations; suggestions are presented in Appendix C.

The 1297 controller contains **ESD-sensitive components.** Use appropriate precautions in connecting, disconnecting, and handling the controller. See installation suggestions in Appendix C for protecting the controller from ESD damage.

CAUTION

Working on electrical systems is potentially dangerous. You should protect yourself against uncontrolled operation, high current arcs, and outgassing from lead acid batteries:

UNCONTROLLED TRACTION OPERATION — Some conditions could cause the traction system to run out of control. Disconnect the motor or jack up the vehicle and get the drive wheels off the ground before attempting any work on the traction motor control circuitry. NOTE: If the wrong throttle input signal type is selected with the 13XX programmer, the vehicle may suddenly begin to move.

UNCONTROLLED HYDRAULIC OPERATION — Some conditions could cause the hydraulic system to run out of control. Disconnect the pump motor or make sure the hydraulic system has enough room to operate before attempting any work on the pump motor control circuitry. NOTE: If the wrong hydraulic throttle input signal type is selected with the 13XX programmer, the hydraulic system may suddenly begin to operate.

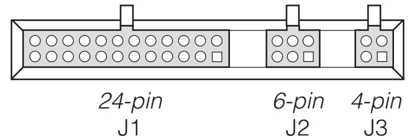
HIGH CURRENT ARCS — Batteries can supply very high power, and arcs can occur if they are short circuited. Always open the battery circuit before working on the motor control circuit. Wear safety glasses, and use properly insulated tools to prevent shorts.

LEAD ACID BATTERIES — Charging or discharging generates hydrogen gas, which can build up in and around the batteries. Follow the battery manufacturer's safety recommendations. Wear safety glasses.

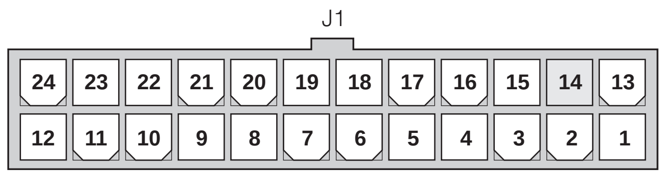
CONNECTIONS

Low Current Connections

Three low current connectors (J1, J2, J3) are built into the 1297 controller. They are located in a row on the top of the controller:



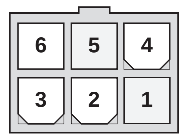
The 24-pin connector (J1) provides the logic control connections for the contactor drivers and switches that are wired directly to the vehicle. The mating connector is a 24-pin Molex Mini-Fit Jr. connector part number 39-01-2245 using type 5556 terminals.



J1 **Pin 1**	keyswitch input (KSI)
J1 **Pin 2**	interlock
J1 **Pin 3**	mode switch input—M1 (open), M2 (closed)
J1 **Pin 4**	wiper/0–5V input for traction throttle
J1 **Pin 5**	horn input
J1 **Pin 6**	emergency reverse input
J1 **Pin 7**	lowering valve driver output
J1 **Pin 8**	auxiliary driver output
J1 **Pin 9**	emergency reverse check output
J1 **Pin 10**	pot high output
J1 **Pin 11**	Lift switch input
J1 **Pin 12**	forward switch input (no multiplexer); Lift limit switch input (multiplexer)
J1 **Pin 13**	display data output
J1 **Pin 14**	[not used]
J1 **Pin 15**	display ground reference output
J1 **Pin 16**	display power output
J1 **Pin 17**	main contactor driver output
J1 **Pin 18**	load hold valve driver output
J1 **Pin 19**	horn driver output
J1 **Pin 20**	electromagnetic brake driver output
J1 **Pin 21**	wiper/0–5V input for hydraulic throttle
J1 **Pin 22**	pot low input
J1 **Pin 23**	Lower switch input
J1 **Pin 24**	reverse switch input (no multiplexer); coast switch input (multiplexer)

A 6-pin low power Molex connector (J2) is provided for the tiller multiplexer controls. The mating connector is a Molex Mini-Fit Jr. p/n 39-01-2065 using type 5556 terminals. The multiplexer uses four of J2's six pins: 2, 3, 4, and 6.

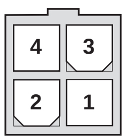
J2



J2 **Pin 1**	+15V supply (limited to 20 mA)
J2 **Pin 2**	ground return (B-)
J2 **Pin 3**	multiplexer data line (+5V)
J2 **Pin 4**	clock (+5V)
J2 **Pin 5**	display data line (+5V)
J2 **Pin 6**	KSI

For applications not using the multiplexer, J2 can be used as an alternative connector for the display. The display uses only three of J2's six pins: 1, 2, and 5.

J3



J3 **Pin 1**	receive data (+5V)
J3 **Pin 2**	ground (B-)
J3 **Pin 3**	transmit data (+5V)
J3 **Pin 4**	+15V supply (100mA)

A 4-pin low power connector (J3) is provided for the 13XX programmer. A complete programmer kit, including the appropriate connecting cable, can be ordered; see Curtis PMC programmer manual for further information on the various programmers available for programming Curtis PMC controllers.

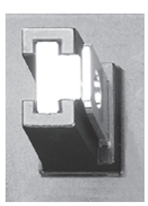
J3 can also be used for the display. Although the display is typically wired directly into Pins 13, 15, and 16 of the 24-pin connector (J1), it can alternatively be plugged into J3 and unplugged when the programmer is used. Only Pins 2, 3, and 4 of J3 are needed for the display.

High Current Connections

Six tin-plated solid copper bus bars are provided for the high current connections to the battery (**B+** and **B-**), the two motor armatures (**TRACTION** and **PUMP**), and the traction motor field connections (**F1** and **F2**), located as shown in Figure 2. The bus bars incorporate threaded mounting studs designed to accept mounting bolts. This simplifies the assembly and reduces the mounting hardware necessary for the power connections. The **B+**, **B-**, **TRACTION**, and **PUMP** bus bars are threaded to accept M8 bolts, and the **F1** and **F2** bus bars are threaded to accept M4 bolts. This provides secure vibration resistant connections on all power terminals. The tightening torque applied to the bolts should not exceed the following limits:

M8 bolts: 16.3 N·m (12 ft-lbs)
M4 bolts: 5.4 N·m (4 ft-lbs).

Exceeding these specifications could damage the bus bars' internal threads, resulting in loose connections.



B+, **B-**, **TRACTION M-**, **PUMP M-**

F1, **F2**

WIRING: Standard Configuration *without multiplexer*

Figure 3 shows the typical wiring configuration for applications where a tiller multiplexer is not used.

For walkie applications the interlock switch is typically activated by the tiller, and an emergency reverse switch on the tiller handle provides the emergency reverse signal. **For rider applications** the interlock switch is typically a seatswitch or a footswitch, and there is no emergency reverse.

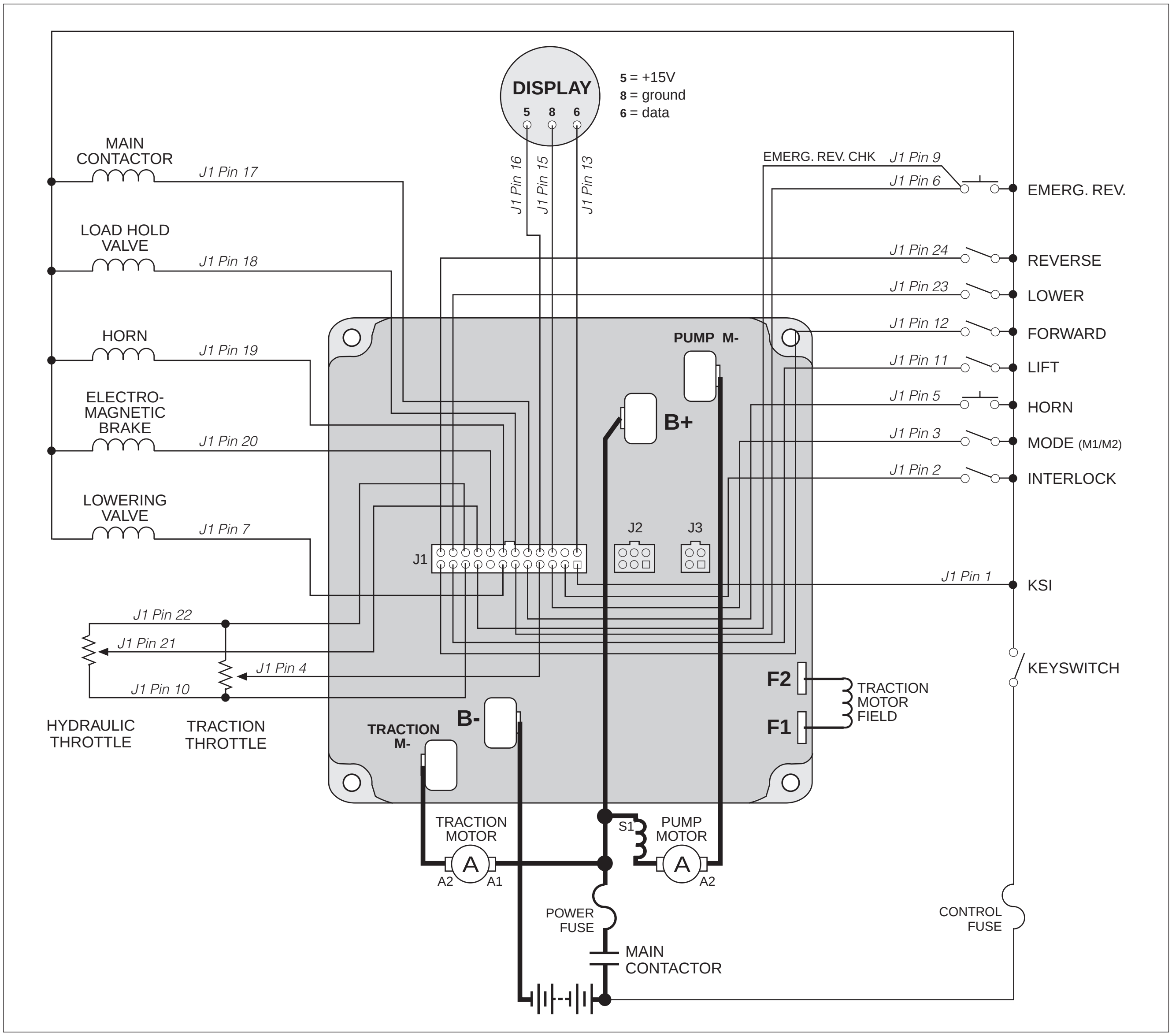


Fig. 3 *Standard wiring configuration, Curtis PMC 1297 controller, with no tiller multiplexer connected to the 6-pin connector.*

Power Wiring

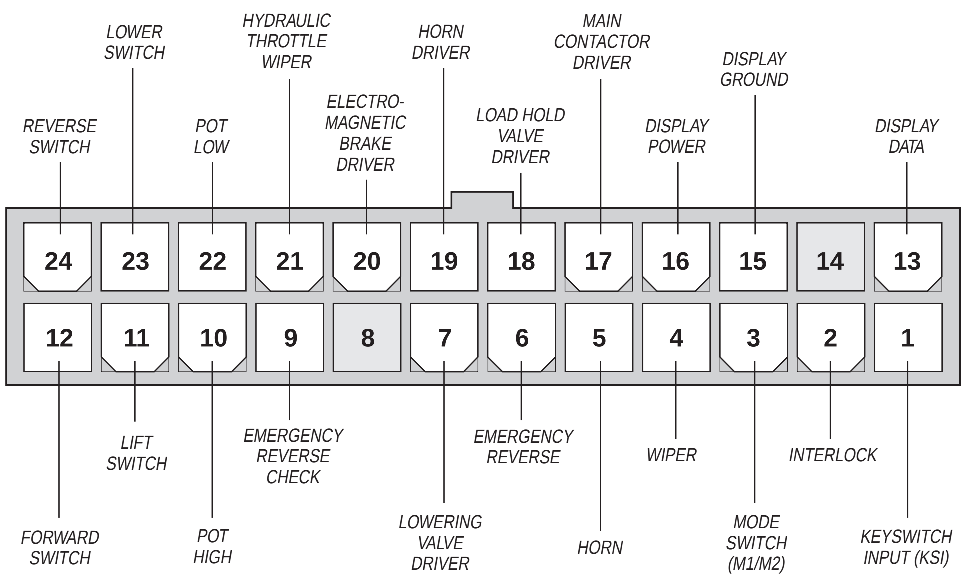
Traction motor armature wiring is straightforward, with the armature's A1 connection going to the controller's **B+** bus bar and its A2 connection going to the controller's **TRACTION M-** bus bar. The traction motor's field connections are less obvious. The direction of vehicle travel with the forward direction selected will depend on how the motor's field connections are made to the controller's two field terminals and how the motor shaft is connected to the drive wheels through the vehicle's drive train. **CAUTION:** The polarity of the **F1** and **F2** connections will affect the operation of the emergency reverse feature. The forward and reverse switches and the field connections must be configured so that the vehicle drives away from the operator when the emergency reverse button is pressed.

The pump motor is wired as shown, with its S1 connection going to the **B+** bus bar and its A2 connection going to the **PUMP M-** bus bar.

Standard Control Wiring

Wiring for the input switches and contactors is shown in Figure 3; the connector is shown in more detail below.

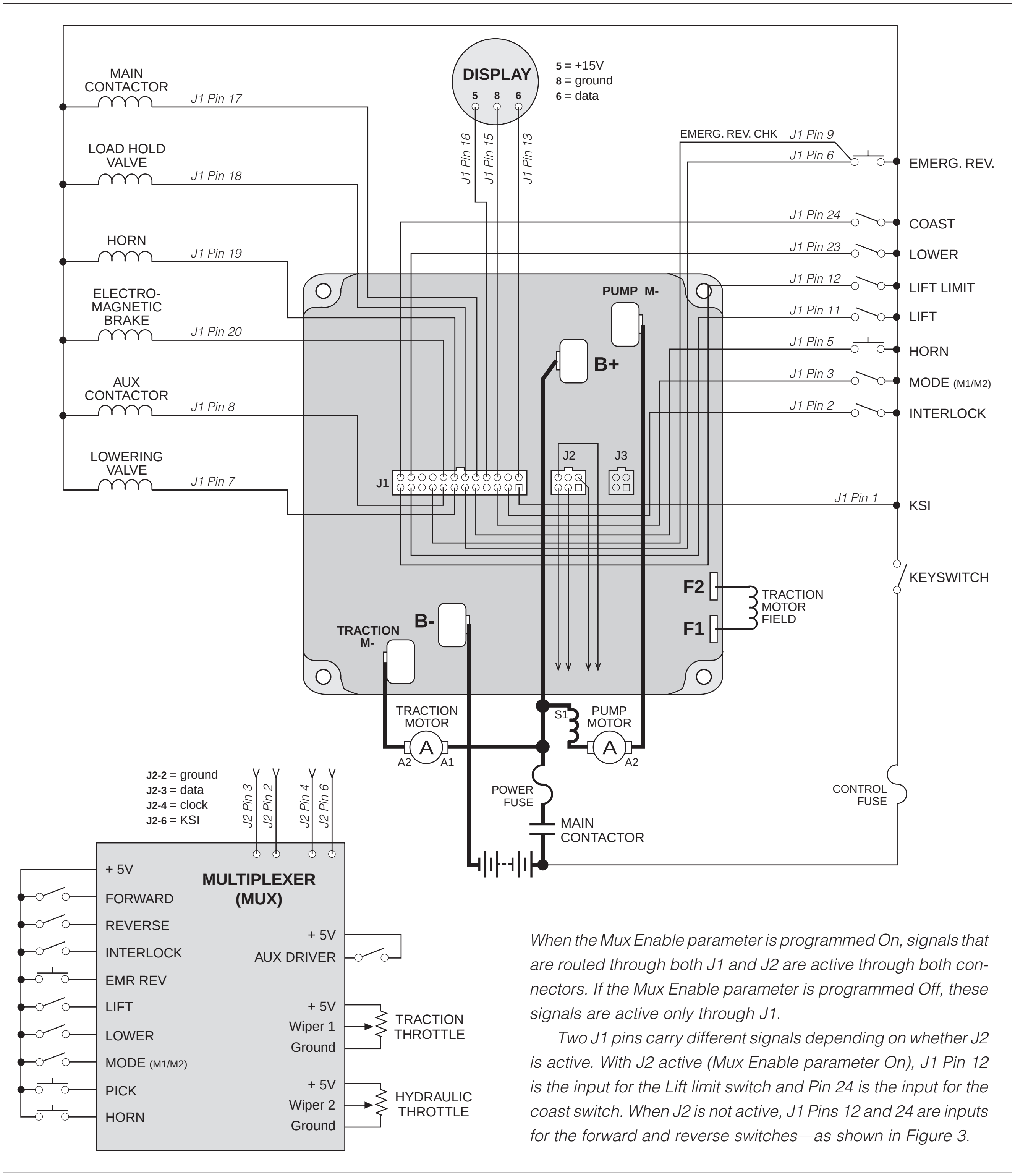
24-pin detail (see Fig. 3):



The main contactor coil must be wired directly to the controller as shown in Figure 3. The controller can be programmed to check for welded or missing contactor faults and uses the main contactor coil driver output to remove power from the controller and motors in the event of various other faults. **If the main contactor coil is not wired to J1 Pin 17, the controller will not be able to open the main contactor in serious fault conditions and the system will therefore not meet EEC safety requirements.**

WIRING: Standard Configuration *with multiplexer*

Figure 4 shows the typical wiring configuration for applications where a tiller multiplexer is used.



When the Mux Enable parameter is programmed On, signals that are routed through both J1 and J2 are active through both connectors. If the Mux Enable parameter is programmed Off, these signals are active only through J1.

Two J1 pins carry different signals depending on whether J2 is active. With J2 active (Mux Enable parameter On), J1 Pin 12 is the input for the Lift limit switch and Pin 24 is the input for the coast switch. When J2 is not active, J1 Pins 12 and 24 are inputs for the forward and reverse switches—as shown in Figure 3.

Fig. 4 *Standard wiring configuration, Curtis PMC 1297 controller, with 1312 tiller multiplexer connected to the 6-pin connector (J2).*

Power Wiring

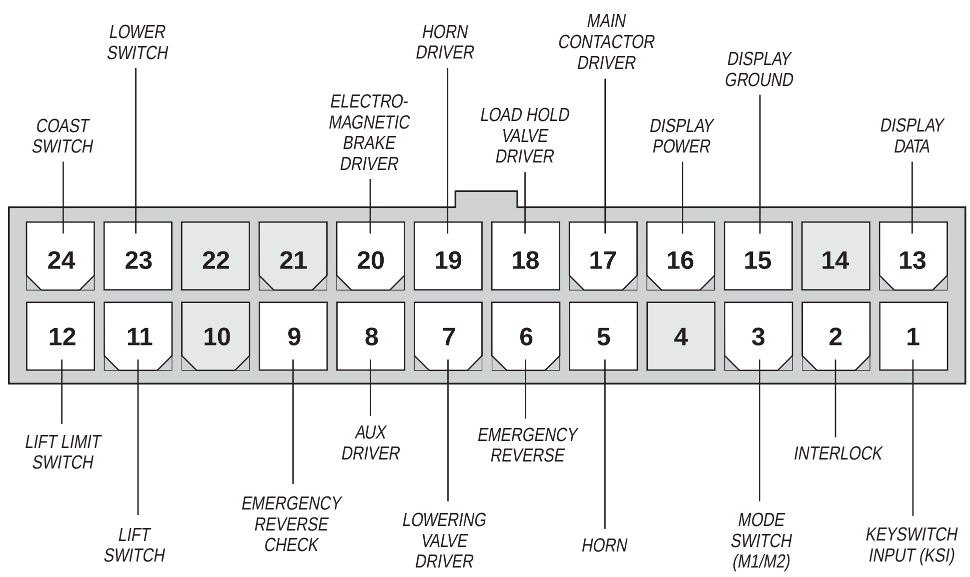
Traction motor armature wiring is straightforward, with the armature's A1 connection going to the controller's **B+** bus bar and its A2 connection going to the controller's **TRACTION M-** bus bar. The traction motor's field connections are less obvious. The direction of vehicle travel with the forward direction selected will depend on how the motor's field connections are made to the controller's two field terminals and how the motor shaft is connected to the drive wheels through the vehicle's drive train. ***CAUTION:*** The polarity of the **F1** and **F2** connections will affect the operation of the emergency reverse feature. The forward and reverse switches and the field connections must be configured so that the vehicle drives away from the operator when the emergency reverse button is pressed.

The pump motor is wired as shown, with its S1 connection going to the **B+** bus bar and its A2 connection going to the **PUMP M-** bus bar.

Standard Control Wiring

Wiring for the input switches and contactors is shown in Figure 4; the connector is shown in more detail below.

24-pin detail (see Fig. 4):



The main contactor coil must be wired directly to the controller as shown in Figure 4. The controller can be programmed to check for welded or missing contactor faults and uses the main contactor coil driver output to remove power from the controller and motors in the event of various other faults. **If the main contactor coil is not wired to J1 Pin 17, the controller will not be able to open the main contactor in serious fault conditions and the system will therefore not meet EEC safety requirements.**

WIRING: Throttles

Various throttles can be used with the 1297 controller. They are categorized as one of four types in the programming menu of the 13XX programmer. Only Types 2 and 4 can be used for the hydraulic throttle.

- Type 1: two-wire 5kΩ–0 potentiometer throttles
- Type 2: 0–5V throttles, current source throttles, three-wire pot throttles, and electronic throttles—*wired for single-ended operation*
- Type 3: two-wire 0–5kΩ potentiometer throttles
- Type 4: 0–5V and three-wire pot throttles—*wired for wigwag-style operation*

Table 1 summarizes the operating specifications for these four throttle types. NOTE: For Type 2 and Type 4 throttles, the controller reads only voltage at the wiper input—even when potentiometers are used.

Table 1 THROTTLE WIPER INPUT THRESHOLD VALUES

THROTTLE TYPE	PARAMETER	MAXIMUM THROTTLE FAULT	THROTTLE DEADBAND (0% speed request)	HPD (25% throttle active range)	THROTTLE MAX (100% modulation)	MINIMUM THROTTLE FAULT
1	Wiper Voltage	5.00 V	3.80 V	2.70 V	0.20 V	0.06 V
	Wiper Resistance	7.50 kΩ	5.50 kΩ	3.85 kΩ	0 kΩ	—
2	Wiper Voltage	0.06 V	0.20 V	1.50 V	5.00 V	5.80 V
	Wiper Resistance	—	—	—	—	—
3	Wiper Voltage	0.06 V	0.20 V	1.30 V	3.80 V	5.00 V
	Wiper Resistance	—	0 kΩ	1.65 kΩ	5.50 kΩ	7.50 kΩ
4	Wiper Voltage	0.50 V	2.50 V (Fwd/Lift) * 2.50 V (Rev/Lower) *	3.10 V (Fwd/Lift) 1.90 V (Rev/Lower)	4.40 V (Fwd/Lift) 0.60 V (Rev/Lower)	4.50 V
	Wiper Resistance	—	—	—	—	—

Notes: The upper and lower deadbands are valid for nominal 5kΩ potentiometers or 5V sources with the default Throttle Deadband and Throttle Max parameter settings of 0% and 100% respectively. These values will change with variations in the Throttle DB and Throttle Max parameter settings—*see Section 3A, pages 34 and 36, and Section 3B, pages 51 and 53.*

The HPD thresholds are 25% of the active range and therefore dependent on the programmed Throttle DB and Throttle Max settings (which define the active range). For Type 4 *hydraulic* throttles, the thresholds in the HPD column apply to the Hydraulic Inhibit feature.

* With 0% Throttle Deadband, there is no neutral point on a Type 4 pot. It is recommended that an 8% minimum deadband be used with Type 4 throttles.

For potentiometers, the 1297 provides complete throttle fault protection that meets all applicable EEC regulations. For voltage throttles, the 1297 protects against out-of-range wiper voltages (see Table 1), but does not detect wiring faults; it is therefore the responsibility of the OEM to provide full throttle fault protection in vehicles using voltage throttles.

Wiring for the most common throttles is described in the following text. If the throttle you are planning to use is not covered, 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 13XX programmer) is a 2-wire resistive throttle that connects between the pot wiper pin (Pin 4) and the Pot Low pin (Pin 22), as shown in Figure 5. For Type 1 devices, zero speed corresponds to a nominal 5kΩ measured between the pot wiper and Pot Low pins and full speed corresponds to 0Ω.

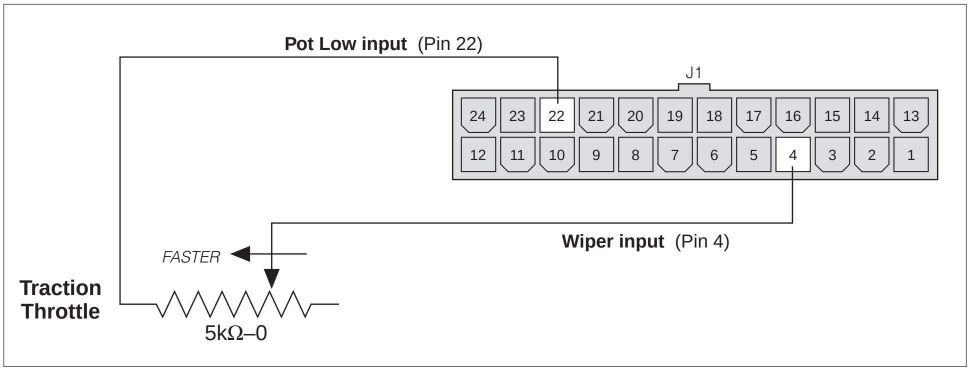


Fig. 5 *Wiring for 5kΩ–0 throttle (“Type 1”).*

Broken wire protection is provided by the controller sensing the current flow from the wiper input (Pin 4) through the potentiometer and into the Pot Low pin (Pin 22). If the Pot Low input current falls below 0.65 mA or its voltage below 0.06 V, a throttle fault is generated and the throttle request is zeroed. NOTE: The Pot Low pin must not be tied to ground (B-).

Single-Ended 0–5V Voltage Source, Current Source, 3-Wire Pot, and Electronic Throttles (“Type 2”)

With these throttles (“Type 2” in the programming menu) the controller looks for a voltage signal at the wiper input. Zero speed corresponds to 0V and full speed to 5V. A variety of devices can be used with this throttle input type, including voltage sources, current sources, and 3-wire pots. The wiring for each is slightly different and each has varying levels of throttle fault protection associated with it.

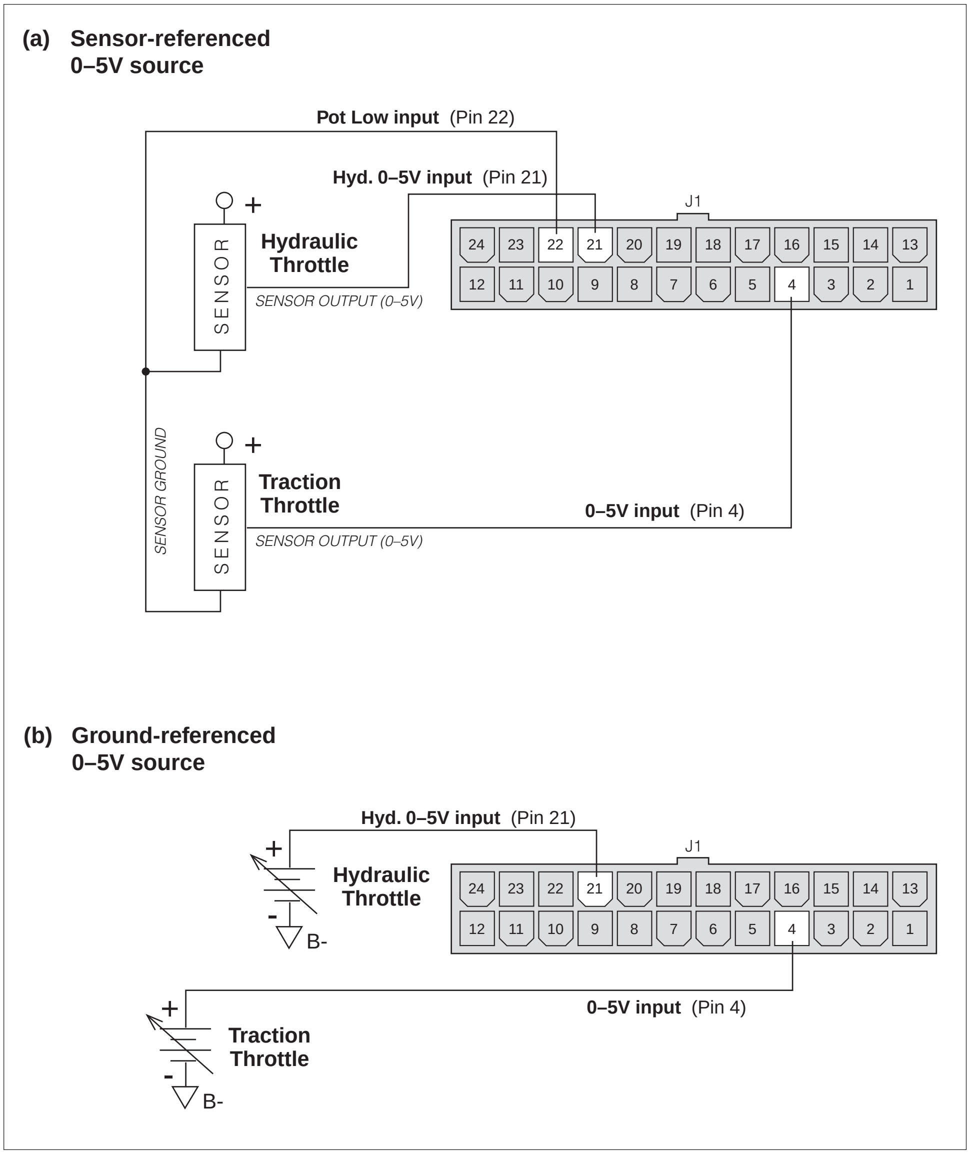
0–5V Throttle

Two ways of wiring the 0–5V throttle are shown in Figure 6. The active range for this throttle is from 0.2V (at 0% Throttle Deadband) to 5.0V (at 100% Throttle Max), measured relative to B-. It is the responsibility of the OEM to provide appropriate throttle fault detection for 0–5V throttles.

Sensor-referenced 0–5V throttles must provide a Pot Low current greater than 0.65 mA to prevent shutdown due to pot faults. It is recommended that the maximum Pot Low current be limited to 55 mA to prevent damage to the Pot Low circuitry.

Ground-referenced 0–5V throttles require setting the Pot Low Check parameter (see Section 3A, page 40) to Off; otherwise the controller will register a throttle fault. For ground-referenced 0–5V throttles, the controller will detect open breaks in the wiper input but cannot provide full throttle fault protection.

Fig. 6 *Wiring for 0–5V throttles ("Type 2").*



Also, the controller recognizes the voltage between the wiper input and B- as the applied throttle voltage and not the voltage from the voltage source relative to the Pot Low input.

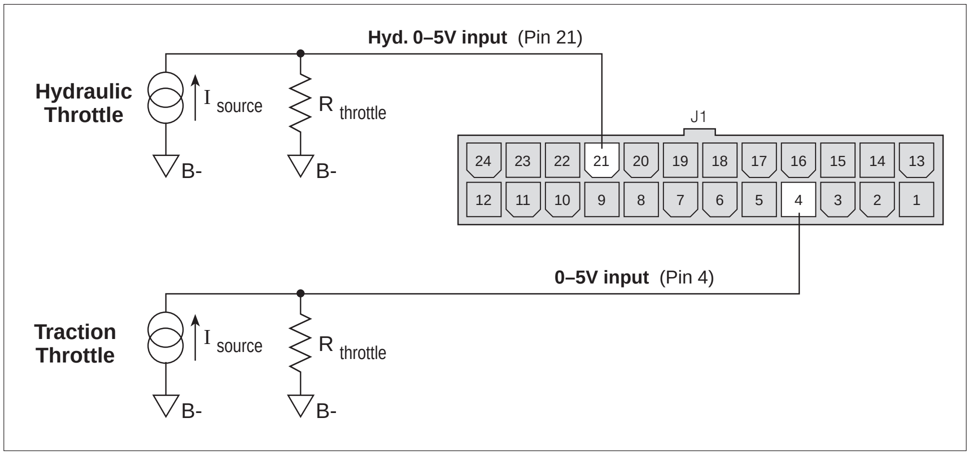
For either throttle input, if the 0–5V throttle input (Pin 4 or 21) exceeds 5.5V relative to B-, the controller will register a fault and shut down.

Current Source Used As a Speed Control Device

A current source can be used as a throttle input as shown in Figure 7. A resistor, $R_{throttle}$, must be used to convert the current source value to a voltage. The resistor should be sized to provide a 0–5V signal variation over the full current range.

It is the responsibility of the OEM to provide appropriate throttle fault detection for current sources used as throttles.

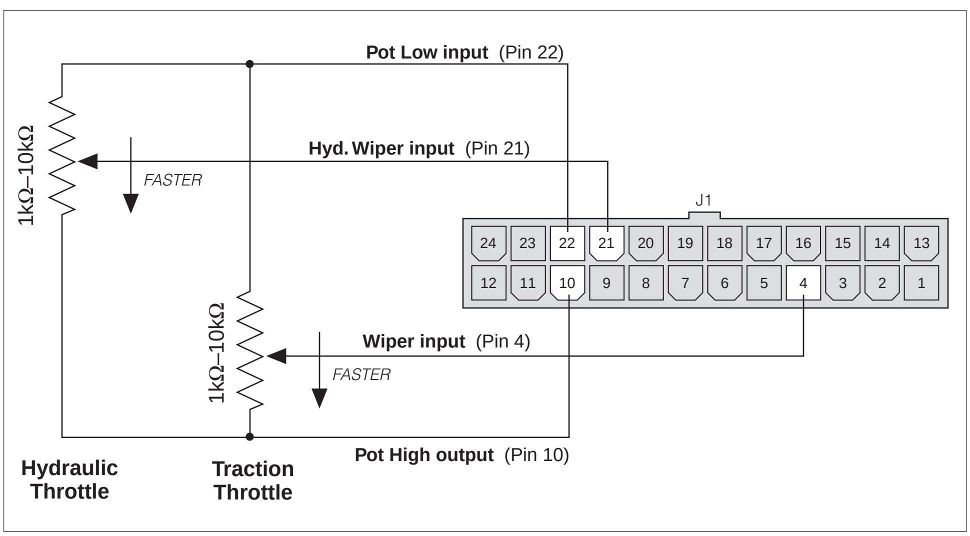
Fig. 7 *Wiring for current source throttle ("Type 2").*



3-Wire Pot Throttle (1kΩ–10kΩ)

The 3-wire potentiometer is used in its voltage divider mode, with the voltage source and return being provided by the 1297 controller. Pot High provides a current limited 5V source to the pot, and Pot Low (Pin 22) provides the return path. Wiring is shown in Figure 8 and also in the standard wiring diagrams, Figures 3 and 4. Potentiometers with total resistance values between 1kΩ and 10kΩ can be used.

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

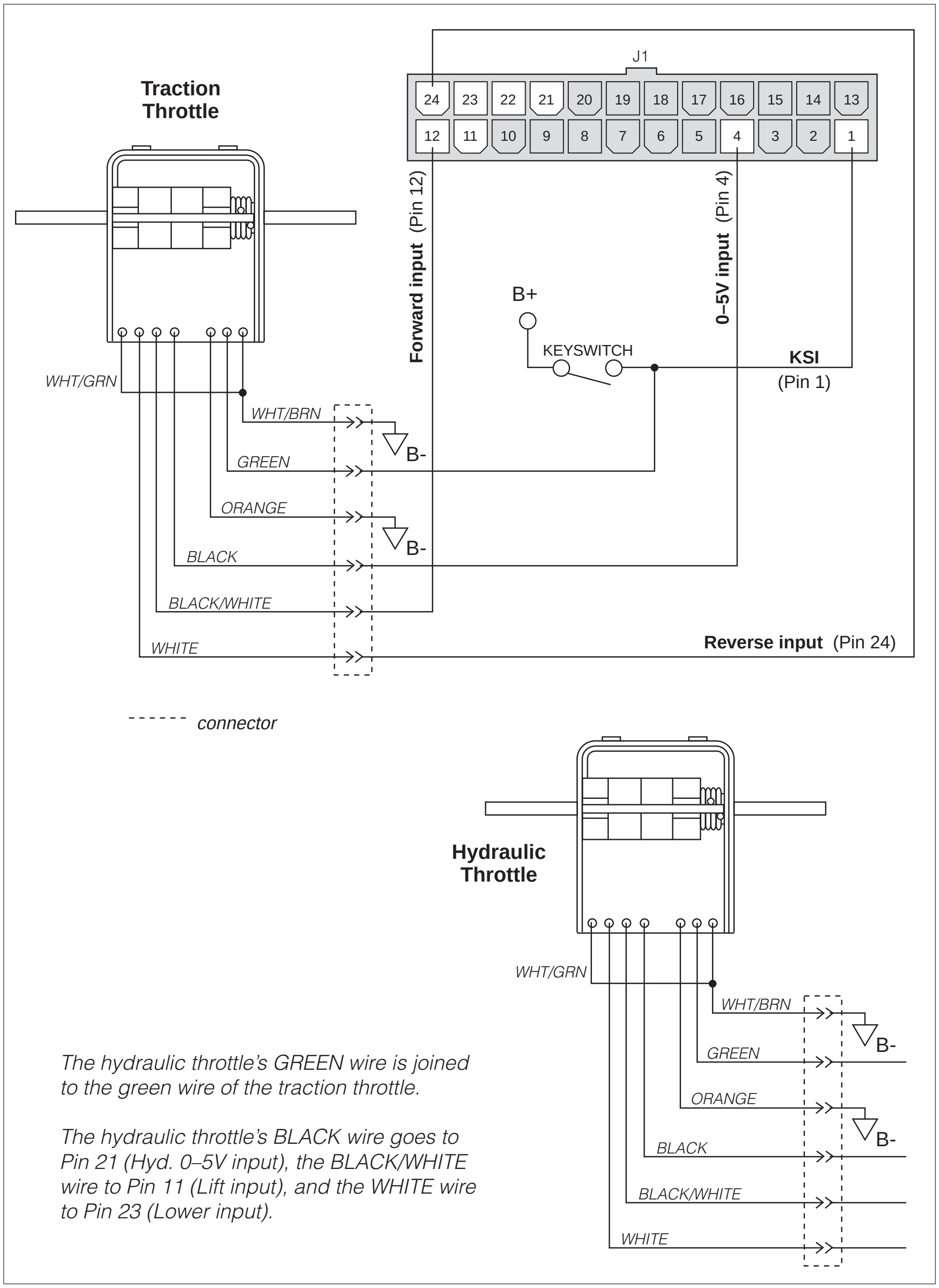


When a 3-wire pot is used and the Pot Low Check parameter (see Section 3A, page 40) is set to On, the controller provides full fault protection in accordance with EEC requirements. NOTE: Pot Low Check applies only to traction throttles.

Curtis ET-XXX Electronic Throttle

The Curtis ET-XXX provides a 0–5V throttle input and also Forward/Reverse inputs (traction throttle) or Lift/Lower inputs (hydraulic throttle) for the 1297 controller. Wiring for the ET-XXX is shown in Figure 9. When an electronic throttle is used, the Pot Low Check parameter (see Section 3A, page 40) must be set to Off; otherwise the controller will register a throttle fault.

Fig. 9 *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 OEM to provide any additional throttle fault detection necessary.

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 pot wiper pin (Pin 4) and the Pot Low pin, as shown in Figure 10. Zero speed corresponds to 0Ω measured between the two pins and full speed corresponds to 5 kΩ.

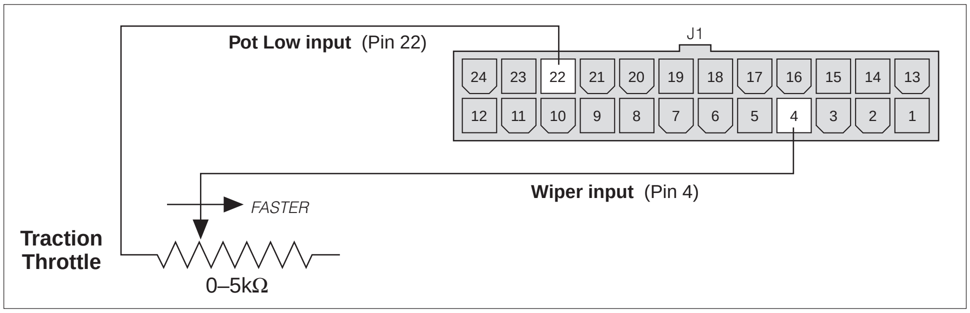


Fig. 10 *Wiring for 0–5kΩ throttle ("Type 3").*

Broken wire protection is provided by the controller sensing the current flow from the wiper input (Pin 4) through the potentiometer and into the Pot Low pin (Pin 22). If the Pot Low input current falls below 0.65 mA or its voltage below 0.06 V, a throttle fault is generated and the throttle request is zeroed. NOTE: The Pot Low pin must not be tied to ground (B-).

Wigwag-Style 0–5V Voltage Source and 3-Wire Pot Throttle ("Type 4")

These throttles ("Type 4" in the programming menu) operate in true wigwag style. No signals to the controller's forward and reverse (or lift and lower) inputs are required; the action is determined by the wiper input value. The interface to the controller for Type 4 devices is similar to that for Type 2 devices. The neutral point will be with the wiper at 2.5 V, measured between Pin 4 or 21 and B-.

For the traction throttle, the controller will provide increasing forward speed as its wiper input value (Pin 4) is increased, with maximum forward speed reached at 4.5 V. The controller will provide increasing reverse speed as the wiper input value is decreased, with maximum reverse speed reached at 0.5 V. For the hydraulic throttle, the controller will provide increasing Lift speed as its wiper input value (Pin 21) is increased, with maximum Lift speed reached at 4.5 V. The controller will provide increasing Lower speed as the wiper input value is decreased, with maximum Lower speed reached at 0.5 V. The minimum and maximum wiper voltage for either throttle must not exceed the 0.5V and 4.5V fault limits.

When a 3-wire pot is used and the Pot Low Check parameter (see Section 3A, page 40) is set to On, the controller provides full fault protection for Type 4 traction throttles. Any potentiometer value between 1 kΩ and 10 kΩ is supported. When a voltage throttle is used, it is the responsibility of the OEM to provide appropriate throttle fault detection.

NOTE: If your Type 4 throttle has an internal neutral switch, this internal neutral switch should be wired to the forward switch input (Pin 12). The controller will behave as though no throttle is requested when the neutral switch is high, and will use the throttle value when the neutral switch is low.

WIRING: Auxiliary Driver (*REQUIRES MULTIPLEXER*)

The 1297 controller provides an auxiliary driver at Pin 8. This low side driver, designed to energize a contactor coil, can be used to perform a variety of functions—such as engaging a brush motor. The output is rated at 2 amps, is overcurrent protected, and the turn-off is voltage clamped. The recommended wiring for an auxiliary contactor coil is shown in Figure 4. The contactor coil or driver load should **not** be connected directly to B+. The on/off switch for the auxiliary driver is located on the multiplexer.

WIRING: Coast and Pick (*REQUIRES MULTIPLEXER*)

When a multiplexer is used, J1 Pin 24 is the Coast input—as shown in Figure 4, page 10. When the tiller is locked in the Coast position (activating the Coast switch), the multiplexer's Pick switch can be used to drive the vehicle a short distance forward. When the Pick switch is released, the vehicle coasts to a stop.

WIRING: Emergency Reverse

To implement the emergency reverse feature, J1 Pin 6 (the emergency reverse input) must be connected to battery voltage. Emergency reverse is activated when the keyswitch is on and the emergency reverse switch is pressed. After the emergency reverse switch is released, normal controller operation is not resumed until neutral (no direction) is selected or until the interlock switch is cycled. The recommended wiring is shown in Figures 3 and 4, pages 8 and 10. The controller provides maximum braking torque as soon as the emergency reverse switch is closed. The vehicle will then be automatically driven in the reverse direction at the programmed emergency reverse current limit until the emergency reverse switch is released.

CAUTION

CAUTION: The polarity of the **F1** and **F2** connections will affect the operation of the emergency reverse feature. The forward and reverse switches and the **F1** and **F2** connections must be configured so that the vehicle drives away from the operator when the emergency reverse button is pressed.

WIRING: Emergency Reverse Check

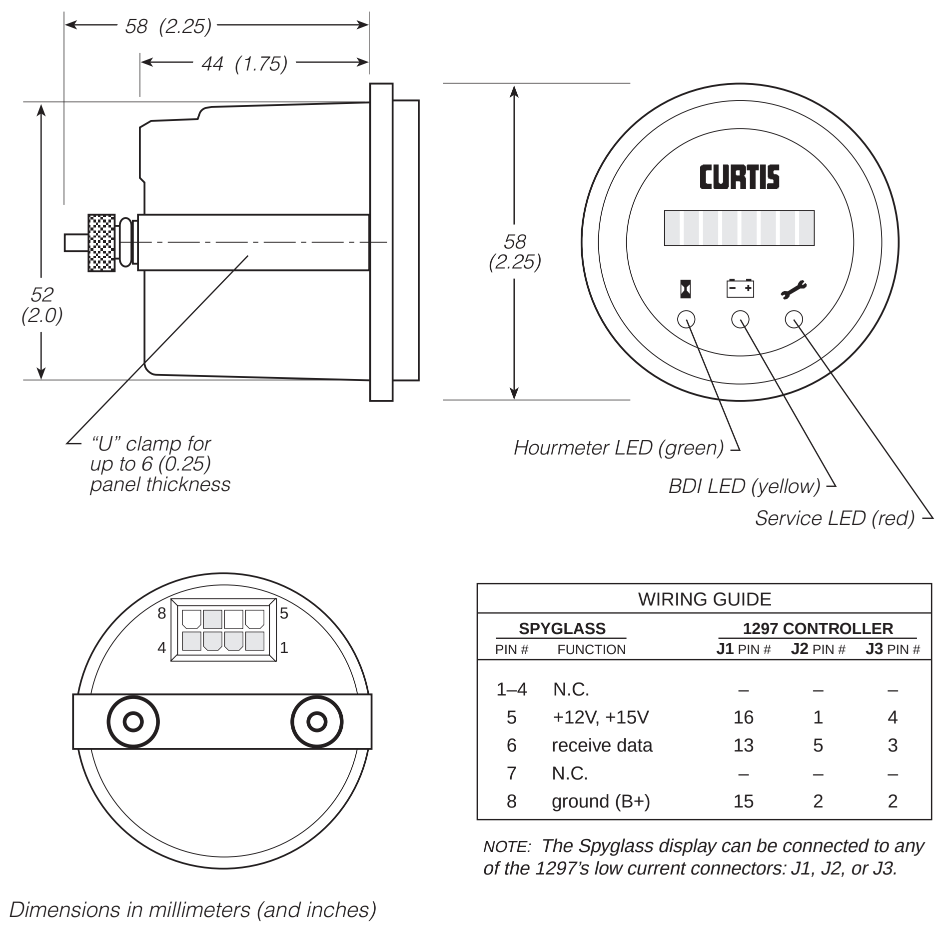
Al wire connected directly to the emergency reverse switch provides for broken wire detection when that feature is programmed On (see Section 3A, page 42). The emergency reverse check output wire periodically pulses the emergency reverse circuit to check for continuity in the wiring. If there is no continuity, the controller output is inhibited until the wiring fault is corrected.

The emergency reverse check wire is connected to J1 Pin 9 as shown in Figures 3 and 4, pages 8 and 10. 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.

WIRING: Spyglass Display

The Curtis 840 Spyglass features an 8-character LCD display that sequences between hourmeter, BDI, and fault messages. Three indicator LEDs—hourmeter, BDI, and service—are also located on the face of the gauge.

The mating 8-pin connector is Molex 39-01-2085, with 39-00-0039 (18–24 AWG) pins.



WIRING GUIDE

SPYGLASS PIN #	SPYGLASS FUNCTION	1297 CONTROLLER J1 PIN #	1297 CONTROLLER J2 PIN #	1297 CONTROLLER J3 PIN #
1–4	N.C.	–	–	–
5	+12V, +15V	16	1	4
6	receive data	13	5	3
7	N.C.	–	–	–
8	ground (B+)	15	2	2

NOTE: The Spyglass display can be connected to any of the 1297's low current connectors: J1, J2, or J3.

Fig. 11 *Wiring guide and mounting dimensions for Curtis Spyglass display.*

CONTACTOR, SWITCHES, and OTHER HARDWARE

Main Contactor

A main contactor should be used with the 1297 controller. Otherwise, the controller's fault detection will not be able to fully protect the controller, traction system, and hydraulic system from damage in a fault condition. The contactor allows the controller and both motors to be disconnected from the battery. This provides a significant safety feature, because it means the battery power can be removed if a controller or wiring fault results in battery power being applied to either motor inappropriately.

A single-pole, single-throw (SPST) contactor with silver-alloy contacts, such as an Albright SW180 or SW200 (available from Curtis), is recommended for use as the main contactor. The contactor coils should be specified with a continuous rating at the nominal battery pack voltage.

The 1297 controller provides a low-side contactor coil driver (at J1 Pin 17) for the contactor. The driver output is rated at 2 amps, is overcurrent protected at 3 amps, and is checked for open coil faults. An active clamping circuit at 70 V provides fast turn-off and protects the driver from inductive voltage kickback spikes. The controller also performs a welded contactor check and a missing main contactor check each time the interlock switch is engaged. Controller output is inhibited if these contactor checks are not passed.

For information on programming the various contactor-related parameters, see Section 3C, page 57.

Keyswitch and Interlock Switch

The vehicle should have a master on/off switch to turn the system off when not in use. The keyswitch input provides logic power for the controller.

The interlock switch—which is typically implemented as a tiller switch, deadman footswitch, or seatswitch—provides a safety interlock for the system.

The keyswitch and interlock switch provide current to drive the main contactor coil and the valve solenoid coils as well as the controller's internal logic circuitry, and must be rated to carry these currents.

Forward/Reverse, Lift/Lower, Mode, Emergency Reverse, Horn, Lift Limit, Coast, and Pick Switches

These input switches can be any type of single-pole, single-throw (SPST) switch capable of switching the battery voltage at 25 mA. Typically the Emergency Reverse, Horn, and Pick switches are momentary switches, active only while they are being depressed.

Circuitry Protection Devices

To protect the control circuitry from accidental shorts, a low current fuse (appropriate for the maximum current draw) should be connected in series with the battery feed to the keyswitch. Additionally, a high current fuse should be wired in series with the main contactor to protect the motors, controller, and batteries from accidental shorts in the power system. The appropriate fuse for each application should be selected with the help of a reputable fuse manufacturer or dealer. The standard wiring diagrams (Figures 3 and 4) show the recommended location for each fuse.

Valves

The hydraulic line's load holding valve (if used) and lowering valve should be large enough to provide adequate flow when open.

The load holding valve's solenoid coil should be rated at the nominal battery voltage of the system and must not exceed the 2 amp rating of its driver. The lowering valve solenoid coil should be rated at or below the nominal battery voltage and should be capable of opening the valve completely using not less than half an amp of current and not more than 3 amps.

The 1297 controller provides a low-side load-holding valve solenoid driver at J1 Pin 18; this driver output is rated at 2 amps, and is overcurrent protected at 3 amps. A low-side lowering valve solenoid driver is provided at J1 Pin 7; this driver output is rated at 3 amps, is overcurrent protected, is checked for open coil faults, and can drive either a proportional lowering valve or a simple open/closed lowering valve.

An active clamping circuit at 70 V provides fast turn-off and protects the drivers from inductive voltage kickback spikes.

For information on programming the various valve-related parameters, see Section 3B, page 49.

3

PROGRAMMABLE PARAMETERS

The 1297 controller has nearly one hundred parameters that can be adjusted by means of a 13XX programmer. These programmable parameters allow various performance characteristics to be customized to fit the needs of individual applications or system operators.

Each controller is either a generic model or an OEM-specific model. Generic controllers are shipped with the default parameter settings shown in Table D-1, and have model numbers ending "01" (e.g., 1297-2401). OEM-specified models are shipped with the default parameter settings designated by the OEM, and have model numbers that identify this particular configuration (e.g., 1297-2417).

In addition to specifying parameter values, the OEM can designate whether a parameter will have User or OEM-only access rights. Accordingly, two versions of the various 13XX programmers are available: the 13XX-**1**101 is the User programmer (which can adjust only those parameters with User access rights) and the 13XX-**2**101 is the OEM programmer (which can adjust all the parameters with User or OEM access rights).

The 1297's programmable parameters are divided into three groups:

A Traction Parameters

B Hydraulic Parameters

C Shared Parameters

which in turn are divided into subgroups by topic:

A Traction Parameters
- — *Acceleration*
- — *Braking*
- — *Speed*
- — *Throttle*
- — *Field*
- — *Emergency reverse*
- — *Other traction parameters*

B Hydraulic Parameters
- — *Pump*
- — *Valve control*
- — *Hydraulic throttle*

C Shared Parameters
- — *Contactor and sequencing delay*
- — *Multiplexer (MUX)*
- — *Hourmeters*
- — *BDI.*

The individual parameters are listed on the next page.

A: TRACTION

(parameters related to the traction motor and drive system)

Acceleration Parameters
- Drive Current Limit, M1–M2
- Acceleration Rate, M1–M2
- Current Ratio
- Boost Enable

Braking Parameters
- Braking Current Limit, M1–M2
- Brake Rate, M1–M2
- Deceleration Rate, M1–M2
- Coast Deceleration Rate
- Taper Rate
- Throttle Deceleration Rate
- Interlock Braking Current Limit
- Interlock Brake Rate
- Interlock Braking Delay
- Restraint
- Variable Braking
- Electromagnetic Brake Type
- Electromagnetic Brake Delay

Speed Parameters
- Maximum Speed, M1–M2
- Creep Speed
- High Speed Latch
- Interlock Override
- Load Compensation

Throttle Parameters
- Throttle Type
- Throttle Deadband
- Throttle Maximum
- Throttle Map
- Pot Low Check

Field Parameters
- Field Minimum
- Field Maximum
- Field Map Start
- Field Map
- Field Check

Emergency Reverse Parameters
- Emergency Reverse Current Limit
- Emergency Reverse Check
- Emergency Reverse Acceleration
- Emergency Reverse Time Limit
- Emergency Reverse Direction Intlk

Other Traction Parameters
- Anti-tiedown
- HPD
- SRO

B: HYDRAULICS

(parameters related to the pump motor and hydraulics)

Pump Parameters
- Pump Current Limit
- Pump Max Speed
- No Load Pump Current Limit
- No Load Pump Speed
- Pump Acceleration
- Pump Deceleration
- Pump Lock C/L
- Pump Lock Delay
- Pump BDI Lockout
- Pump BDI Warning
- Hydraulic Inhibit

Valve Parameters
- Lowering Valve Maximum Current
- Lowering Valve Minimum Current
- Lowering Valve Dither %
- Lowering Valve Current Acceleration
- Lowering Valve Current Deceleration
- Load Hold Delay
- Lowering Valve Check

Hydraulic Throttle Parameters
- Hydraulic Throttle Type
- Hydraulic Throttle Deadband
- Hydraulic Throttle Maximum
- Hydraulic Throttle Map
- Variable Lift
- Variable Lower

C: SHARED

(parameters related to both traction and hydraulics)

Contactor and Sequencing Delay Parameters
- Sequencing Delay
- Main Contactor Interlock
- Main Contactor Open Delay
- Main Contactor Diagnostics

Multiplexer Parameter
- Multiplexer Enable

Hourmeter Parameters
- Adjust Hours High
- Adjust Hours Middle
- Adjust Hours Low
- Set Hours, Total
- Set Hours, Traction
- Set Hours, Pump
- Service Timer Hours, Total
- Service Timer Hours, Traction
- Service Timer Hours, Pump
- Disable Timer Hours, Total
- Disable Timer Hours, Traction
- Disable Timer Hours, Pump
- Traction Fault Speed
- Pump Fault Speed
- Service Timer Reset, Total
- Service Timer Reset, Traction
- Service Timer Reset, Pump

BDI Parameters
- BDI Reset Volts
- BDI Full Volts
- BDI Empty Volts

☞ Individual parameters are described in the following text in the order they are listed on this page. They are listed by the abbreviated names that are displayed in the programmer's Program Menu. Not all of these parameters are displayed on all controllers; the list for any given controller depends on its specifications.

For a list of the individual parameters in the order in which they appear in the Program Menu, see Section 6: Programmer Menus.

A. TRACTION PARAMETERS

The various traction parameters adjust the vehicle's operating characteristics—its acceleration, braking, speed, and responsiveness. These parameters allow the vehicle to be tailored to a specific application, or to a specific operator's preferences.

The MultiMode™ feature of the 1297 controller allows operation in two distinct modes. These two modes can be programmed to provide two different sets of operating characteristics, which can be useful for different conditions. For example, Mode 1 could be set up for slow precise indoor maneuvering and Mode 2 for faster, long distance, outdoor travel. There are six parameters that can be individually set in the two modes:

Drive Current Limit, M1–M2
Acceleration Rate, M1–M2
Brake Current Limit, M1–M2
Brake Rate, M1–M2
Deceleration Rate, M1–M2
Maximum Speed, M1–M2.

It should be noted that the acceleration and braking parameters determine controller output and not the actual accelerating/braking time (or distance); the time (or distance) required to achieve the requested speed is influenced by a variety of factors—including initial speed, vehicle load, and terrain.

Acceleration Parameters

M1–M2, DRIVE C/L

The **drive current limit** parameter allows adjustment of the maximum current the controller will supply to the traction motor during drive operation. Setting this parameter at a low value reduces the maximum torque applied to the drive system by the motor, which may be desirable in Mode 1 if it is configured as a slow speed mode. The drive current limit is adjustable from 50 amps to the controller's full rated drive current. (The full rated drive current depends on the controller model; see specifications in Table E-1.)

The drive current limit is tuned as part of the vehicle performance adjustment process (Section 5).

M1–M2, ACCEL RATE

The **acceleration rate** defines the time it takes the controller to accelerate from 0% output to 100% output when full throttle is requested. A larger value represents a longer acceleration time and a gentler start. Fast starts can be achieved by reducing the acceleration time, i.e., by adjusting the accel rate to a smaller value. The accel rate is adjustable from 0.1 to 3.0 seconds.

The accel rate is tuned as part of the vehicle performance adjustment process (Section 5).

CURRENT RATIO

The **current ratio** parameter defines how much of the programmed drive current will be available to the traction motor at reduced throttle requests. The current ratio parameter can be set to 1, 2, 3, or 4. These settings correspond to the following ratios:

SETTING	RATIO
1	1 : 1
2	2 : 1
3	4 : 1
4	8 : 1

For example, with the current ratio set at 1 and 20% throttle requested, 20% of the battery voltage and 20% of the drive current will be allowed to flow in the motor (assuming a 50% throttle map setting). If the current ratio is set at 2 under these same conditions, 40% of the current will be available; if it is set at 3, 80%. The controller will not allow more than the programmed drive current to flow in the motor. If the current ratio is set at 4 with 20% throttle requested, the controller will allow only 100% of the drive current and not 160%.

High current ratio values will allow quicker startup response and improved ramp climbing with partial throttle, but may cause too much jumpiness.

The current ratio is tuned as part of the vehicle performance adjustment process (Section 5).

NOTE: Current ratio is only effective in drive; it does not affect regenerative braking.

BOOST ENABLE

In situations where the controller detects that the motor is about to stall, the **boost enable** feature provides a burst of extra torque by briefly applying a higher current (120% of the programmed drive current limit). This can be useful for occasionally getting the vehicle out of a pothole or over an obstacle. If the operator rocks the vehicle by reversing and rethrottling while in boost, the field will remain at max field to provide the maximum stall torque and minimum delay time. Boost enable can be programmed On or Off.

Each boost is limited to 6 seconds, followed by a 30 second cool-down period, with a total of 15 seconds of boost allowed within each 3 minute period. Performance is more consistent if boost enable is programmed Off.

Braking Parameters

M1–M2, BRAKE C/L

The **braking current limit** parameter allows adjustment of the maximum current the controller will supply to the motor during braking. The braking current limit is adjustable from 50 amps up to the controller's full rated braking current. (The full rated braking current depends on the controller model; see specifications in Table E-1.)

The braking current limit is tuned as part of the vehicle performance adjustment process (Section 5).

M1–M2, BRAKE RATE

The **braking rate** defines the time it takes the controller to increase from 0% braking output to 100% braking output when a new direction is selected. A larger value represents a longer time and consequently gentler braking. Faster braking is achieved by adjusting the braking rate to a smaller value. The braking rate is adjustable from 0.1 to 3.0 seconds.

M1–M2, DECEL RATE

The **deceleration rate** defines the time it takes the controller to decelerate from 100% output to 0% output. The decel rate determines the vehicle's braking characteristic for any reduction in throttle that does not include a request for the opposite direction. A lower value represents a faster deceleration and thus a shorter stopping distance. The decel rate is adjustable from 0.1 to 10.0 seconds.

COAST DECEL

The **coast deceleration rate** defines how quickly the controller reduces it output to zero when the Pick switch is released. This parameter allows adjustment for different sized vehicles. Lower values represent faster deceleration and thus a shorter coasting distance. The coast decel rate is adjustable from 0.1 to 10.0 seconds.

TAPER RATE

The **taper rate** determines how quickly the vehicle changes direction when the opposite direction is selected. Low taper rate values result in fast and abrupt direction transitions. Higher taper rate values result in slower and smoother direction transitions. The taper rate is adjustable from 1 to 20.

The taper rate is tuned as part of the vehicle performance adjustment process (Section 5).

THROTTLE DECEL

The **throttle deceleration rate** parameter adjusts the rate at which the vehicle transitions to braking when throttle is first reduced. If the throttle decel rate is set low, deceleration is initiated abruptly. The transition is smoother if the throttle decel rate is higher; however, setting the throttle decel parameter too high can cause the vehicle to feel uncontrollable when the throttle is released, as it will continue to drive for a short period. The throttle decel rate is adjustable from 0.1 to 1.0 second, with a value of 0.3 or 0.4 working well for most vehicles.

When the armature current goes negative (i.e., at the point when positive torque transitions to negative torque), the normal decel rate goes into effect.

INT BRAKE C/L

If the interlock switch is opened while the vehicle is being driven, the controller will send braking current to the motor. This braking—which is called interlock braking—greatly reduces wear on the vehicle's electromagnetic brake and also enables the vehicle to meet more stringent stopping distance requirements. The **interlock braking current limit** parameter allows adjustment of the maximum braking current the controller will supply to the motor during interlock braking. The interlock braking current limit is adjustable from 50 amps up to the controller's full rated braking current. (The full rated braking current depends on the controller model; see specifications in Table E-1.)

INT BRAKE RATE

The **interlock braking rate** parameter defines the time it takes the controller to increase from 0% braking output to 100% braking output when interlock braking is initiated. The interlock braking rate is adjustable from 0.0 to 3.0 seconds.

INT BRAKE DLY

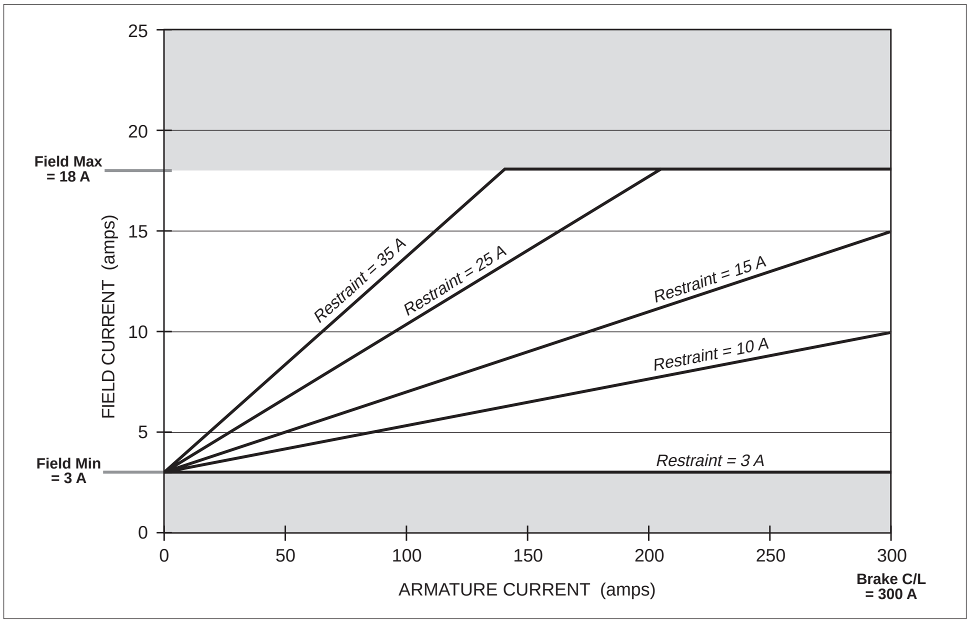
The **interlock braking delay** feature allows the interlock switch to be cycled within a set time (the braking delay), thus preventing inadvertent activation of interlock braking. This feature is especially useful in applications where the interlock switch may bounce or be momentarily cycled during operation. The interlock braking delay parameter can be set from 0.0 to 30.0 seconds, with zero corresponding to no delay.

RESTRAINT

Because the 1297 controller is configured to provide regenerative braking, overspeed causes the controller to create a braking current and thus limit or "restrain" the overspeed condition. The **restraint** parameter determines how strongly the controller tries to limit the vehicle speed to the existing throttle setting. It is applicable when throttle is reduced or when the vehicle begins to travel downhill.

At zero throttle, the restraint function tries to keep the motor at zero speed, which helps hold the vehicle from running away down ramps. The higher the restraint value, the stronger the braking force applied to the motor and the

Fig. 12 *Ramp restraint map for controller with Field Min set at 3 amps, Field Max set at 18 amps, and braking current limit set at 300 amps.*



slower the vehicle will creep down ramps. This creeping speed depends on the restraint setting, the steepness of the ramp, and the vehicle load weight. The restraint feature can never hold a vehicle perfectly stationary on a ramp and is not intended to replace a mechanical or electromagnetic brake for this purpose.

The restraint parameter establishes a mapping of field current to armature current, as shown in Figure 12, and is adjustable from the programmed minimum field (Field Min) to the full rated current. As shown in the diagram, restraint is limited by the programmed maximum field (Field Max). Setting the restraint parameter to a high value will cause strong braking, in an effort to bring the vehicle speed down to the requested speed. Extremely high values may cause the vehicle speed to oscillate (“hunt”) while in ramp restraint.

The restraint parameter is tuned as part of the vehicle performance adjustment process (Section 5).

VARIABLE BRAKE

The **variable braking** parameter defines how the controller will apply braking force when braking is requested. If the variable braking parameter is programmed On, the amount of braking current applied by the controller will be a function of the throttle’s position when braking is requested. With variable braking, the operator can use the throttle to control the amount of braking force applied to a moving vehicle. Increasing throttle in the direction opposite to the vehicle’s motion will apply increasing amounts of regenerative braking current to the motor, slowing the vehicle more quickly.

If a fixed amount of braking force is preferred, the variable braking parameter should be programmed Off. With variable braking Off, the controller applies the full programmed braking current as soon as direction is reversed.

E-M BRAKE TYPE

The **electromagnetic brake type** parameter configures the low side brake driver at J1 Pin 20. Driver output is rated at 2 amps and is monitored for overcurrent faults. An internal diode provides coil suppression through the KSI input (J1 Pin 1). The electromagnetic brake driver can be programmed to operate in any of the configurations (i.e., options 0 through 4) described in Table 2.

E-M BRAKE DLY

The **electromagnetic brake driver open delay** parameter allows a delay after the interlock switch has been opened before the brake driver drops out. The delay is useful for maintaining braking power for a short time after the interlock switch has been opened. This parameter is adjustable from 0.0 to 30.0 seconds. When set to zero, there is no delay and the brake driver opens as soon as the interlock switch is opened and the sequencing delay expires. This parameter is not valid when brake driver option 0 is selected (see Table 2).

Table 2 CONFIGURATION OPTIONS: ELECTROMAGNETIC BRAKE DRIVER (J1 Pin 20)

OPTION	DESCRIPTION OF OPERATION
0	Brake Driver disabled.
1	Electromagnetic brake used like a parking brake. The Brake Driver powers the brake coil when the interlock switch closes, and opens it immediately when the interlock switch opens. There is no delay, other than the specified Brake Delay, between the Brake Driver being turned off and the interlock switch opening.
2	Electromagnetic brake engages whenever the throttle is in neutral and the vehicle is not moving. The Brake Driver turns on and disengages the brake when a direction switch closes. The Brake Driver turns off, engaging the brake, after the controller reaches neutral state* and the specified Brake Delay time expires. With Option 2, the Brake Driver remains on after the emergency reverse switch opens if a direction switch is still closed. The Brake Driver turns off only after the specified Brake Delay when controller reaches neutral state.* The interlock switch must be closed for the Brake Driver to energize the brake coil and release the brake. The Brake Driver turns off, engaging the brake, when the interlock switch opens and the Brake Delay time expires.
3	Electromagnetic brake engages whenever the throttle is in neutral and the vehicle is not moving <u>or</u> after the emergency reverse switch closes and is then released. During normal operation, Brake Driver Option 3 controls braking as in Option 2. However, if emergency reverse is engaged, the Brake Driver turns off, releasing the brake <u>after</u> the emergency reverse switch opens and the Brake Delay time expires. After the emergency reverse switch opens, the Brake Driver turns off even if controller is not in neutral state.* The interlock switch must be closed for the Brake Driver to energize the brake coil and release the brake. The Brake Driver turns off, engaging the brake, when the interlock switch opens and the Brake Delay time expires.
4	Electromagnetic brake engages whenever the interlock switch is open (as in Option 1) and also after the emergency reverse switch has been released. The interlock switch must be closed for the Brake Driver to energize the brake coil and release the brake. The Brake Driver turns off, engaging the brake, when the interlock switch opens and the Brake Delay time expires. Also, if emergency reverse is engaged, the Brake Driver turns off, releasing the brake <u>after</u> the emergency reverse switch opens and the Brake Delay time expires. After the emergency reverse switch opens, the Brake Driver turns off even if controller is not in neutral state.*

* The neutral state is reached when the traction throttle is in neutral, no direction is selected (both direction switches open), and any braking is completed.

Speed Parameters

M1–M2, MAX SPEED

The **maximum speed** parameter defines the maximum controller voltage output at full throttle. The maximum speed parameter is adjustable from 0% to 100% of full output.

The maximum speed is tuned as part of the vehicle performance adjustment process (Section 5).

CREEP SPEED

The **creep speed** parameter defines the initial controller output generated when a direction is first selected. No applied throttle is necessary for the vehicle to enter the creep mode, only a direction signal. The controller 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 cycle. For most applications, the default setting of 0% is appropriate. For heavy vehicles, however, increasing the creep speed may improve controllability by reducing the amount of throttle required to start the vehicle moving. In any case, the creep speed should always be set low enough so there is some neutral deadband before the vehicle starts to move and it should never be set so high the vehicle is moving too fast when the throttle returns to small values just above the deadband.

NOTE: The programmed creep speed is not displayed as the "Throttle %" value in the programmer's Test Menu when a direction is selected and zero throttle is applied; only the 0% throttle command is displayed.

H/S LATCH

The **high speed latch** parameter is only applicable when the mode switch is a momentary switch. When the high speed latch parameter is programmed On, it allows the mode switch to be "latched" in the M2 position (which is typically the high speed position) without the operator having to keep it pressed in. In other words, it makes the momentary switch function as a pushbutton latching switch. The switch automatically "unlatches" when the vehicle changes direction, and must be re-latched if desired in the new direction.

CAUTION

CAUTION: When the vehicle is traveling in high speed mode with the high speed latch parameter programmed On, emergency reverse is disabled.

INT OVERRIDE

The **interlock override** parameter, when programmed On, allows the vehicle to be driven with the interlock switch open. The interlock override feature is useful in situations where it is necessary to move the vehicle but there is not room to lower the tiller—for example, in a corner.

If the interlock override feature is desired, you will probably want to configure M2 (mode switch closed) as the slow speed mode, and M1 (mode switch open) as the high speed mode. This is opposite of the typical setup. NOTE: The interlock override feature and the high speed latch parameters are mutually exclusive; you cannot have both.

To initiate override, close the mode switch (M2) while the vehicle is stopped with the interlock switch open.

To resume normal operation, the interlock or KSI must be cycled.

LOAD COMP

The **load compensation** parameter actively adjusts the applied motor voltage as a function of motor load current. This results in more constant vehicle speeds over variations in driving surface (ramps, rough terrain, etc.) without the vehicle operator constantly adjusting the throttle position; it also helps equalize loaded and unloaded vehicle speeds. The load compensation parameter is adjustable from 0 to 25% of the controller's PWM output. High values will cause the controller to be more aggressive in attempting to maintain vehicle speed. However, too much load compensation can result in jerky vehicle starts and speed oscillation ("hunting") when the vehicle is unloaded.

The load compensation parameter is tuned as part of the vehicle performance adjustment process (Section 5).

Throttle Parameters

THROTTLE TYPE

The 1297 controller accepts a variety of throttle inputs. Instructions are provided in Section 2 for wiring the most commonly used throttles: 5kΩ–0 and 0–5kΩ 2-wire rheostats, 3-wire pots (single-ended or wigwag), 0–5V throttles (single-ended or wigwag), current sources (single-ended or wigwag), and the Curtis ET-XXX electronic throttle.

The **throttle type** parameter can be programmed to 1, 2, 3, or 4. The standard throttle input signal type options are listed in Table 3.

Table 3 PROGRAMMABLE THROTTLE TYPES: Traction Throttle

THROTTLE TYPE	DESCRIPTION
1	2-wire rheostat, 5kΩ–0 input
2	single-ended 3-wire potentiometer with 1kΩ to 10kΩ range; 0–5V voltage source; current source; or Curtis ET-1XX electronic throttle
3	2-wire rheostat, 0–5kΩ input
4	wigwag 3-wire potentiometer with 1kΩ to 10kΩ range; 0–5V voltage source; or current source

THROTTLE DB

The **throttle deadband** parameter defines the throttle pot wiper voltage range that the controller interprets as neutral. Increasing the throttle deadband setting increases the neutral range. This parameter is especially useful with throttle assemblies that do not reliably return to a well-defined neutral point, because it allows the deadband to be defined wide enough to ensure that the controller goes into neutral when the throttle mechanism is released.

Examples of deadband settings (0%, 10%, 40%) are shown in Figure 13 for the four throttle types (see Table 3). In all the examples in Figure 13, the throttle max parameter is set at 100%.

The throttle deadband parameter is adjustable from 0% to 40% of the nominal throttle wiper range; the default setting is 10%. The nominal throttle wiper voltage range depends on the throttle type selected. See Table 1 (page 12) for the characteristics of your selected throttle type.

The throttle deadband is tuned as part of the vehicle performance adjustment process (Section 5).

Fig. 13 *Effect of adjusting the throttle deadband parameter (throttle types 1 and 2).*

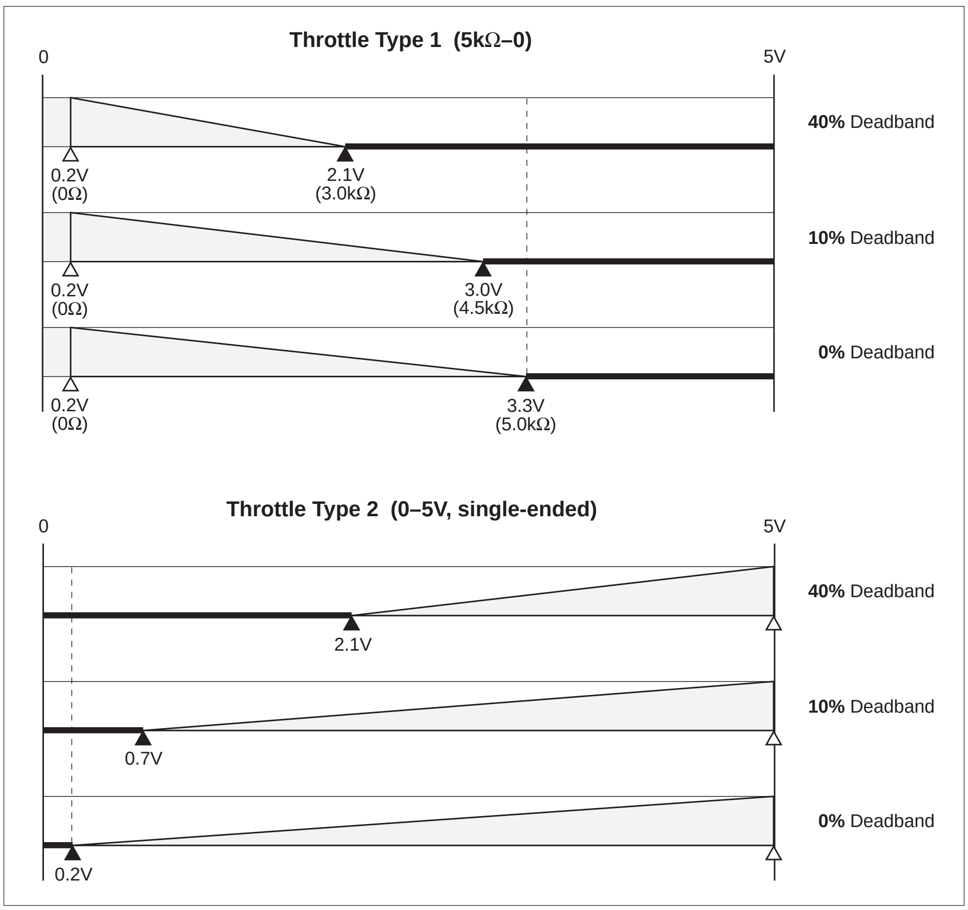
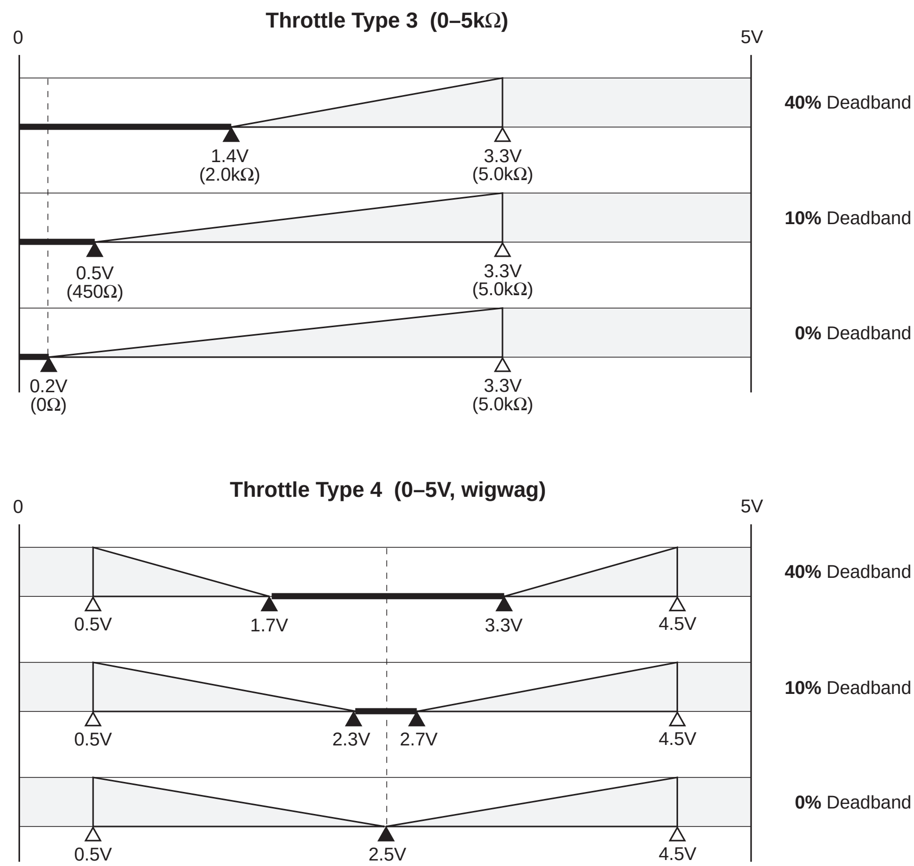
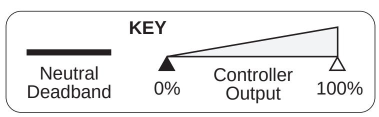


Fig. 13, cont'd *Effect of adjusting the throttle deadband parameter (throttle types 3 and 4).*





Notes: Voltages shown are at the pot wiper relative to B-.

For throttle types 1 and 3, the deadband points are defined in terms of the nominal 5kΩ pot resistance. Using a pot of greater or lesser resistance will give different values for the deadband points.

Throttle Max parameter set at 100%.

THROTTLE MAX

The **throttle maximum** parameter sets the wiper voltage or resistance required to produce 100% controller output. Decreasing the throttle max setting reduces the wiper voltage or resistance and therefore the full stroke necessary to produce full controller output. This feature allows reduced-range throttle assemblies to be accommodated.

Examples are shown in Figure 14 to illustrate the effect of three different throttle max settings (100%, 90%, 60%) on the full-stroke wiper voltage or resistance required to attain 100% controller output for the four throttle types.

The programmer displays the throttle max parameter as a percentage of the throttle range. The throttle max parameter can be adjusted from 100% to 60%; the default setting is 90%. The nominal throttle wiper range depends on the throttle type selected. See Table 1 (page 12) for the characteristics of your selected throttle type.

The throttle max parameter is tuned as part of the vehicle performance adjustment process (Section 5).

Fig. 14 *Effect of adjusting the throttle max parameter (throttle types 1 and 2).*

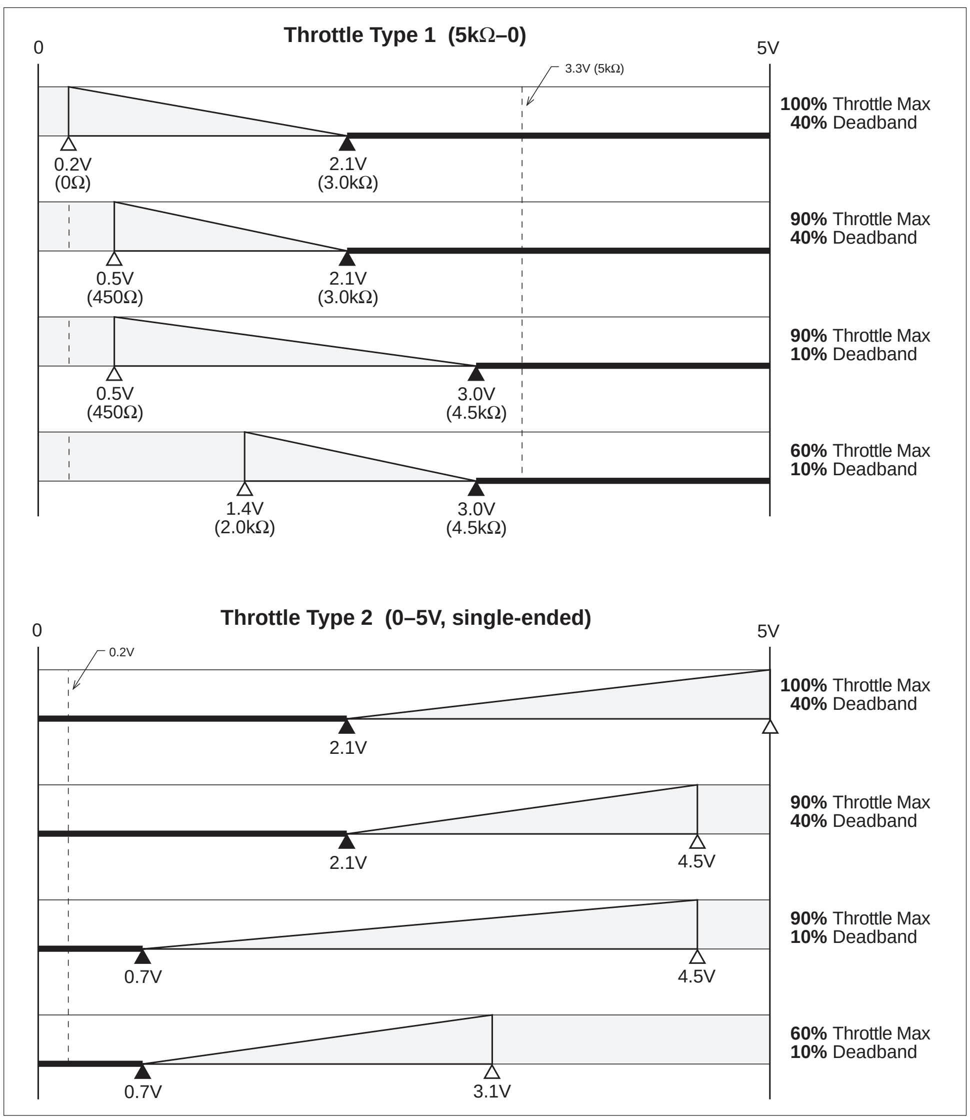
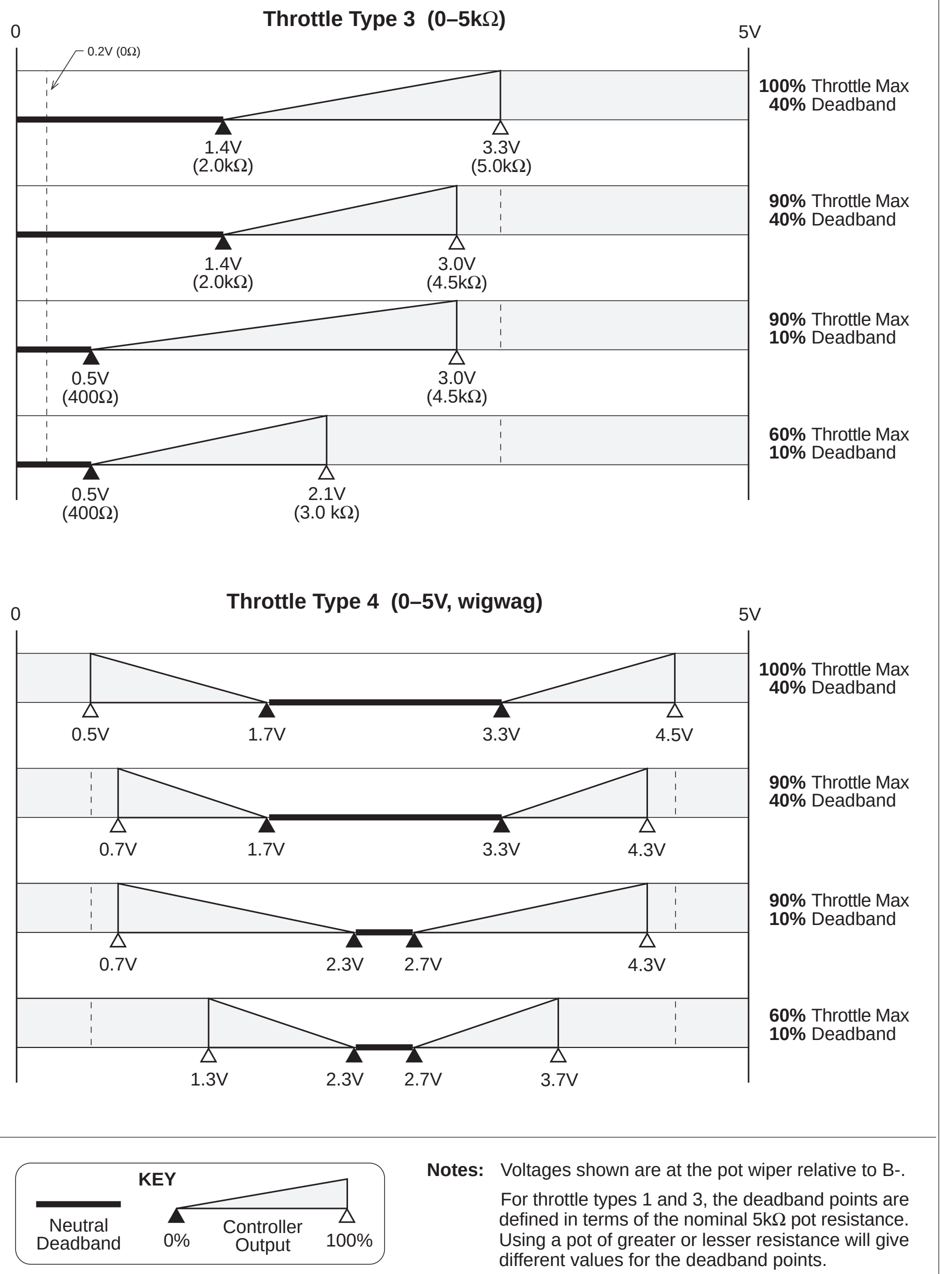


Fig. 14, cont'd
Effect of adjusting the throttle max parameter (throttle types 3 and 4).



Notes: Voltages shown are at the pot wiper relative to B-.

For throttle types 1 and 3, the deadband points are defined in terms of the nominal 5kΩ pot resistance. Using a pot of greater or lesser resistance will give different values for the deadband points.

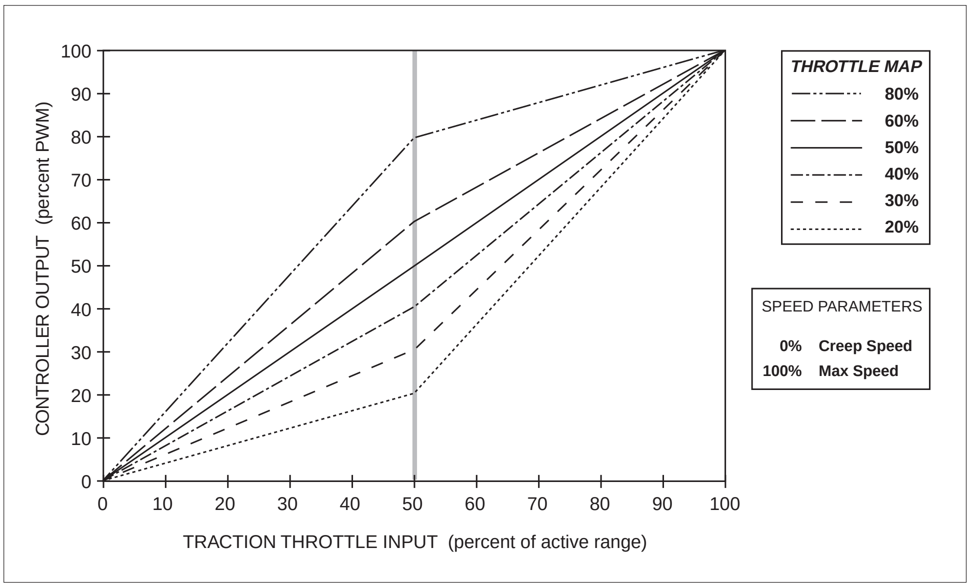
THROTTLE MAP

The **throttle map** parameter determines the static throttle map of the controller. This parameter modifies the vehicle's response to the throttle input. Setting the throttle map parameter at 50% provides a linear output response to throttle position. Values below 50% reduce the controller output at low throttle settings, providing enhanced slow speed maneuverability. Values above 50% give the vehicle a faster, more responsive feel at low throttle settings.

The throttle map setting can be programmed between 20% and 80%. The setting refers to the PWM output at half throttle, as a percentage of the throttle's full active range. The throttle's active range is the voltage or resistance between the 0% modulation point (the throttle deadband threshold) and the 100% modulation point (the throttle max threshold).

With creep speed set at 0% and maximum speed set at 100%, a throttle map setting of 50% will give 50% output at half throttle. As noted above, the 50% ramp shape is always a linear response. A throttle map setting of 80% will give 80% output at half throttle. Six throttle map profiles (20, 30, 40, 50, 60, and 80%) are shown in Figure 15; in all these examples the creep speed is set at 0% and the maximum speed at 100%.

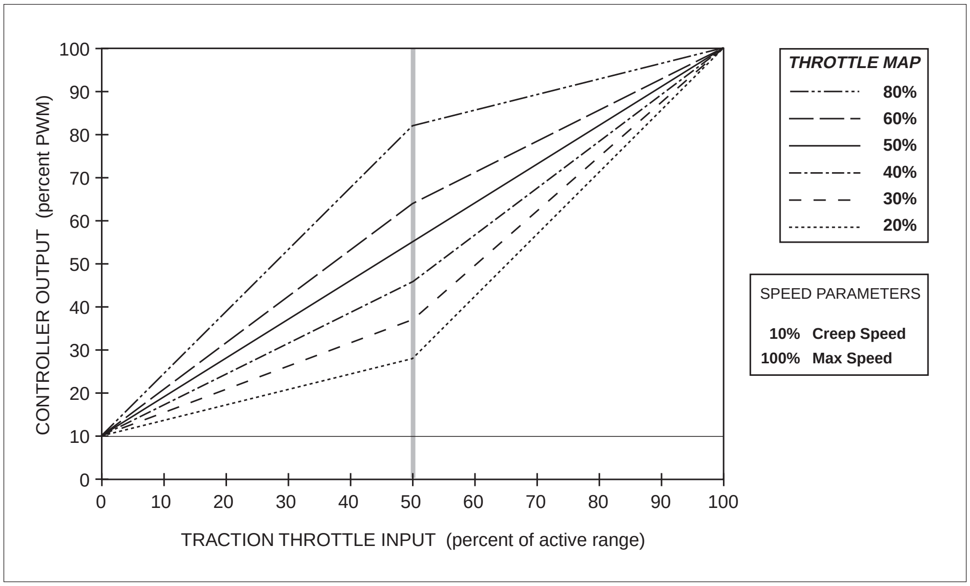
Fig. 15 *Throttle maps for controller with maximum speed set at 100% and creep speed set at 0%.*



Raising the creep speed parameter or lowering the maximum speed parameter limits the controller's output range, as shown in Figures 16 and 17. Controller output is always a percentage of the range defined by the speed parameters (the range between the creep speed and maximum speed settings).

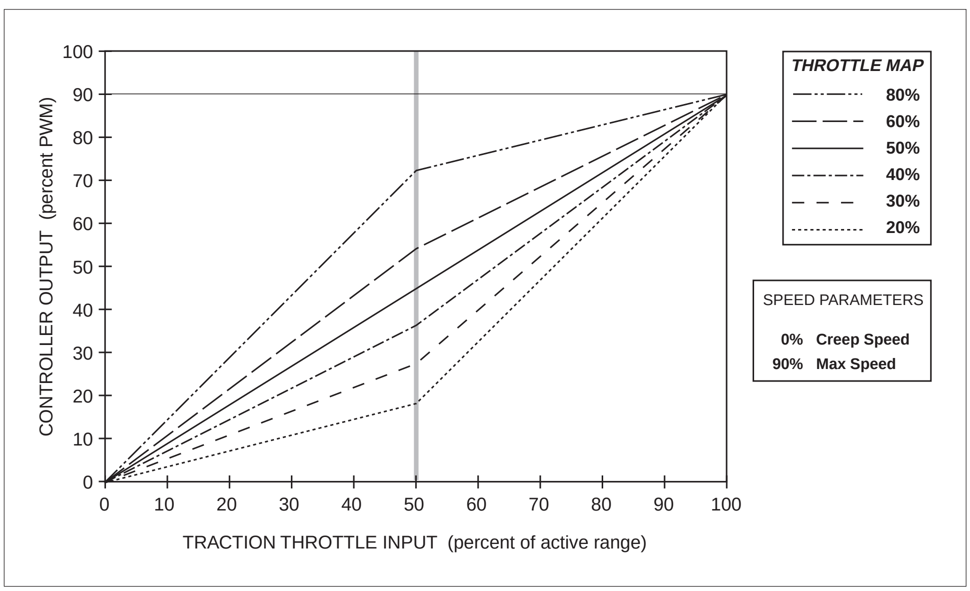
In Figure 16, the creep speed is increased to 10% and the maximum speed is left at 100%, resulting in a controller output range of 90%. With these speed settings, a 50% throttle map will result in 55% output (45% + 10%) at half throttle.

Fig. 16 *Throttle maps for controller with maximum speed set at 100% and creep speed set at 10%.*



In Figure 17, the maximum speed is decreased to 90% and the creep speed is left at 0%; again, the controller output range is 90%. With these speed settings, a 50% throttle map will result in 45% output at half throttle.

Fig. 17 *Throttle maps for controller with maximum speed set at 90% and creep speed set at 0%.*



The throttle map operates within the window established by the Creep Speed, Max Speed, Throttle Deadband, and Throttle Max parameters, as shown in Figure 18. Creep Speed and Max Speed define the controller's output range, while Throttle Deadband and Throttle Max define the throttle's active

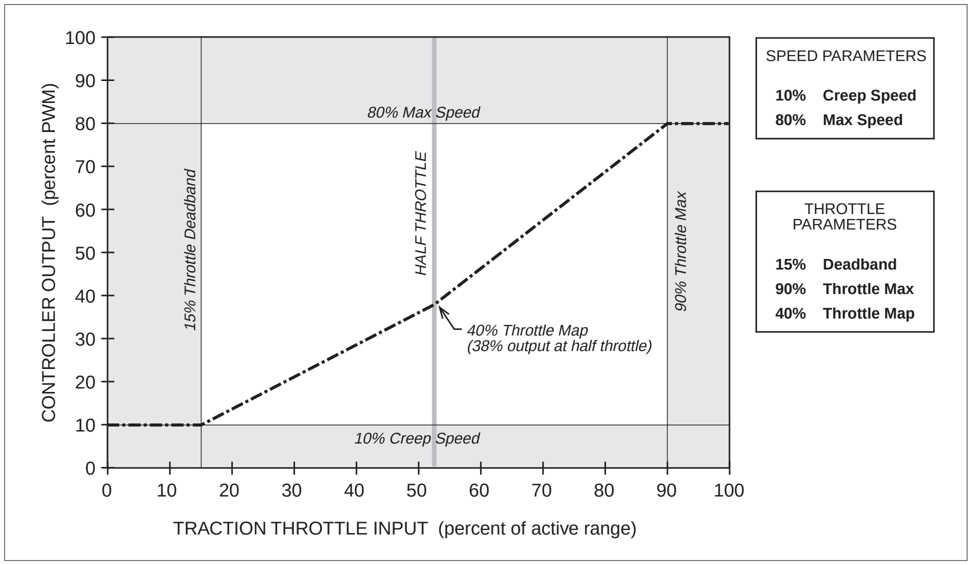


Fig. 18 *Influence of various parameters on controller output response to throttle demand.*

range. These four parameters, together with the throttle map, determine the controller's output response to throttle demand.

The throttle map parameter is tuned as part of the vehicle performance adjustment process (Section 5).

POT LOW CHECK

The **pot low check** feature checks the voltage at the wiper input (J1 Pin 4) and faults the controller if this voltage drops below 0.06 V. The pot low check parameter can be enabled (programmed On) or disabled (programmed Off). Disabling the pot low check feature is useful when single-wire, ground (B-) referenced voltage throttle inputs are used. It is recommended that the pot low check parameter be set to On in any application where a resistive throttle is used. This will provide maximum throttle fault detection and provide the safest possible vehicle operation.

Field Parameters

FIELD MIN

The **minimum field current limit** parameter defines the minimum allowed field winding current. The minimum field current limit setting determines the vehicle's maximum speed. Field Min can be adjusted from 2 amps up to the programmed Field Max value.

The Field Min parameter is tuned as part of the vehicle performance adjustment process (Section 5).

FIELD MAX

The **maximum field current limit** parameter defines the maximum allowed field winding current. The maximum field current limit setting determines the vehicle's maximum torque and limits the power dissipation in the field winding itself. Field Max can be adjusted from the programmed Field Min value up to the controller's full rated field current. (The full rated field current depends on the controller model; see specifications in Table E-1.)

The Field Max parameter is tuned as part of the vehicle performance adjustment process (Section 5).

FLD MAP START

The **field map start** parameter defines the armature current at which the field map starts to increase; it is adjustable from 25 amps up to the controller's full rated armature current value. (The full rated armature current depends on the controller model; see specifications in Table E-1.)

The field map start parameter is used to equalize the vehicle's maximum speed when loaded and unloaded. Increasing the field map start parameter value will increase the maximum load weight that the vehicle can carry while maintaining maximum speed on a level surface.

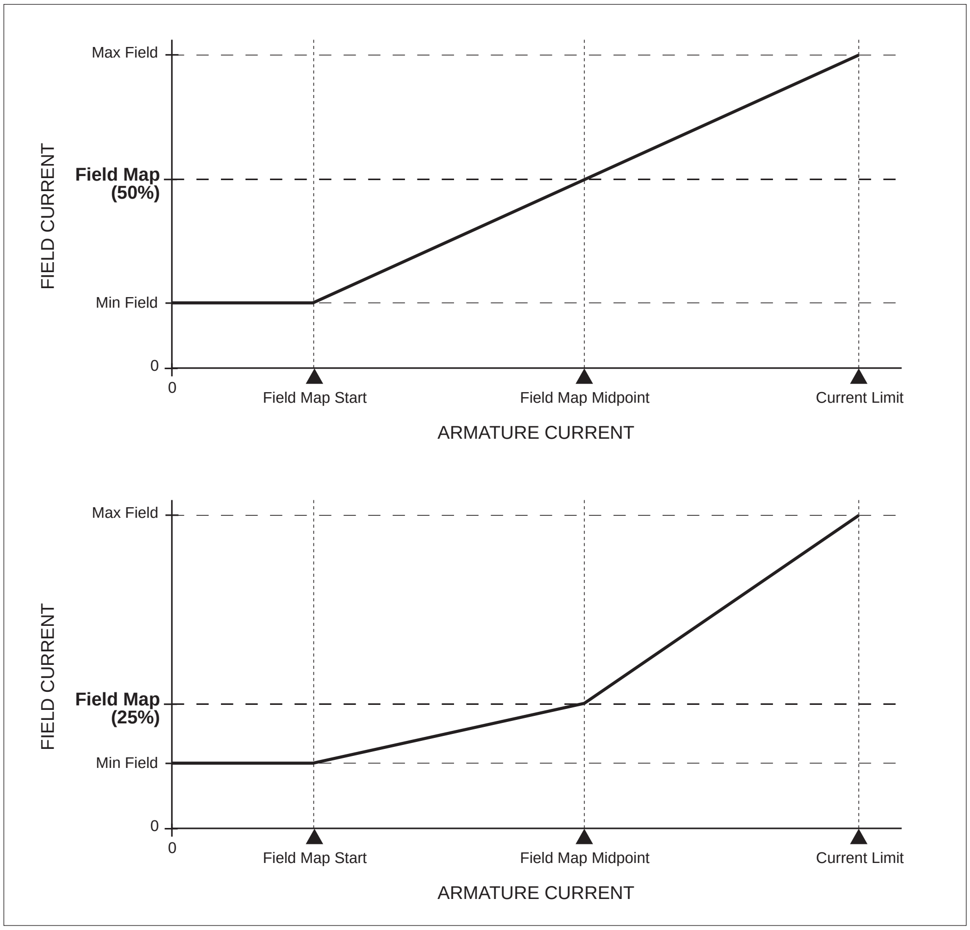
The field map start parameter is tuned as part of the vehicle performance adjustment process (Section 5).

FIELD MAP

The **field map** parameter controls how much field current is applied for a given armature current. This parameter, along with the other field current parameters (Field Min, Field Max, and Field Map Start), allows the OEM to set the vehicle's speed and power performance characteristics.

The field map parameter is set as a percentage of the field current between the Field Min and Field Max values. As shown in Figure 19, the field map parameter adjusts the field current at a point halfway between the programmed Field Map Start current and the full armature current (which is the controller's

Fig. 19 *Field current relative to armature current, with field map parameter set at 50% and at 25%.*



programmed drive current limit). This point is referred to as the Field Map Midpoint.

With the field map parameter set at 50%, the motor's field current increases linearly with increasing armature current—thus emulating a series wound motor. Decreasing the field map parameter reduces the field current at a given armature current, i.e., it weakens the field. As the field current is reduced, the motor will be able to maintain speeds closer to the maximum speed value as its load increases; however, the motor's capability to produce torque at these higher speeds will decrease.

The field map parameter is tuned as part of the vehicle performance adjustment process (Section 5).

FIELD CHECK

The **field check** parameter enables the field open fault check, when it is programmed On. In applications where the motor field is too low to provide valid fault data (< 5 amps at 97% PWM), this parameter should be programmed Off. In most applications, it should be programmed On.

Emergency Reverse Parameters

EMR REV C/L

The **emergency reverse current limit** parameter defines the maximum braking current provided through the motor when the optional emergency reverse function is engaged. The emergency reverse current limit is adjustable from 50 amps up to the controller's full rated braking current. (The full rated braking current depends on the controller model; see specifications in Table E-1.)

EMR REV CHECK

The **emergency reverse check** parameter is applicable only when the emergency reverse feature is being used in the application. If emergency reverse is not being used, this parameter should be set to Off.

When enabled (programmed On), the emergency reverse check tests for continuity from the emergency reverse check output (J1 Pin 9) to the emergency reverse input (J1 Pin 6). Therefore, the emergency reverse wiring should be connected as closely as possible to the controller side of the emergency reverse switch. The recommended wiring is shown in Figures 3 and 4, pages 8 and 10.

EMR REV ACCEL

The **emergency reverse acceleration rate** parameter defines the time it takes the controller to accelerate from 0% to 100% output in the opposite direction when emergency reverse is activated. Larger values represent a longer acceleration time and therefore a gentler response. More abrupt response can be achieved by reducing the acceleration time, i.e., by setting the accel rate to a lower value.

The emergency reverse accel rate is adjustable from 0.0 to 3.0 seconds.

EMR REV TIME LIMIT

The **emergency reverse time limit** parameter can be used to provide a 5 second time limit on emergency reversing. If this parameter is programmed On, emergency reversing will stop after 5 seconds even if the emergency reverse button is still being pushed in; at the end of this 5 second period, the controller will set the drive output to zero. If this parameter is programmed Off, emergency reversing will continue as long as the emergency reverse button is pushed in.

EMR DIR INT

As soon as the emergency reverse button is released, the controller sets the drive output to zero regardless of whether a direction or throttle is still being requested. The **emergency reverse direction interlock** parameter defines how the controller will return to normal operation from this point. If the emergency reverse direction interlock parameter is set to On, the operator can either open both direction switches or cycle the interlock switch to enable normal operation. With the parameter set to Off, the only way for the operator to resume normal operation is by cycling the interlock switch.

Other Traction Parameters

ANTI-TIEDOWN

The **anti-tiedown** feature prevents operators from taping or "tying down" the mode switch in order to operate permanently in Mode 2 (which is typically the high speed mode). Upon startup, when the interlock switch is first closed, the anti-tiedown feature checks which mode is selected. If the mode switch is requesting Mode 2 (i.e., switch closed), the controller will ignore the request and default to Mode 1. The controller will remain in Mode 1 until the mode switch is released and reactivated. Anti-tiedown can be programmed On or Off.

HPD

The **high pedal disable (HPD)** feature prevents the vehicle from driving the motor if the controller is turned on when greater than 25% throttle is applied. 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.

If the operator attempts to start the vehicle with the throttle already applied, the controller will inhibit output to the motor until the throttle is reduced below 25%. For the vehicle to run, the controller must receive a KSI input—or a KSI input and an interlock input—before receiving a throttle input greater than 25%. Either type of HPD (HPD based on KSI input alone or HPD based on KSI plus interlock inputs) can be selected via the programmer. HPD can also be disabled. To meet EEC requirements, the HPD feature must be programmed to Type 1 or Type 2.

Sequencing delay (see page 57) can be used to provide a brief delay before HPD inhibits the controller output, if desired.

No HPD (Type 0)

HPD function is disabled.

Interlock-type HPD (Type 1)

To start the vehicle, the controller must receive both an interlock switch input and a KSI input before receiving a throttle input greater than 25%. Controller operation will be disabled immediately if throttle demand is greater than 25%

at the time the interlock switch is closed. Normal controller operation is regained by reducing the throttle demand to less than 25%.

KSI-type HPD (Type 2)

To start the vehicle, the controller must receive a KSI input before receiving a throttle input greater than 25%. Controller operation will be disabled immediately if throttle demand is greater than 25% at the time KSI is enabled. In this configuration, if throttle is applied before the interlock switch is closed but after the KSI input has been enabled, the vehicle will accelerate to the requested speed as soon as the interlock switch is closed.

SRO

The **static return to off (SRO)** feature prevents the vehicle from being started when "in gear." SRO checks the sequencing of the interlock input—or the interlock input and KSI—relative to a direction input. The interlock input—or the interlock plus KSI inputs—must come on before a direction is selected. If a direction is selected before or simultaneously (within 50 msec) with the interlock input, controller output is inhibited.

Three types of SRO are available, along with a "no SRO" option. The programmer is used to make the selection:

Type 0: no SRO

Type 1: SRO unless interlock input before a direction input

Type 2: SRO unless KSI plus interlock input before a direction input

Type 3: SRO unless KSI plus interlock input before forward direction input.

If your controller is programmed so that KSI and interlock inputs are both required (SRO Type 2), the following sequence must be followed to enable the controller: STEP 1, turn on KSI; STEP 2, activate interlock (input "high"); and then STEP 3, select a direction. The interval between steps 1 and 2 is the same as between steps 2 and 3; that is, KSI input must precede interlock input by at least 50 msec. Once the controller is operational, turning off either KSI or the interlock causes the controller to inhibit its output; re-enabling the controller requires the 3-step sequence.

Similarly, if your controller is programmed so that KSI, interlock, and forward 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 reverse input precedes the interlock input; this can be useful when operating a walkie on ramps.

Sequencing delay (see page 57) can be used to provide a brief delay before SRO inhibits controller output, if desired.

B. HYDRAULIC PARAMETERS

The various hydraulic parameters adjust the hydraulic system's operating characteristics—its acceleration, speed, and responsiveness. These parameters allow the hydraulic system to be tailored to a specific application, or to a specific operator's preferences.

The 1297 controls the speed of the pump motor, and also the valves on the Lift cylinder's hydraulic line. By so doing, it controls the hydraulic path for Lift and Lower operations. The hydraulic path for any other hydraulic operations—e.g., reach, tilt, sideshift, rotate—is provided by the vehicle manufacturer, with the 1297 controlling the pump motor speed but not the hydraulic path itself.

Pump Parameters

PUMP C/L

The **pump current limit** parameter defines the maximum pump motor armature current. The pump current limit is adjustable from 25 amps up to the controller's full rated pump motor current. (The full rated pump current depends on the controller model; see specifications in Table E-1.)

PUMP MAX SPEED

When the Lift switch is closed, the controller activates the load-hold valve, thus enabling the Lift function—as shown in Figure 20. The **maximum pump speed** parameter defines the maximum allowed armature PWM output during Lift operations. The maximum pump speed parameter is adjustable from 0% to 100% of full output.

The maximum pump speed is tuned as part of the vehicle performance adjustment process (Section 5).

NO LOAD C/L

The **no load pump current limit** parameter sets the current that will define the "no load" state. When the pump current is below this ceiling, the pump is considered to have no load, and the no load maximum pump speed will apply. If a separate maximum speed is not desired for unloaded situations, the no load pump current limit can be set at the same value as the regular pump current limit. The no load pump current limit can be adjusted from 0 amps up to the programmed pump current limit.

NO LOAD SPEED

The **no load maximum pump speed** parameter allows a higher maximum pump speed to be in effect when the pump motor is operating below the set "no load" current limit. The no load maximum pump speed parameter has the same

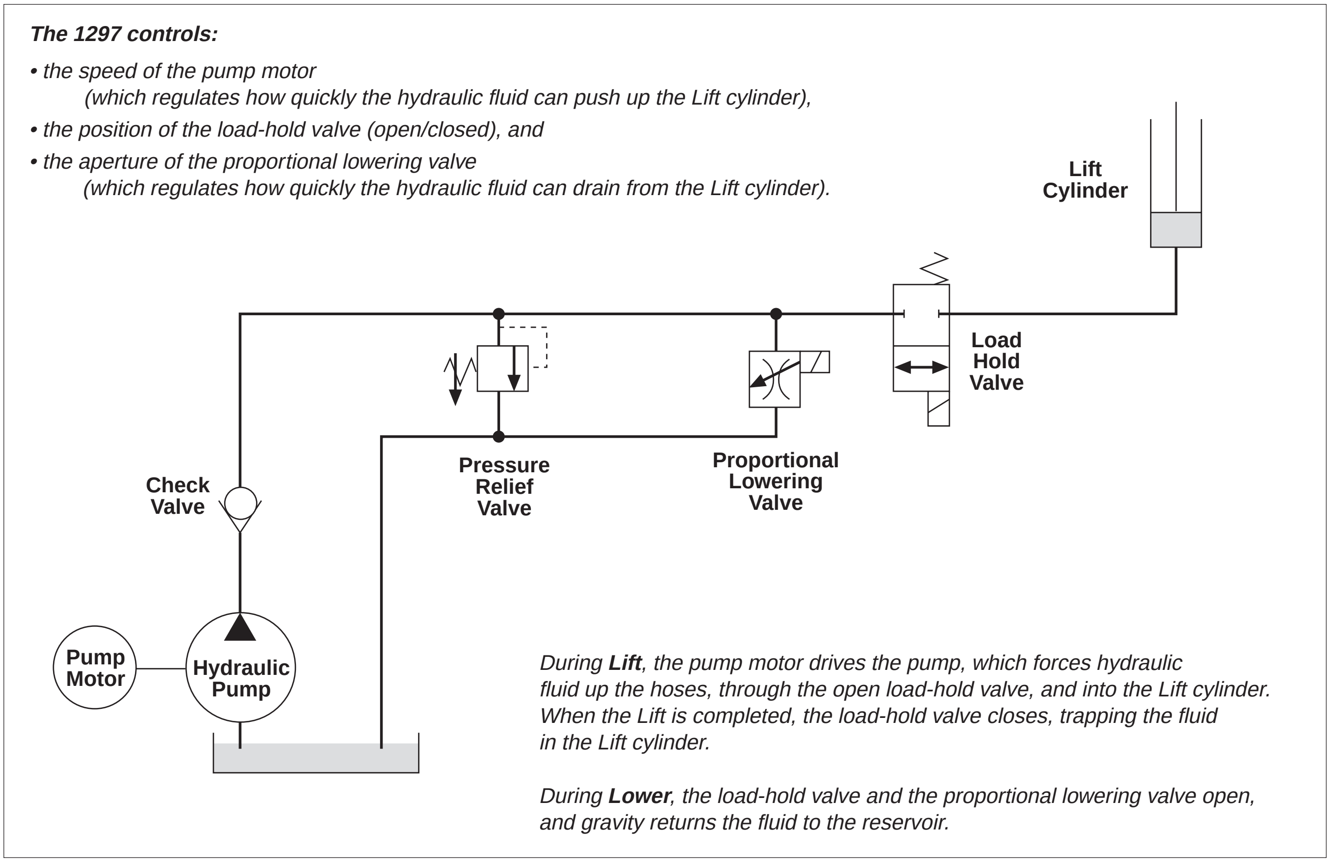


Fig. 20 *Hydraulic system diagram.*

adjustment range as the regular maximum pump speed parameter (0–100% full PWM output). If separate loaded and unloaded maximum speeds are not desired, this parameter can be set to the same value as the regular maximum pump speed parameter.

PUMP ACCEL

The **pump acceleration rate** parameter defines the time it takes for the controller to accelerate from 0% output to 100% output to the pump motor when Lift is requested with full hydraulic throttle. A larger value represents a longer acceleration time and a gentler start to the Lift operation. The pump accel rate is adjustable from 0.1 to 3.0 seconds.

PUMP DECEL

The **pump deceleration rate** parameter defines the time it takes for the controller to decelerate from 100% output to 0% output to the pump motor when the hydraulic throttle is reduced from full to none, or when the Lift switch is opened. The pump decel rate is adjustable from 0.1 to 3.0 seconds.

Lift Lockout Parameters

Lift operation can be prevented during overcurrent conditions or when the battery state-of-charge is below 20%. These are safety measures to protect the operator and the pump motor. In addition, both Lift and Lower can be prevented if more than 25% throttle is requested at the time the interlock switch is closed.

PUMP LOCK C/L

The **pump lockout current limit** parameter allows Lift operation to be prohibited when the pump motor current exceeds the set threshold. This threshold is adjustable from 25 amps to more than the controller's full rated pump current; the ceiling is 50 amps above the rated current. (The full rated pump current depends on the controller model; see specifications in Table E-1.)

PUMP LOCK DLY

The **pump lockout delay** parameter allows a delay after the pump motor current exceeds the pump lockout current limit before Lift operation is prohibited. The pump lockout delay is adjustable from 0.1 to 25.0 seconds.

PUMP BDI L/O

The **pump BDI lockout** feature prevents Lift operation when the battery state-of-charge is below 20%. This parameter can be programmed On or Off. When programmed On, if the battery S-O-C drops below 20% during a Lift operation, the Lift in progress will be completed but further Lift requests will be ignored as long as the battery S-O-C stays below 20%. If programmed Off, the Lift will continue operating until the undervoltage cutoff point is reached.

PUMP BDI WRN

If the battery state-of-charge is less than 25%, the **pump BDI lockout warning** feature beeps the horn twice each time Lift is requested, thus alerting the operator to the low S-O-C condition. The warning parameter can be programmed On or Off.

HYD INHIBIT

The **hydraulic inhibit** feature prevents Lift or Lower operation if the hydraulic throttle request is >25% when the interlock switch is closed. The hydraulic inhibit parameter can be programmed On or Off. Sequencing delay (see page 57) can be used to provide a brief delay before controller output is inhibited.

Valve Control Parameters

The 1297 controls the operation of the load-hold valve and the proportional lowering valve, as shown in Figure 21. By so doing, it controls the hydraulic path for Lift and Lower operations. Some hydraulic systems have a proportional lowering valve but no load-hold valve. Others have a simple open/closed lowering valve in place of a proportional valve. In these systems, variable lowering (i.e., lowering in proportion to the amount of throttle applied) is not possible. See box at the bottom of the next page for more information about this kind of system.

LV MAX CURR

The Lower speed is determined by the aperture of the lowering valve. The **LV maximum current parameter** sets the maximum current the controller will provide to the lowering valve. The LV maximum current is programmable from 0.0 to 3.0 amps.

For proportional valves, the LV maximum current can be set to limit the valve's full aperture. Non-proportional valves always open completely; for these valves, the LV maximum current should be set to the valve's full current rating.

LV MIN CURR

The **LV minimum current** parameter sets the minimum current through the lowering valve. Most proportional valves need a non-zero closed current in order to start opening immediately when Lower is requested. The LV minimum current is programmable from 0.0 to 1.0 amp. For non-proportional lowering valves, the controller does not look at this parameter so its setting is irrelevant.

LV DITHER

The lowering valve dither feature provides a constantly changing current in the coil to produce a rapid back-and-forth motion of the valve. This keeps proportional valves lubricated and allows low-friction, precise movement. The **LV dither %** parameter specifies the amount of dither as a percentage of the LV maximum current, and is applied in a continuous 200 Hz cycle of none–add%–none–subtract%. The LV dither is programmable from 0 to 100%.

For non-proportional lowering valves, where the valve's opening and closing is spring-activated, dither is not applicable. If your application uses this type of lowering valve, set the dither parameter to 0%.

LV ACCEL

The **LV current acceleration rate** parameter specifies how long it will take the lowering valve current to increase from 0% to 100%. The LV current accel rate is programmable from 0.0 to 3.0 seconds.

LV DECEL

The **LV current deceleration rate** parameter specifies how long it will take the lowering valve current to decrease from 100% to 0%. The LV current decel rate is programmable from 0.0 to 3.0 seconds.

LV CHECK

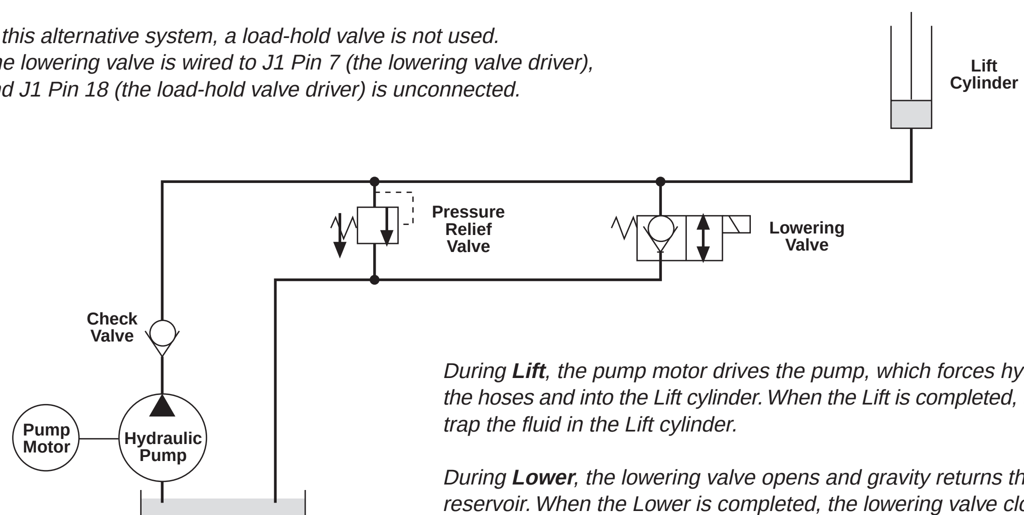
The **LV check** parameter defines whether the controller performs missing coil checks on the lowering valve solenoid coil. When this parameter is set to On, the controller senses the current at the lowering valve driver output (Pin 7) to confirm that the coil is properly connected. If the criteria for this test are not met, the controller will inhibit operation and issue a valve fault. This test is not performed if the LV check parameter is set to Off.

LOAD HOLD DLY

The **load hold delay** parameter specifies how long the load-hold valve is kept open at the end of a Lift or Lower action. The delay time is programmable from 0.0 to 1.0 seconds. The delay starts after the LV deceleration time (to allow the lowering valve to close at the completion of a Lower action) and after the pump deceleration time (to allow the pump speed to reach zero at the completion of a Lift action). The load-hold valve is either open or shut, which means that it closes abruptly. To prevent jitter it is important that the delay time be set long enough so that the hydraulic fluid has stopped flowing before the load-hold valve snaps shut.

Alternative hydraulic system, with a simple (open/closed) lowering valve instead of a proportional lowering valve.

In this alternative system, a load-hold valve is not used.
The lowering valve is wired to J1 Pin 7 (the lowering valve driver), and J1 Pin 18 (the load-hold valve driver) is unconnected.



*During **Lift**, the pump motor drives the pump, which forces hydraulic fluid up the hoses and into the Lift cylinder. When the Lift is completed, the check valves trap the fluid in the Lift cylinder.*

*During **Lower**, the lowering valve opens and gravity returns the fluid to the reservoir. When the Lower is completed, the lowering valve closes and this check valve plus the check valve at the pump keep the hydraulic fluid in place.*

Hydraulic Throttle Parameters

Most applications use a throttle to provide variable speed control of Lift and Lower. A throttle gives the operator more flexibility and control over performance than is provided by the Lift and Lower switches alone. Without a throttle, when the Lift switch is closed, the pump accelerates to the set maximum pump speed in the set pump acceleration time; when the Lower switch is closed, the lowering valve current ramps from 0% to 100% in the set LV acceleration time. For variable speed control, a throttle is required.

The hydraulic throttle is wired in parallel with the main traction throttle, as shown in the diagrams in the throttle wiring section (Section 2).

HYD THRTL TYPE

The 1297 controller accepts a variety of hydraulic throttle inputs. Instructions are provided in Section 2 for wiring the most commonly used throttles: 3-wire pots (single-ended or wigwag), 0–5V throttles (single-ended or wigwag), current sources (single-ended or wigwag), and the Curtis ET-XXX electronic throttle.

The **hydraulic throttle type** parameter can be programmed to 2 or 4. The standard throttle input signal type options are listed in Table 4.

Table 4 PROGRAMMABLE THROTTLE TYPES: Hydraulic Throttle

THROTTLE TYPE	DESCRIPTION
2	single-ended 3-wire potentiometer with 1kΩ to 10kΩ range; 0–5V voltage source; current source; or Curtis ET-1XX electronic throttle
4	wigwag 3-wire potentiometer with 1kΩ to 10kΩ range; 0–5V voltage source; or current source

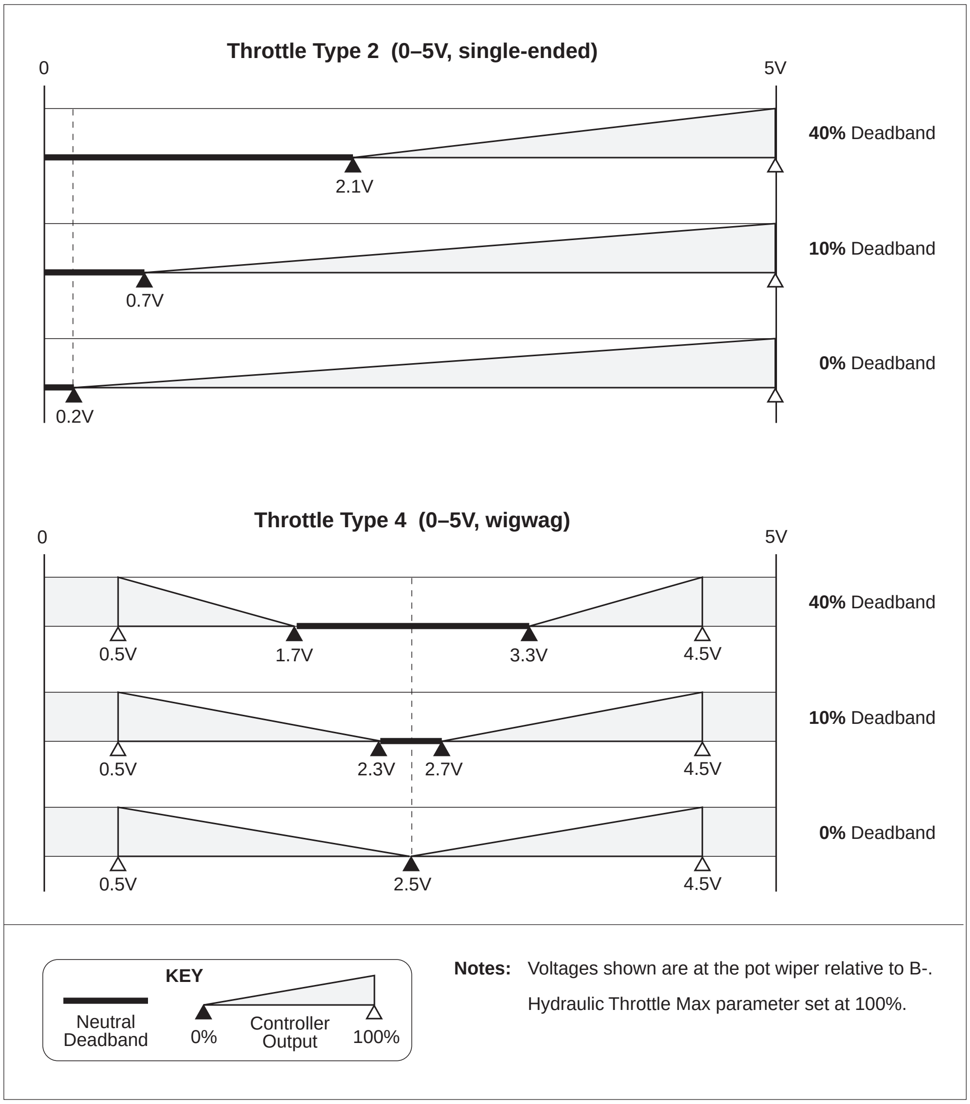
HYD THRTL DB

The **hydraulic throttle deadband** parameter defines the pot wiper voltage range the controller interprets as neutral. Increasing the throttle deadband setting increases the neutral range. This parameter is especially useful with throttle assemblies that do not reliably return to a well-defined neutral point, because it allows the deadband to be defined wide enough to ensure that the controller goes into neutral when the throttle mechanism is released.

Examples of deadband settings (40%, 10%, 0%) are shown in Figure 21 for throttle types 2 and 4.

The programmer displays the hydraulic throttle deadband parameter as a percentage of the nominal wiper voltage range and is adjustable from 0% to 40%. The default deadband setting is 10%. The nominal wiper voltage range depends on the throttle type selected. See Table 1 (page 12) for the characteristics of your selected throttle type.

Fig. 21 *Effect of adjusting the hydraulic throttle deadband parameter.*

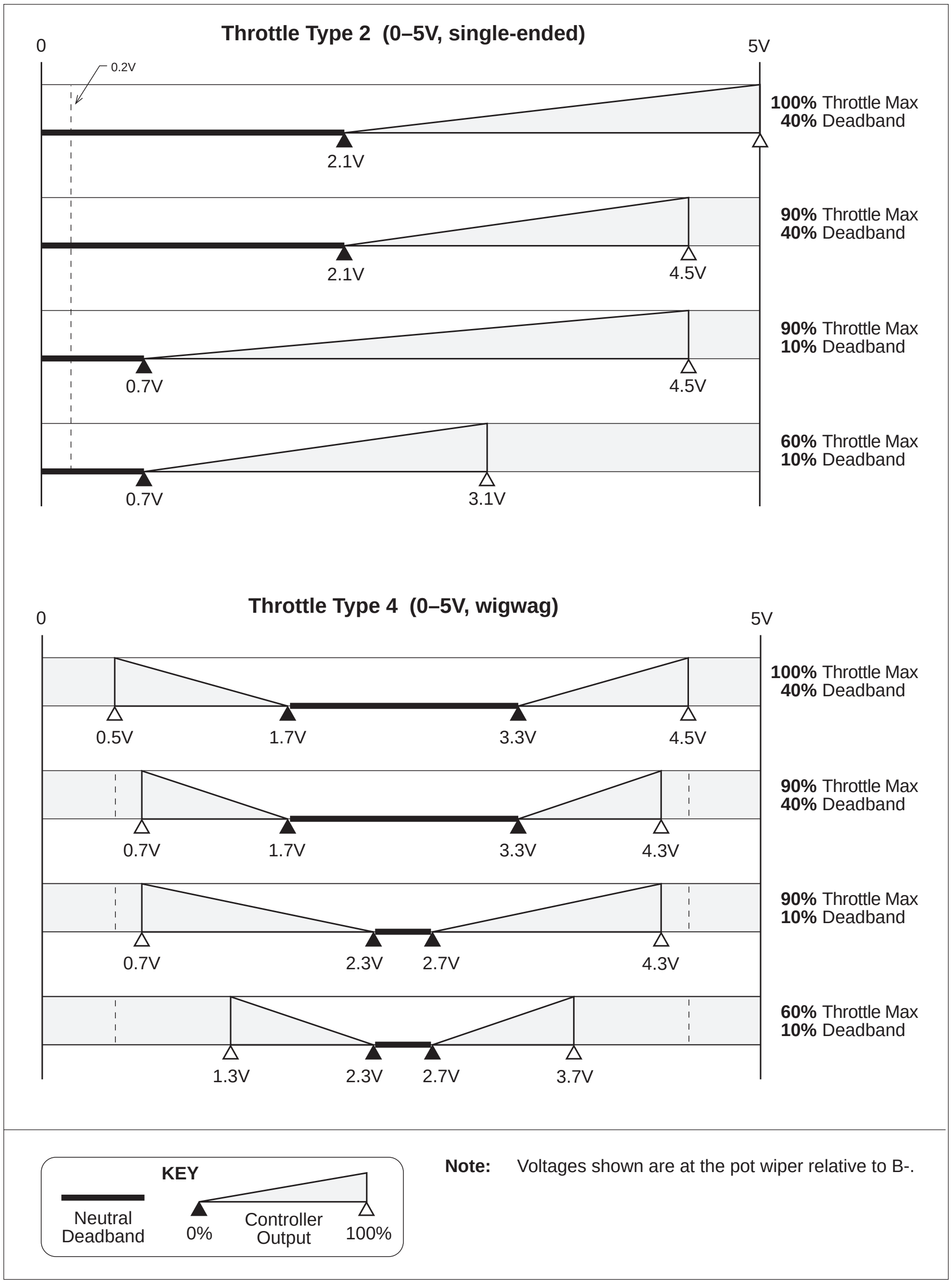


HYD THRTL MAX

The **hydraulic throttle maximum** parameter sets the throttle wiper voltage required to produce 100% controller output. Decreasing the hydraulic Throttle Max setting reduces the wiper voltage and therefore the full stroke necessary to produce full controller output. This feature allows reduced-range throttle assemblies to be accommodated.

Examples are shown in Figure 22 for throttle types 2 and 4. These examples illustrate the effect of three different Throttle Max settings (100%, 90%, 60%) on the full-stroke wiper voltage required to attain 100% controller output.

Fig. 22 *Effect of adjusting the hydraulic Throttle Max parameter.*



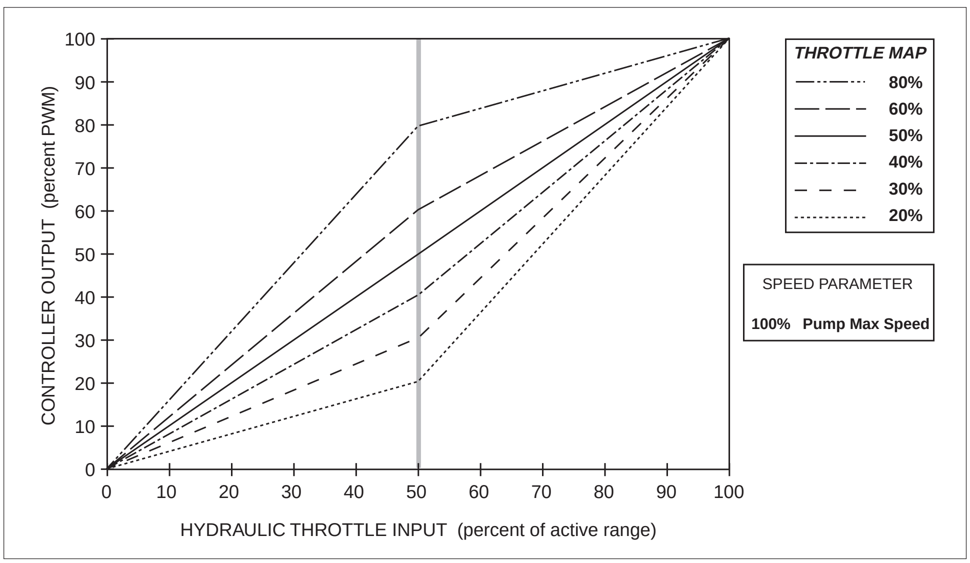
The programmer displays hydraulic Throttle Max as a percentage of the throttle's active voltage range. The nominal voltage range depends on the throttle type selected. See Table 1 (page 12) for the characteristics of your selected throttle type. The hydraulic Throttle Max parameter can be adjusted from 100% to 60%, in 1% increments.

HYD THRTL MAP

The **hydraulic throttle map** parameter modifies the response to a throttle input. This parameter determines the controller output for a given amount of applied throttle. Setting the throttle map parameter at 50% provides a linear output response to throttle position. Values below 50% reduce the controller output at low throttle requests, providing enhanced slow speed Lift control. Values above 50% give the Lift a faster, jumpier feel at low throttle requests.

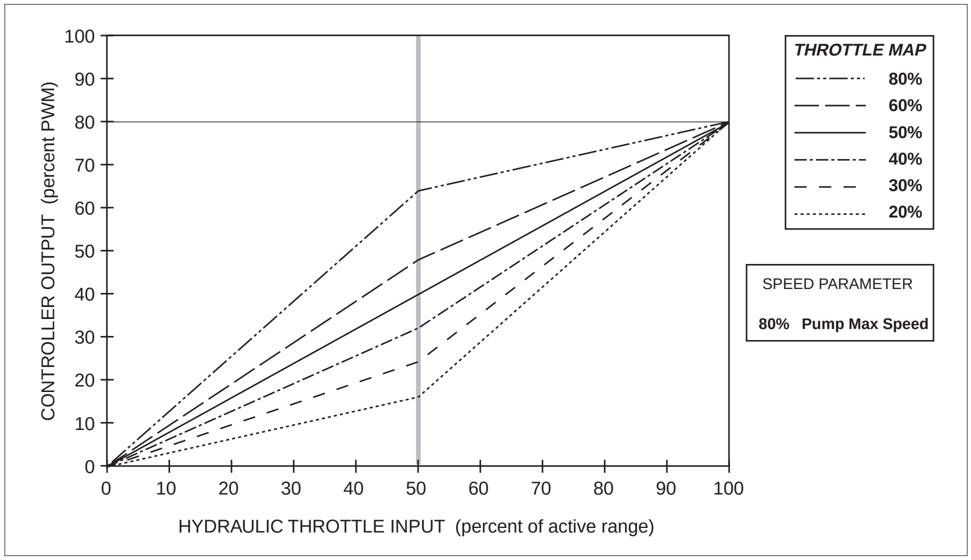
The throttle map can be programmed between 20% and 80%. The number refers to the controller output at half throttle, as a percentage of the throttle's full active range. The throttle's active range is the voltage or resistance between the 0% output point (throttle deadband) and the 100% output point (throttle max). For example, if the maximum pump speed is set at 100%, a throttle map setting of 50% will give 50% output at half throttle. The 50% setting corresponds to a linear response. Six throttle map profiles (20, 30, 40, 50, 60, and 80%) are shown as examples in Figure 23, with the maximum pump speed set at 100%.

Fig. 23 *Hydraulic throttle maps for Lift, for controller with maximum speed set at 100%.*



Reducing the maximum pump speed will limit the controller's output range. Throttle map profiles with the maximum pump speed reduced from 100% to 80% are shown in Figure 245. The throttle map is always a percentage of the controller's output range. So, in these examples, the throttle map is a percentage of the 0–80% output range; a 40% throttle map setting will give 32% output at half throttle (40% of 80% = 32%). Controller output will begin

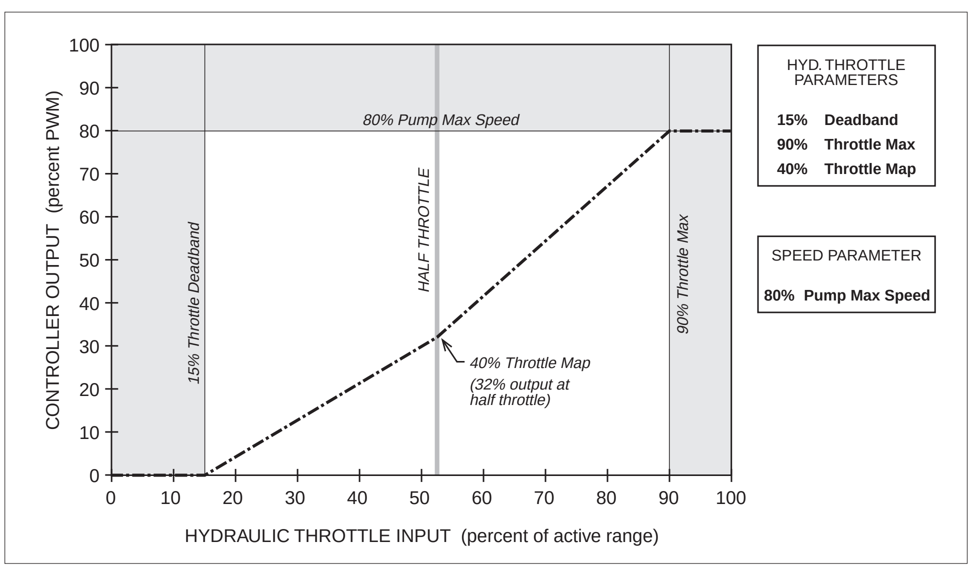
Fig. 24 *Hydraulic throttle maps for Lift, for controller with maximum speed set at 80%.*



to increase as soon as the throttle is rotated out of its normal neutral range (deadband). Controller output will continue to increase, following the curve defined by the throttle map setting, as the throttle input increases and will reach maximum output when the throttle input enters the upper deadband (crosses the Throttle Max threshold).

The hydraulic throttle map for Lift operates within the window established by the Pump Max Speed, Hydraulic Throttle Deadband, and Hydraulic Throttle Max parameters, as shown below in Figure 25. Pump Max Speed defines the controller's output range, while Hydraulic Throttle Deadband and Hydraulic Throttle Max define the hydraulic throttle's active range. These three parameters, together with the hydraulic throttle map, determine the controller's output response to throttle demand for Lift operation.

Fig. 25 *Influence of various parameters on controller output response to hydraulic throttle Lift demand.*



<u>For Lower operations</u> in applications using proportional lowering valves, the throttle maps are similar to those shown in Figures 23 and 24 for Lift

operation—with % LV current along the *y* axis instead of % PWM, and the speed ceiling being determined by the programmed LV Max Current rather than by the programmed Pump Max Speed.

VARIABLE LIFT

The **variable lift** parameter enables throttle control of Lift speed. When variable lift is programmed Off, the pump speed is determined by the maximum pump speed parameter. When variable lift is programmed On, the pump speed is proportional to the amount of hydraulic throttle applied.

VARIABLE LOWER

The **variable lower** parameter enables throttle control of Lower speed if a proportional lowering valve is used. When variable lower is programmed Off, the proportional valve aperture is determined by the LV maximum current parameter. When variable lower is programmed On, the proportional valve aperture is proportional to the amount of hydraulic throttle applied.

When a non-proportional lowering valve is used, the variable lower parameter has only a slight effect. When programmed On, it will cause the point at which the valve snaps open to be reached more or less quickly depending on the amount of throttle applied.

C. SHARED PARAMETERS

In addition to the traction parameters and hydraulic parameters, there are a number of parameters that affect both the traction and the hydraulic systems. These shared parameters include the sequencing delay, various contactor parameters, the enable for the multiplexer, and all the hourmeter and BDI parameters.

Sequencing Delay Parameter

SEQUENCING DLY

The **sequencing delay** feature allows the interlock switch to be cycled within a set time (the sequencing delay), thus preventing inadvertent activation of various lockout features. This feature is especially useful in applications where the interlock switch may bounce or be momentarily cycled during operation. The sequencing delay parameter can be set from 0.0 to 3.0 seconds, with zero corresponding to no delay.

Sequencing delay affects two traction features (HPD and SRO) and one hydraulic feature (hydraulic inhibit).

Contactor Parameters

MAIN CONT INT

The **main contactor interlock** parameter allows the OEM to define a dual switch requirement to operate the vehicle. When this parameter is programmed On, both the KSI input (J1 Pin 1) and the interlock input (J1 Pin 2) must be pulled high (to B+) before the controller will engage the main contactor. The contactor will open after the interlock switch is opened and the sequencing and contactor delays expire. When this parameter is set to Off, only KSI input is required for the main contactor to be engaged.

MAIN OPEN DLY

The **main contactor open delay** parameter is applicable only if the main contactor interlock parameter has been set to On. The delay can then be set to allow the contactor to remain closed for a period of time after the interlock switch is opened. The delay is useful for preventing unnecessary cycling of the contactor and for maintaining power to auxiliary functions that may be used for a short time after the interlock switch has opened.

The main contactor open delay is programmable from 0 to 40 seconds.

MAIN CONT DIAG

The **main contactor diagnostics** parameter, when set to On, performs ongoing checks to ensure that the main contactor has closed properly each time it is commanded to so, and that it has not welded closed. These checks are not performed if the main contactor diagnostics parameter is set to Off. The main contactor driver, however, is always protected from overcurrents, short circuits, and overheating.

Multiplexer Parameter

MUX ENABLE

The **multiplexer enable** parameter, when programmed On, enables the J2 connector—and thus the multiplexer—as shown in Figure 4, page 10. When the multiplexer parameter is programmed Off, the J2 connector is inactive.

Hourmeter Parameters

Three hourmeters are built into the 1297 controller, each with non-volatile memory:

- *a total hourmeter, that measures the total operating time (KSI on-time),*
- *a traction hourmeter, that measures the traction motor on-time, and*
- *a pump hourmeter, that measures the pump motor on-time.*

Each of these three hourmeters has a corresponding service timer and disable timer. Hourmeter information is viewable via the Spyglass display.

For each hourmeter, the service timer is used to set the time before scheduled maintenance is due. When the set service time expires, the disable timer starts and the service timer resets. If the disable time expires before the scheduled maintenance is performed, the controller defaults to the set disable speed.

Hourmeter "Preset" Settings

The 1297 controller is shipped from the factory with each of its three hourmeters preset to 0. If the controller is being installed in a new vehicle, these presets do not need to be adjusted. If the controller is being installed in a "used" vehicle, however, it may be desirable to transfer the existing hourmeter values to the new controller. To do this, the existing decimal hourmeter values must be converted to 8-bit binary values, as follows.

ADJ HOURS HIGH

The **adjust hours high** parameter is used to adjust the high byte of the hourmeter preset; it can be set from 0 to 151. To calculate this value, divide the desired hours by 6,553.6 and enter the integer portion of the result for the Adjust Hours High value.

ADJ HOURS MID

The **adjust hours middle** parameter is used to adjust the middle byte of the hourmeter preset; it can be set from 0 to 255. To calculate this value, multiply the Hours High value by 6,553.6, subtract the result from the desired hours, divide by 25.6, and enter this integer value for the Adjust Hours Middle value.

ADJ HOURS LOW

The **adjust hours low** parameter is used to adjust the low byte of the hourmeter preset; it can be set from 0 to 255. To calculate this value, subtract the Hours Middle integer value from the total Hours Middle value (in other words, take the remainder), multiply by 256, and enter this integer value for the Adjust Hours Low value.

SET TOTL HRS

The **set total hours** parameter is used to apply the preset high, middle, and low byte values to the total (i.e., KSI on-time) hourmeter. First, adjust the byte values as desired for the total hourmeter. Then, program the Apply Total Hours parameter On, which automatically loads the preset values. Once they have been loaded, the apply hours parameter should be programmed Off.

SET TRAC HRS

The **set traction hours** parameter is used to apply preset high, middle, and low byte values to the traction hourmeter. First, adjust the byte values as desired for the traction hourmeter. Then, program the Apply Traction Hours parameter On, which automatically loads the preset values. Once they have been loaded, the apply hours parameter should be programmed Off.

SET PUMP HRS

The **set pump hours** parameter is used to apply preset high, middle, and low byte values to the pump hourmeter. First, adjust the byte values as desired for the pump hourmeter. Then, program the Apply Pump Hours parameter On, which automatically loads the preset values. Once they have been loaded, the apply hours parameter should be programmed Off.

Hourmeter Service Timer Setting

SRVC TOTL HRS

The **total service hours** parameter is used to set the timer for the next scheduled overall maintenance. The total service timer can be adjusted between 0.0 and 50.0, in 0.1 increments, with 25.0 being equivalent to 2,500 hours (25.0 × 100).

SRVC TRAC HRS

The **traction service hours** parameter is used to set the timer for the next scheduled traction motor maintenance. The traction service timer can be adjusted between 0.0 and 50.0, in 0.1 increments, with 25.0 being equivalent to 2,500 hours (25.0 × 100).

SRVC PUMP HRS

The **pump service hours** parameter is used to set the timer for the next scheduled pump motor maintenance. The pump service timer can be adjusted between 0.0 and 50.0, in 0.1 increments, with 25.0 being equivalent to 2,500 hours (25.0 × 100).

Hourmeter Disable Timer Setting

DIS TOTL HRS

The **total disable hours** parameter is used to set the total disable timer; it can be adjusted between 0 and 250 hours, in 1 hour increments. If the total disable timer expires, the traction fault speed and pump fault speed both go into effect.

DIS TRAC HRS

The **traction disable hours** parameter is used to set the traction disable timer; it can be adjusted between 0 and 250 hours, in 1 hour increments. If the traction disable timer expires, the traction fault speed goes into effect.

DIS PUMP HRS

The **pump disable hours** parameter is used to set the pump disable timer; it can be adjusted between 0 and 250 hours, in 1 hour increments. If the pump disable timer expires, the pump fault speed goes into effect.

TRAC FAULT SPD

The **traction fault speed** parameter sets the maximum drive speed in the event the traction disable timer expires or the total disable timer expires; it can be adjusted between 0–100% of Max Speed, and applies to both M1 Max Speed and M2 Max Speed.

PUMP FAULT SPD

The **pump fault speed** parameter sets the maximum pump motor speed in the event the pump disable timer expires or the total disable timer expires; it can be adjusted between 0–100% of Pump Max Speed.

Hourmeter Reset Service Times

SERVICE TOTL

When the total service timer expires, the controller automatically sets the **service total** parameter On. The user must then program the service total parameter Off to indicate the appropriate service has been performed.

SERVICE TRAC

When the traction service timer expires, the controller automatically sets the **service traction** parameter On. The user must then program the service traction parameter Off to indicate the appropriate service has been performed.

SERVICE PUMP

When the pump service timer expires, the controller automatically sets the **service pump** parameter On. The user must then program the service pump parameter Off to indicate the appropriate service has been performed.

Battery Discharge Indicator (BDI) Parameters

The battery discharge indicator constantly calculates the battery state-of-charge whenever KSI is on. When KSI is turned off, the present battery state-of-charge is stored in non-volatile memory. BDI information is viewable via the Spyglass display and via the Test Menu of the 13XX programmer. Three parameters are used to adjust the display.

The standard values for flooded lead acid and sealed maintenance-free batteries are listed below.

	BATTERY TYPE	
	FLOODED	SEALED
Reset volts (VPC)	2.09	2.09
Full volts (VPC)	2.04	2.04
Empty volts (VPC)	1.73	1.90

Custom values can be entered based on specific batteries in consultation with a Curtis applications engineer.

RESET VOLTS

The **reset voltage** parameter sets the voltage that is used to detect the 100% state-of-charge point on a battery with no load. Whenever this voltage is present for 6 seconds (except during regenerative braking) the BDI is reset to 100%. The reset voltage value can be set from 0.90 to 3.00 VPC, in 0.01 VPC increments. NOTE: These values are set without the decimal point, so the range appears as 90 to 300 (i.e., VPC × 100) on the programmer.

FULL VOLTS

The **full voltage** parameter sets the battery voltage considered to be a 100% state-of-charge; when a loaded battery drops below this voltage, it begins to lose charge. The full voltage value can be set from 0.90 to 3.00 VPC, in 0.01 VPC increments. NOTE: These values are set without the decimal point, so the range appears as 90 to 300 (i.e., VPC × 100) on the programmer.

EMPTY VOLTS

The **empty voltage** parameter sets the voltage considered to be a 0% state-of-charge; when the battery remains under this voltage consistently, the BDI will read 0% state of charge. The empty voltage value can be set from 0.90 to 3.00 VPC, in 0.01 VPC increments. NOTE: These values are set without the decimal point, so the range appears as 90 to 300 (i.e., VPC × 100) on the programmer.

4 INSTALLATION CHECKOUT

Carefully complete the following checkout procedure before operating the vehicle. If you find a problem during the checkout, refer to the diagnostics and troubleshooting section (Section 7) for further information.

The installation checkout can be conducted with or without a 13XX programmer. The checkout procedure is easier with a programmer. Otherwise, observe the Status LED (located in the controller's label area) or the optional Spyglass display for diagnostic codes. The codes are listed in Section 7.

Before starting the procedure, check that the hydraulic hoses are secure, and the system primed with oil.

CAUTION

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

Do not stand, or allow anyone else to stand, directly in front of or beside the vehicle during the checkout.

Make sure the keyswitch is off, the throttles are in neutral, and all the switches are open.

Wear safety glasses and use well-insulated tools.

1. If a programmer is available, connect it to the 4-pin connector (J3).

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. The display should indicate "No Known Faults." Close the interlock switch (if one is used in your application). The Status 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 7 (Diagnostics and Troubleshooting).

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

4. *First, check out the traction system.* With the interlock switch closed, select a direction and apply throttle. The motor should begin to turn in the selected direction. If it does not, first verify the wiring to the forward and reverse switches. If the wiring is correct, turn off the controller, disconnect the battery, and exchange the motor's field connections (the **F1** and **F2** cables) on the controller. The motor should now turn in the proper direction. The motor should turn proportionately faster with increasing throttle. If not, refer to Section 7. ***CAUTION:*** The polarity of the **F1** and **F2** connections will affect the operation of emergency reverse. The forward and reverse switches and the field connections must be configured so that the vehicle drives away from the operator when the emergency reverse button is pressed.

5. If you are using a programmer, put it into the test mode. Observe the status of the forward, reverse, and mode switches, and—if your application has emergency reverse—the emergency reverse switch. Cycle each switch in turn, observing the programmer. The programmer should display the correct status for each switch.

   If your application has a multiplexer, cycle these switches on the multiplexer also.

6. Take the vehicle down off the blocks and drive it in a clear area. It should have smooth acceleration and good top speed. If not, see Section 5: Vehicle Performance Adjustment.

7. Test the braking of the vehicle.

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

9. On walkies, verify that emergency reverse is working correctly. If you have the optional emergency reverse check wiring, verify the checking circuit by momentarily disconnecting one of the emergency reverse wires. The vehicle should coast to a stop and a fault should be indicated.

10. *Next, check out the hydraulic system.* If you are using a programmer, put it into the test mode. Observe the status of the Lift and Lower switches. Cycle each switch in turn, observing the programmer. The programmer should display the correct status for each switch.

    If your application has a multiplexer, cycle the Lift and Lower switches on the multiplexer also.

11. Drive the vehicle to a location that will provide enough room for the hydraulic functions to be tested; if indoors, be sure the ceiling height is adequate.

12. Using the hydraulic throttle, operate the Lift and Lower. They should accelerate and decelerate smoothly.

13. Verify that the hydraulic inhibit feature performs as desired.

14. If you used a programmer, disconnect it when you have completed the checkout procedure.

BENCH TESTING WITH A 13XX PROGRAMMER

With the simple bench test setup shown in Figure 26, the controller parameters can be verified or adjusted without the controller being wired into a vehicle. The wiring can be expanded to conduct a complete functional test on the bench; if you want to do this, contact Curtis for further information.

The complete in-vehicle installation checkout, as described in Steps 1–14, should still be conducted before the vehicle is operated.

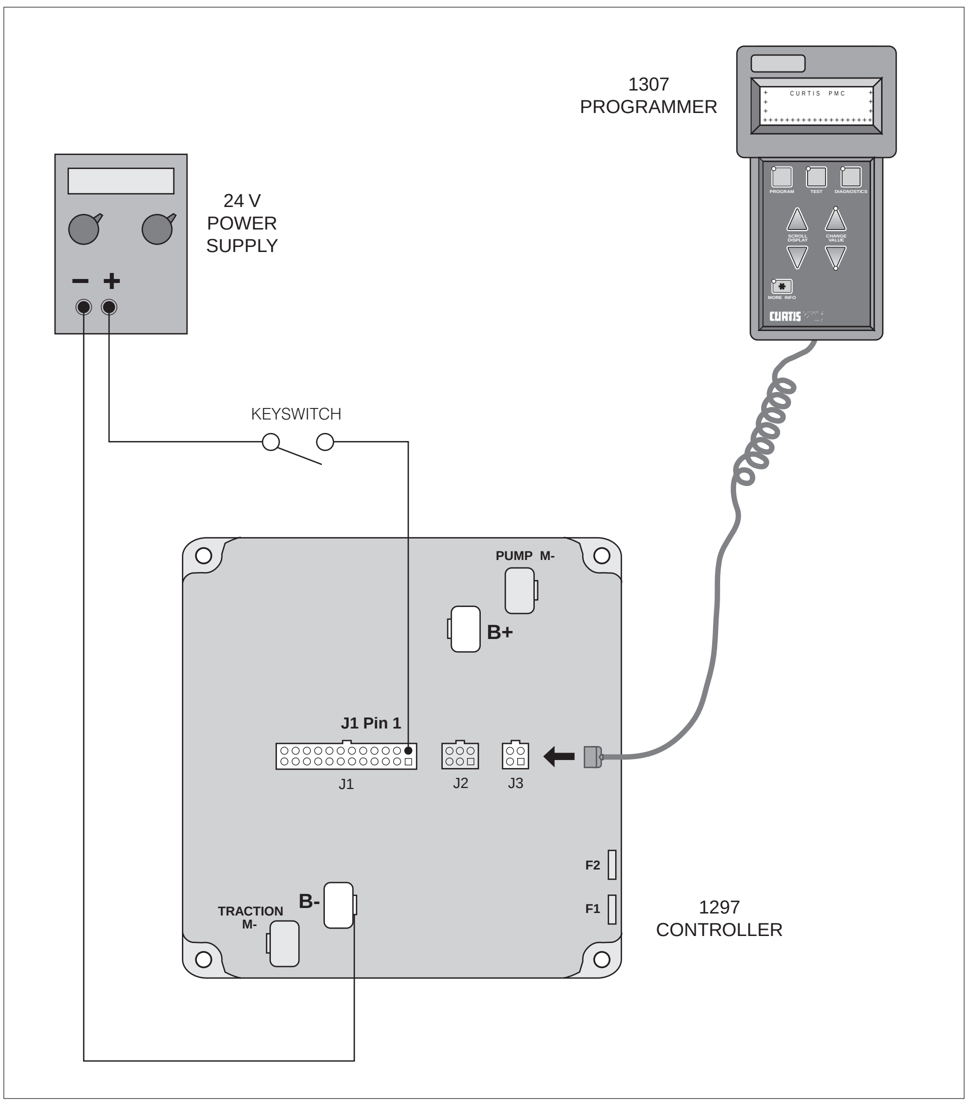


Fig. 26 *Bench test setup for verifying and adjusting the controller's parameters.*

5

VEHICLE PERFORMANCE ADJUSTMENT

The 1297 controller is a very powerful vehicle control system. Its wide variety of adjustable parameters allow many aspects of vehicle performance to be optimized. This section provides explanations of what the major tuning parameters do and instructions on how to use these parameters to optimize the performance of your vehicle. Traction system tuning is described first, followed by hydraulic system tuning.

TRACTION TUNING: MAJOR

The tuning procedures should be conducted in the sequence given, because successive steps build upon the ones before. It is important that the effect of these programmable parameters be understood in order to take full advantage of the 1297 controller's powerful features. Please refer to the descriptions of the applicable parameters in Section 3A if there is any question about what any of them do.

Once a vehicle/motor/controller combination has been tuned, the parameter values can be made standard for that system or vehicle model. Any changes in the motor, the vehicle drive system, or the controller will require that the system be tuned again to provide optimum performance.

The 1297's MultiMode™ feature allows the vehicle to be configured to provide two distinct operating modes. Typically, Mode 1 is optimized for precision maneuvering and Mode 2 for faster outdoor travel. If your vehicle is intended to operate in two modes, some of the tuning procedures must be performed twice—once for each mode.

Four major performance characteristics of the traction system are usually tuned on a new vehicle:

① Tuning the throttle's active range

② Tuning the controller to the motor

③ Setting the vehicle's unloaded top speed

④ Equalization of loaded and unloaded vehicle speed.

These four characteristics should be tuned in the order listed.

① Tuning the Throttle's Active Range

Before attempting to optimize any specific vehicle performance characteristics, it is important to ensure that the controller output is operating over its full range. To do this, the throttle should be tuned using a 13XX programmer. The procedures that follow will establish Throttle Deadband and Throttle Max parameter values that correspond to the absolute full range of your particular throttle mechanism. It is advisable to allow some buffer around the absolute full range of the throttle mechanism to allow for throttle resistance variations over time and temperature as well as variations in the tolerance of potentiometer values between individual throttle mechanisms.

①-A Tuning the Throttle Deadband

STEP 1. Jack the vehicle wheels up off the ground so that they spin freely.

STEP 2. Plug the 13XX programmer into the controller, and turn on the keyswitch. If your application has an interlock switch, close it.

STEP 3. When the programmer instructs you to select a menu, select the Test Menu. The Throttle % parameter should be visible in the initial display. You will need to reference the value displayed here.

STEP 4. Scroll down until the Forward Input parameter is visible. The display should indicate that the forward switch is Off.

STEP 5. Slowly rotate the throttle forward until the display indicates that the forward switch is On. Use care with this step as it is important to identify the threshold throttle position at which the forward switch is engaged and the controller recognizes the forward command.

STEP 6. Without moving the throttle, scroll up to display the Throttle % parameter and read the value shown. This value should be zero. If the Throttle % value is zero, proceed to Step 7. If it is greater than zero, the Throttle Deadband must be increased. Select the Program Menu and enter a higher value for the Throttle Deadband. Repeat Steps 5 and 6 until the Throttle % is zero at the forward direction engagement point.

STEP 7. While observing the Throttle % value in the programmer's Test Menu, continue to rotate the throttle past the forward switch engagement point. Note where the Throttle % value begins to increase, indicating that the controller has begun to supply drive power to the motor. If the throttle had to be rotated further than desired before the Throttle % value began to increase, the Throttle Deadband must be decreased and the procedure repeated from Step 5. If the amount of rotation between the point at which the forward switch is engaged and the Throttle % value begins to increase is acceptable, the Throttle Deadband is properly tuned.

STEP 8. If a bidirectional (wigwag) throttle assembly is being used, the procedure should be repeated for the reverse direction. The Throttle Deadband value should be selected such that the throttle operates correctly in both forward and reverse.

①-B Tuning the Throttle Max

STEP 1. Jack the vehicle wheels up off the ground so that they spin freely.

STEP 2. Plug the 13XX programmer into the controller and turn on the keyswitch. If your application has an interlock switch, close it.

STEP 3. When the programmer instructs you to select a menu, select the Test Menu. The Throttle % parameter should be visible in the initial display. You will need to reference the value displayed here.

STEP 4. Rotate the throttle forward to its maximum speed position and observe the Throttle % value. This value should be 100%. If it is less than 100%, the Throttle Max value must be <u>de</u>creased to attain full controller output at the maximum throttle position. Select the Program Menu, and decrease the Throttle Max setting. Repeat this step until the Throttle % value is 100%.

STEP 5. Now that the full throttle position results in a 100% value for Throttle %, slowly reduce throttle until the Throttle % value drops below 100% and note the throttle position. This represents the extra range of motion allowed by the throttle mechanism. If this range is large, you may wish to decrease it by increasing the Throttle Max value. This will provide a larger active throttle range and more vehicle control. Using the programmer, increase Throttle Max and repeat the test until an appropriate amount of extra range is attained.

STEP 6. If a wigwag throttle is being used, repeat the procedure for the reverse direction. The Throttle Max value should be selected such that the throttle operates correctly in both forward and reverse.

② Tuning the Controller to the Motor

The 1297 controller has the flexibility to be tuned to nearly any separately excited motor from any manufacturer. Parameters in the 13XX programmer's Program Menu allow full control of the motor's maximum armature current during driving and braking and full control of the motor's maximum and minimum field current as well as the field current relationship to the armature current. This flexibility allows motor performance to be maximized while protecting it from operating outside its safe commutation region.

In order to properly tune the controller, the following information should be obtained from the motor manufacturer:

– peak motor armature current rating
– maximum motor field current rating
– minimum motor field current rating
– motor field resistance, hot and cold.

The performance of a separately excited motor depends on temperature. This is due to the change in field winding resistance as the motor heats up through use. When the field winding temperature increases, so does its resistance; therefore, the maximum current that can be forced through the winding is reduced. Reductions in the field current over the motor's typical operating temperature range can be 10% to 50%. Since the maximum available field current determines the maximum torque that can be produced by the motor, the vehicle's performance under load and up inclines will change as the motor heats up. The change in performance can be limited by tuning the motor when it is hot rather than cold. Therefore, it is recommended that the following procedure be performed with a hot motor.

STEP 1. Using the programmer's Program Menu, set the Drive Current Limit parameter in each mode to the smaller of: (a) the motor's peak armature current rating, or (b) the controller's full rated drive current. This setting can be adjusted later to establish the desired vehicle driving feel in each mode.

STEP 2. Set the Braking Current Limit parameter in each mode to the smaller of: (a) the motor's peak armature current rating, or (b) the controller's full rated braking current. This setting can be adjusted later to establish the desired vehicle braking feel in each mode.

STEP 3. To set the Field Max parameter, first decide whether you want to maintain consistent vehicle operation throughout the motor's temperature range. If you do, proceed to Step 4. If, however, maintaining operational consistency across motor temperature is <u>not</u> a concern—but achieving maximum torque <u>is</u>—proceed to Step 5.

STEP 4. For the most consistent operation across temperature, set the Field Max to the maximum field current available at low battery voltage and with a hot motor. To determine this value, divide the low battery voltage (typically 70% of nominal) by the high temperature field winding resistance specification provided by the manufacturer. Set the Field Max to this value. This setting will provide good consistency between motor performance in both hot and cold states.

STEP 5. For the maximum torque regardless of temperature, set the Field Max to the motor's rated absolute maximum field current. To determine the absolute maximum field current, divide the nominal battery voltage by the low temperature field winding resistance specification provided by the manufacturer. Set the Field Max to this value. This setting will provide the maximum possible torque under all conditions.

This has now set the Max Field parameter. The next step is to set the Min Field parameter. NOTE: **The Field Min parameter should never be set below the rated value specified by the manufacturer.** Operating the motor at lower field currents than specified will result in operation outside the motor's safe commutation region and will cause arcing between the brushes and commutator, significantly reducing motor and brush life. The Field Min parameter value can be increased from the manufacturer's specified value to limit the vehicle's top speed. (Setting the vehicle's top speed will be addressed in Procedure ③.)

If the controller is tuned such that the system is operating outside the motor's safe commutation region, there will be audible and visual indications. Under normal operation, the motor will emit a whine with a pitch that increases with increasing rotation speed. If a "scratchy" sound is also heard, this is usually an indication that pin arcing is occurring in the motor and it is operating outside its safe commutation region. This operation is normally accompanied by a strong smell from the motor. If the brushes and commutator bars are visible, arcing may be visible. The further outside the safe commutation region the motor is operating, the worse the arcing will be. **Operation outside the safe commutation region is very detrimental to the motor.** The Field Min and possibly also the Field Map parameter should be increased until the indications of arcing stop. Decreasing the Field Map Start parameter will also help to move operation back into the safe commutation region.

③ Setting the Vehicle's Unloaded Top Speed

The controller and vehicle should be configured as follows before starting this procedure:

- Max Speed = 100%
- Drive Current Limit as established in procedure ②
- Field Map = 50%
- Field Map Start = 50% of the specified drive current limit
- Field Min = motor manufacturer's specified minimum (if available); otherwise, 5 amps
- Load Comp = 0
- The vehicle should be unloaded
- The vehicle battery should be fully charged.

The vehicle should be driven on a flat surface in a clear area during this procedure. Since the vehicle may initially be traveling at speeds in excess of the final intended speed, precautions should be taken to ensure safety of test personnel and anyone in the test area.

STEP 1. Select the programmer's Program Menu and scroll down until the Field Min parameter is visible in the display.

STEP 2. Power up the vehicle and apply full throttle. While driving the vehicle with full throttle applied, adjust the Field Min parameter to set the desired top speed. Increasing the Field Min value decreases the vehicle's top speed; decreasing the Field Min value increases the vehicle's top speed. ***CAUTION:*** Do not decrease the Field Min below the motor manufacturer's recommended minimum field current value. And, as a general rule, do not increase Field Min above the following values.

150 amp controller	8	amps
250 amp controller	10	amps
350 amp controller	15	amps

STEP 3. If the Field Min is increased to the listed value and the vehicle's top speed has still not been sufficiently reduced, the Max Speed parameter should be used to bring the top speed down to the desired level. First, decrease the Field Min value, setting it to optimize smooth starting. Then adjust the Max Speed parameter per Step 4 to bring the vehicle's top speed down to the desired level. NOTE: If the Field Min parameter is set too high, the high initial torque created by the high field current may cause overly abrupt starts; this is why we recommend using the Max Speed parameter in those cases where a moderate Field Min setting does not sufficiently reduce the vehicle's top speed.

STEP 4. Scroll up the Program Menu until the Max Speed parameter is visible in the display. While driving the vehicle with the Field

Min set at the value selected in Step 3, decrease the Max Speed parameter value until the desired vehicle top speed is set.

STEP 5. *For Walkie/Rider Applications:* Typically, different top speeds are desired for walkie and rider operation. To tune a walkie/rider vehicle's top speed, first tune it for rider operation by using the Field Min parameter. Then, to set the top speed for walkie operation, leave the Field Min parameter alone and decrease the Max Speed parameter until the desired walking vehicle speed is reached.

Equalization of Loaded and Unloaded Vehicle Speed

The top speed of a loaded vehicle can be set to approach the unloaded top speed by tuning the controller's Field Map Start and Load Compensation parameters. It is recommended that you review the description of the Field Map Start and Load Compensation parameters in Section 3 before starting this procedure.

STEP 1. The vehicle's unloaded top speed should already have been set. If it was not, it should be set before the vehicle's loaded top speed is established.

STEP 2. Once the vehicle's unloaded top speed has been set, load the vehicle to its desired load capacity. Leave the Field Min and Max Speed parameters at the settings determined during the unloaded test.

STEP 3A. If the intent is to minimize the difference between the loaded and unloaded vehicle speeds, then:
(i) Drive the fully loaded vehicle on flat ground with full throttle applied. When the vehicle reaches maximum speed, observe the armature current displayed in the programmer's Test Menu.
(ii) Set the Field Map Start parameter slightly higher than the observed armature current value.
(iii) Test the loaded/unloaded speed variation. If the observed variation is unacceptable, proceed to "(iv)."
(iv) Increase the Load Comp parameter and retest the speed regulation. The Load Comp parameter can be increased until the desired regulation is achieved or the vehicle begins to oscillate ("hunt") at low throttle. If the loaded/unloaded speed variation is acceptable but the average speed is not, adjustments can be made to the Field Min parameter.

STEP 3B. If the intent is to make the loaded speed less than the unloaded speed (for reasons of safety, efficiency, or reduced motor heating), then:
(i) Unload the vehicle and drive it on flat ground with full throttle applied. When the vehicle reaches maximum speed, observe the

armature current displayed in the programmer's Test Menu.

(ii) Set the Field Map Start parameter to the observed armature current value.

(iii) Load the vehicle and drive it on flat ground with full throttle applied. Further adjustments to the vehicle's loaded speed can now be made by varying the Field Map parameter. Increasing the Field Map value will decrease the vehicle's loaded speed, and decreasing the Field Map value will increase the vehicle's loaded speed.

CAUTION: If the Field Map Start parameter is set too high, the motor's safe commutation region may be exceeded. If this is the case, reduce the Field Map Start parameter to a safe value. Then, adjust the Field Map parameter as needed to reach the desired loaded top speed. Reducing the Field Map value will help bring the loaded speed closer to the unloaded speed. However, care must still be taken because it is possible for too low Field Map values—like too high Field Map Start values—to result in exceeding the motor's safe commutation region.

TRACTION: FINE TUNING

Four additional vehicle performance characteristics can be adjusted:

- ⑤ Response to reduced throttle
- Response to increased throttle
- Smoothness of direction transitions
- Ramp climbing.

These characteristics are related to the "feel" of the vehicle and will be different for various applications. Once the fine tuning has been accomplished, it should not have to be repeated on every vehicle.

Typically, Mode 1 is configured for precision maneuvering, with the six Mode 1 parameters (M1 Drive Current Limit, M1 Braking Current Limit, M1 Accel Rate, M1 Decel Rate, M1 Braking Rate, and M1 Maximum Speed) tuned exclusively to provide comfortable vehicle response at low speeds.

⑤ Response to Reduced Throttle

The way the vehicle behaves when the throttle is reduced or completely released can be adjusted to suit your application, using the Decel Rate and Restraint parameters. Refer to the description of these parameters in Section 3 before beginning this procedure.

STEP 1. Set the Decel Rate based on the desired time for the vehicle to stop upon release of throttle when traveling at full speed with full load. If the vehicle brakes too abruptly when the throttle is released, increase the Decel Rate.

STEP 2. The default Restraint setting (8 amps) should work well for most vehicles. If the vehicle exhibits excessive overspeed when driving down a ramp, increase the Restraint value. If the vehicle "speed hunts" while driving down a ramp or brakes too abruptly at low or released throttle, decrease the Restraint value.

STEP 3. If the Restraint value has been adjusted, retest braking behavior when throttle is reduced to ensure that it still has the desired feel. If it does not, the Decel Rate should be re-adjusted as in Step 1.

Response to Increased Throttle

The way the vehicle reacts to quick or slow increased throttle requests can be modified using the Accel Rate, Current Ratio, and Throttle Map parameters. Optimal vehicle response is tuned by adjusting these parameters and then accelerating the vehicle from a dead stop under various throttle transition conditions.

STEP 1. Set Throttle Map = 50%.

STEP 2. Drive the vehicle and adjust the Accel Rate for the best overall response. If the vehicle starts too slowly under all driving conditions, the Accel Rate should be reduced.

STEP 3. Increasing vehicle acceleration. If acceleration feels good for slow or moderate throttle transitions but the vehicle initially starts too slowly, set the Current Ratio parameter to 2 or higher.

STEP 4. Achieving better control at low speeds. If the vehicle responds well for fast, full range throttle transitions but is too jumpy during low speed maneuvering, reduce the Throttle Map and/or set the Current Ratio to 1.

Smoothness of Direction Transitions

Additional fine tuning can be performed to enhance the vehicle's transitions between braking and driving.

STEP 1. Ensure that the Braking Rate parameter has been set for the desired response (see Section 3A, page 25).

STEP 2. If the transition is too abrupt: increase the Taper Rate and/or set the Variable Braking parameter to On. Secondary adjustments can be made by increasing the Accel Rate.

STEP 3. If the transition is too slow: decrease the Taper Rate and set Creep Speed to 5% or greater. Secondary adjustments can be made by decreasing the Accel Rate or increasing the Current Ratio.

¤ Ramp Climbing

The vehicle's response to increased gradients such as loading ramps can be tuned via the Field Map parameter. Decreasing the Field Map parameter allows faster vehicle speeds while climbing ramps, but it also has the effect of reducing the ability of the controller to generate torque in the vehicle's mid-range speeds.

STEP 1. If faster vehicle speed is desired when climbing ramps, decrease the Field Map parameter value until the desired ramp climbing speed is attained. It should be noted that if the motor's torque capability is exceeded under the conditions of load weight and ramp gradient, vehicle speed will be limited by the motor's capability and the desired vehicle speed may not be attainable. The system will find a compromise point at which sufficient motor torque is generated to climb the ramp at an acceptable speed. If the Field Map parameter value is reduced to 0% and the desired speed is still not attained, the system is being limited by the motor's torque capability under these operating conditions. ***CAUTION:*** be careful when reducing the Field Map parameter since at low Field Map values it is possible that the motor could be operated outside its safe commutation region.

STEP 2. If the drive system cannot produce sufficient torque for a fully loaded vehicle to climb the desired ramp, try increasing the Field Map, Field Max, and/or Drive Current Limit parameters. The impact of increasing these parameter values on other driving characteristics must be evaluated. Increasing the Field Max will provide more field current, and increasing the Drive Current Limit will provide more armature current. If the Field Max is set at the manufacturer's specified limit and the Drive Current Limit is set at the rated maximum, then vehicle speed up the ramp is limited by the motor or the vehicle's gearing and cannot be increased by tuning the controller. NOTE: To determine whether the controller's armature current is at its set value during ramp climbing, read the Arm Current value in the programmer's Test Menu.

HYDRAULIC TUNING

Tuning the hydraulic system is more straightforward than tuning the drive system, because the parameters are not so inter-related. Nonetheless, it is important that the effect of these programmable parameters be understood in order to take full advantage of the 1297 controller's powerful features. Please refer to the descriptions of the applicable parameters in Section 3B if there is any question about what any of them do.

Once a vehicle/motor/controller combination has been tuned, the parameter values can be made standard for that system or vehicle model. Any changes in the pump motor, the hydraulic system, or the controller will require that the system be tuned again to provide optimum performance.

The following ten-step procedure is recommended. If your application does not use a hydraulic throttle, skip directly to Step H-5(b).

Step H-1. Select the Hydraulic Throttle Type (2 or 4) and then set the other throttle parameters: Hydraulic Throttle Deadband, Hydraulic Throttle Max, and Hydraulic Throttle Map. Initially, use these default settings: DB=10%, throttle max=90%, and map=50%.

Step H-2. Tune the active throttle range. Adjust the Hydraulic Deadband and Throttle Max settings using the multi-step procedures outlined for their traction throttle equivalents on pages 67–68.

Step H-3. If a proportional valve is used and variable-speed Lower is desired, set the Variable Lower parameter to On. A throttle is required.

Step H-4. If variable-speed Lift is desired, set Variable Lift to On. A throttle is required.

Step H-5. (a) If your application uses a proportional lowering valve, set the LV Max Current and LV Min Current based on the valve manufacturer's ratings.
(b) If your application uses a non-proportional (open/closed) lowering valve, set the LV Max Current to the full current rating of the valve; the LV Min Current setting is moot.

Step H-6. Set the Pump C/L to the pump motor's rated current, and the Lift Max Speed to 100%.

Step H-7. Test the hydraulic system and adjust the Lift Max speed, the LV Max Current (if a proportional lowering valve is used), and the Throttle Map parameter (if your application includes a hydraulic throttle) to give the desired performance.

Step H-8. To further tune the Lift response, adjust the Pump Accel and Pump Decel rates.

Step H-9. To further tune the Lower response (if a proportional lowering valve is used), adjust the LV Accel and LV Decel rates.

Step H-10. If a bump is felt at the end of Lift or Lower operations, increase the Load Hold Delay value to allow the hydraulic fluid to stop flowing before the load-hold valve closes.

6 PROGRAMMER MENUS

The universal 13XX Curtis PMC programmers allow you to program, test, and diagnose Curtis PMC programmable controllers. For further information about programmer operation, consult the programmer manual or call the Curtis office closest to you.

There are five programmer menus:

- **Program Menu**
- **Test Menu**
- **Diagnostics Menu**
- **Special Diagnostics (Diagnostic History File)**
- **Special Program Menu**.

The first four menus are controller-specific, and are presented below. The items are listed in these menus in the order in which they appear in the actual menus displayed by the 13XX programmer. Depending on the specific 1297 model you have, some of the items may not appear.

The "special" program menu is generic to the various controllers, and is therefore not covered here; see the programmer manual.

1297 PROGRAM MENU *(not all items available on all controllers)*

M1 DRIVE C/L	Mode 1 drive current limit, in amps
M2 DRIVE C/L	Mode 2 drive current limit, in amps
M1 BRAKE C/L	Mode 1 braking current limit, in amps
M2 BRAKE C/L	Mode 2 braking current limit, in amps
M1 ACCEL RATE	Mode 1 acceleration rate, in seconds
M2 ACCEL RATE	Mode 2 acceleration rate, in seconds
M1 DECEL RATE	Mode 1 deceleration rate, in seconds
M2 DECEL RATE	Mode 2 deceleration rate, in seconds
M1 BRAKE RATE	Mode 1 braking rate during direction change, in seconds
M2 BRAKE RATE	Mode 2 braking rate during direction change, in seconds
M1 MAX SPEED	Maximum speed in Mode 1, as % armature PWM
M2 MAX SPEED	Maximum speed in Mode 2, as % armature PWM
CREEP SPEED	Creep speed, as % armature PWM
THROTTLE DECEL	Time for transition to braking mode, in seconds
COAST DECEL	Deceleration rate for coast mode after Pick release, in seconds
INT BRAKE C/L	Interlock braking current limit, in amps
INT BRAKE RATE	Interlock braking rate, in seconds
INT BRAKE DLY	Interlock braking delay, in seconds

Program Menu, **cont'd**

VARIABLE BRAKE	Braking proportional to opposite-direction throttle: on/off
TAPER RATE	Threshold affecting end of regen during direction reversal: 1–20
INT OVERRIDE	Special operation with interlock switch open: on/off
H/S LATCH	Momentary-type mode switch electrically "latchable" in M2: on/off
ANTI-TIEDOWN	Anti-tiedown: on/off
THROTTLE TYPE	Throttle input signal type [1]
THROTTLE DB	Neutral deadband, as % of throttle range
THROTTLE MAX	% of throttle movement at which 100% output occurs
THROTTLE MAP	Throttle map, as % output at half throttle
POT LOW CHECK	Traction throttle fault detection (at J1 Pin 4): on/off
FIELD MIN	Traction motor min. field current, in amps
FIELD MAX	Traction motor max. field current, in amps
FIELD MAP	Field current at midpoint of armature current, in %
FLD MAP START	Armature current at which field current starts increasing, in amps
FIELD CHECK	Traction motor field check: on/off
RESTRAINT	Braking applied in restraint situation, in amps
CURRENT RATIO	Current-to-throttle ratio: 1 (1×), 2 (2×), 3 (4×), or 4 (8×)
BOOST ENABLE	Boost current option enabled: on/off
LOAD COMP	Load compensation: 0 to 25%
SEQUENCING DLY	Sequencing delay, in seconds
SRO	Static return to off (SRO) type [3]
HPD	High pedal disable (HPD) type [2]
MAIN CONT INT	Main contactor control type [4]
MAIN OPEN DLY	Delay after interlock opens, in seconds
MAIN CONT DIAG	Main contactor diagnostics enabled: on/off
E-M BRAKE TYPE	Electromagnetic brake driver type [5]
E-M BRAKE DLY	Delay after interlock switch opens, in seconds
EMR REV CHECK	Emergency reverse wiring check: on/off
EMR REV C/L	Emergency reverse current limit, in amps
EMR ACCEL RATE	Emergency reverse acceleration rate, in seconds
EMR DIR INT	Emerg. rev. exit by cycling dir. switches *or* intk: on/off [6]
EMR TIME LIMIT	5-second time limit for emergency reverse: on/off
PUMP C/L	Pump motor current limit, in amps
PUMP LOCK C/L	Pump motor current at which Lift is locked out, in amps
PUMP LOCK DLY	Time before Lift locked out in overcurrent, in seconds
NO LOAD C/L	Pump motor current that defines "load," in amps
PUMP ACCEL	Pump motor acceleration rate, in seconds
PUMP DECEL	Pump motor deceleration rate, in seconds
HYD THRTL TYPE	Hydraulic throttle input signal type [7]
HYD THRTL DB	Neutral deadband, as % of hydraulic throttle range

(Menu continues on next page.)

Program Menu, **cont'd**

HYD THRTL MAX	% of pump throttle movement at which 100% output occurs
HYD THRTL MAP	Throttle map, as % pump motor PWM at half pump throttle
VARIABLE LIFT	Enables variable Lift: on/off
VARIABLE LOWER	Enables variable Lower: on/off
PUMP MAX SPEED	Pump max. speed during Lift, as % armature PWM
NO LOAD SPEED	Pump max. speed in no-load Lift, as % armature PWM
PUMP BDI L/O	Lift lockout when battery S-O-C <20%: on/off
PUMP BDI WRN	Horn beeps at Lift request if battery S-O-C <25%: on/off
HYD INHIBIT	Hydraulic lockout if throttle >25% at interlock: on/off
LOAD HOLD DLY	Delay after Lift/Lower, in seconds
LV CHECK	Lowering valve check: on/off
LV ACCEL	Acceleration rate for lowering valve current, in seconds
LV DECEL	Deceleration rate for lowering valve current, in seconds
LV MIN C/L	Minimum current for lowering valve, in amps
LV MAX C/L	Maximum current for lowering valve, in amps
LV DITHER	I_{LVcoil} dither for lowering valve, in % LV maximum current
ADJ HOURS HIGH	Hourmeter preset high byte: 0–151
ADJ HOURS MID	Hourmeter preset middle byte: 0–255
ADJ HOURS LOW	Hourmeter preset low byte: 0–255
SET TOTL HRS	Apply preset values to total hourmeter: on/off
SET TRAC HRS	Apply preset values to traction hourmeter: on/off
SET PUMP HRS	Apply preset values to pump hourmeter: on/off
SRVC TOTL HRS	Total service timer setting, in hours
SRVC TRAC HRS	Traction service timer setting, in hours
SRVC PUMP HRS	Pump service timer setting, in hours
DIS TOTL HRS	Total disable timer setting, in hours
DIS TRAC HRS	Traction disable timer setting, in hours
DIS PUMP HRS	Pump disable timer setting, in hours
TRAC FAULT SPD	Max. drive speed if disable timer expires, as % Max Speed
PUMP FAULT SPD	Max. pump speed if disable timer expires, as % Lift Max Speed
SERVICE TOTL	Reset total service timer: on/off
SERVICE TRAC	Reset traction service timer: on/off
SERVICE PUMP	Reset pump service timer: on/off
FULL VOLTS	Voltage considered 100% state of charge, in volts
EMPTY VOLTS	Voltage considered 0% state of charge, in volts
RESET VOLTS	Voltage at which state of charge resets to 100%, in volts
MUX ENABLE	Multiplexer inputs enabled: on/off

Program Menu Notes

[1] Traction throttle types (see Throttle Wiring in Section 2)

Type 1: 5kΩ–0
Type 2: single-ended 0–5V throttles and 3-wire pots
Type 3: 0–5kΩ
Type 4: wigwag 0–5V throttles and 3-wire pots

[2] HPD types (see Section 3A, page 44)

Type 0: No HPD.
Type 1: HPD unless KSI and interlock inputs received before throttle request.
Type 2: HPD unless KSI input is received before throttle request.

[3] SRO types (see Section 3A, page 45)

Type 0: No SRO.
Type 1: SRO unless interlock input is received before a direction is selected.
Type 2: SRO unless KSI + interlock inputs received before direction selected.
Type 3: SRO unless KSI + interlock + forward inputs received in that order.

[4] Main contactor control types (see Section 3C, page 57)

On: Interlock switch input required in addition to KSI to close contactor.
Off: Contactor closes on KSI input alone.

[5] Electromagnetic brake driver types (for detail on options, see Table 2, page 30)

Type 0: no electromagnetic brake driver
Type 1: Option 1
Type 2: Option 2
Type 3: Option 3
Type 4: Option 4

[6] Emergency reverse exit control type
(see Section 3A, page 42)

On: To resume normal operation after emergency reversing has been completed, the operator can either open both direction switches or cycle the interlock switch.
Off: To resume normal operation after emergency reversing has been completed, the operator must cycle the interlock switch.

[7] Hydraulic throttle types (see Hydraulic Throttle Wiring in Section 2)

Type 2: single-ended 0–5V throttles and 3-wire pots
Type 4: wigwag 0–5V throttles and 3-wire pots

1297 TEST MENU *(not all items available on all controllers)*

BATT VOLTAGE	Battery voltage across B+ and B-, in volts
BDI %	Battery state of charge, as % of full charge
HEATSINK TEMP	Heatsink temperature, in °C
THROTTLE %	Throttle reading, as % of full throttle
FIELD CURRENT	Traction motor field current, in amps
ARM CURRENT	Traction motor armature current, in amps
FIELD PWM	Traction motor field duty cycle, as %
ARM PWM	Traction motor armature duty cycle, as %
FORWARD INPUT	Forward switch: on/off [neutral switch for Type 4 throttle]
REVERSE INPUT	Reverse switch: on/off
MODE INPUT	Mode switch: on (M2)/off (M1)
EMR REV INPUT	Emergency reverse switch: on/off
HYD THROTTLE %	Hydraulic throttle reading, as % of full throttle
PUMP CURRENT	Pump motor current, in amps
PUMP PWM	Pump motor duty cycle, as %
LV CURRENT	Lowering valve current, in amps
LV PWM	Lowering valve duty cycle, as %
LIFT INPUT	Lift switch: on/off
LOWER INPUT	Lower switch: on/off
MAIN CONT	Main contactor: open/closed
E-M BRAKE	Electromagnetic brake: on/off
HORN INPUT	Horn driver: on/off
LOAD HOLD	Load-hold valve driver: on/off

1297 DIAGNOSTICS AND DIAGNOSTIC HISTORY

This is 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 here in alphabetical order for easy reference.

ANALOG MUX FAULT	Multiplexer communications interrupted
ANTI-TIEDOWN	Mode switch closed (M2) at startup
BDI LOW	Battery state of charge <20%
DRIVE M-	Traction motor terminal shorted to B- or open
DRIVE SENSOR	Traction motor current sensor error
EMR REV WIRING	Emergency reverse wiring fault
FIELD OPEN	Traction motor field winding open
FIELD SHORT	Traction motor field overcurrent
HPD	HPD fault occurred
HW FAILSAFE	Hardware failsafe activated
HYD INHIBIT	Hydraulic throttle high at interlock
HYD THROTTLE FAULT	Hydraulic throttle fault
LOW BATTERY VOLTAGE	Battery voltage too low
MAIN CONT WELDED	Main contactor welded
MISSING CONTACTOR	Main contactor missing
NO KNOWN FAULTS	No known faults
OVER TEMP CUTBACK	Cutback due to internal temp >85°C
OVERVOLTAGE	Battery voltage too high
PUMP DISABLED	Pump motor disable timer expired
PUMP M-	Pump motor terminal shorted to B- or open
PUMP SENSOR	Pump motor current sensor error
SERVICE PUMP	Pump motor service timer expired
SERVICE TOTAL	Total service timer expired
SERVICE TRAC	Traction motor service timer expired
SRO	SRO fault occurred
THROTTLE WIPER HI	Traction throttle wiring fault (high)
THROTTLE WIPER LO	Traction throttle wiring fault (low)
TOTAL DISABLED	Total disable timer expired
TRAC DISABLED	Traction motor disable timer expired
UNDER TEMP CUTBACK	Cutback due to internal temp <-25°C
VALVE FAULT	Lowering valve fault

7 DIAGNOSTICS AND TROUBLESHOOTING

The 1297 controller provides diagnostics information to assist technicians in troubleshooting pump system problems. The diagnostics information can be obtained by observing the appropriate display on a 13XX programmer, the fault codes issued by the Status LED, or the fault display on the Spyglass gauge. Refer to the troubleshooting chart (Table 5) for suggestions covering a wide range of possible faults.

PROGRAMMER DIAGNOSTICS

The programmer presents complete diagnostic information in plain language. Faults are displayed in the Diagnostics Menu (see column 2 in the troubleshooting chart), and the status of the controller inputs/outputs is displayed in the Test Menu.

Accessing the Diagnostic History Menu provides a list of the faults that have occurred since the diagnostic history file was last cleared. Checking (and clearing) the diagnostic history file is recommended each time the vehicle is brought in for maintenance.

The following 4-step diagnostic and troubleshooting process is recommended: (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 pump system 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, select the Diagnostics Menu, and read the displayed fault information. In this example, the display shows “No Known Faults,” indicating that the controller has not detected anything out of the norm.

STEP 3: Select the Test Menu, 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 system now operates normally, the problem has been corrected.

Table 5 TROUBLESHOOTING CHART

LED CODE	PROGRAMMER LCD DISPLAY	EXPLANATION	POSSIBLE CAUSE
1,1	DRIVE SENSOR	traction motor current sensor error	1. Incorrect traction motor wiring. 2. Controller defective.
1,2	HW FAILSAFE	self-test or watchdog fault	1. Controller defective.
1,3	DRIVE M-	external short of traction motor M- to B-, or FET damage	1. Incorrect traction motor wiring. 2. Controller defective.
1,4	VALVE FAULT	Lowering valve fault	1. Lowering valve or connection open.
2,0	BDI LOW	battery needs to be recharged	1. Battery state-of-charge <20%.
2,1	THROTTLE WIPER HI	traction throttle wiper high	1. Throttle input wire shorted to B+. 2. Defective throttle pot. 3. Wrong throttle type selected.
	THROTTLE WIPER LO	traction throttle wiper low	1. Throttle input wire open or shorted to B-. 2. Defective throttle pot. 3. Wrong throttle type selected.
2,2	PUMP SENSOR	pump motor current sensor error	1. Incorrect pump motor wiring. 2. Controller defective.
2,3	HPD	HPD sequencing error	1. Improper sequence of KSI, interlock, and throttle inputs. 2. Wrong HPD type selected. 3. Misadjusted throttle pot. 4. Interlock switch open. 5. Sequencing delay too short. 6. Wrong throttle type selected.
	SRO	SRO sequencing error	1. Improper sequence of KSI, interlock, and direction inputs. 2. Wrong SRO type selected. 3. Misadjusted throttle pot. 4. Direction switch open. 5. Sequencing delay too short. 6. Wrong throttle type selected.
	ANTI-TIEDOWN	mode switch activated at startup	1. Mode switch shorted to B+. 2. Mode switch “tied down” to select M2 permanently.
2,4	PUMP M-	external short of pump motor M- to B-, or FET damage	1. Incorrect pump motor wiring. 2. Controller defective.
3,1	ANALOG MUX FAULT	tiller multiplexer error	1. MUX card not plugged in. 2. J2 not wired properly. 2. MUX card defective.
	EMR REV WIRING	emergency reverse wiring fault	1. Emergency reverse wire or check wire open.
3,2	MAIN CONT WELDED	main contactor welded	1. Main contactor stuck closed. 2. Main contactor driver shorted.

Table 5 TROUBLESHOOTING CHART, *continued*

LED CODE	PROGRAMMER LCD DISPLAY	EXPLANATION	POSSIBLE CAUSE
3,3	FIELD SHORT	traction motor field shorted	1. Field resistance too low. 2. Field winding shorted to B+ or B-.
	FIELD OPEN	traction motor field open	1. Field winding or connection open.
3,4	MISSING CONTACTOR	missing main contactor	1. Main contactor coil open. 2. Main contactor missing. 3. Wire to main contactor missing.
4,0	TOTAL DISABLED	expired total disable timer	1. Total disable timer expired.
	TRAC DISABLED	expired traction disable timer	1. Traction disable timer expired.
	PUMP DISABLED	expired pump disable timer	1. Pump disable timer expired.
4,1	SERVICE TOTAL	expired total maintenance monitor	1. Total maintenance monitor expired.
	SERVICE TRAC	expired traction maintenance monitor	1. Traction maintenance monitor expired.
	SERVICE PUMP	expired pump maintenance monitor	1. Pump maintenance monitor expired.
4,2	OVERVOLTAGE	battery voltage too high	1. Battery voltage > overvoltage shutdown limit. 2. Operation with charger attached.
	LOW BATTERY VOLTAGE	battery voltage too low	1. Battery voltage < undervoltage cutback limit. 2. Corroded battery terminal. 3. Loose battery or controller terminal.
4,3	OVER TEMP CUTBACK	controller heatsink too hot	1. Temperature >85°C. 2. Excessive load on vehicle. 3. Improper mounting of controller. 4. Operation in extreme environments.
	UNDER TEMP CUTBACK	controller heatsink too cold	1. Temperature < -25°C. 3. Operation in extreme environments.
4,4	HYD THROTTLE FAULT	hydraulic throttle fault	1. Throttle input wire shorted to B+ or B-. 2. Throttle input wire open. 3. Defective throttle pot. 4. Wrong throttle type selected.
	HYD INHIBIT	hydraulic throttle high at interlock	1. Improper sequence of interlock and throttle inputs. 2. Misadjusted throttle pot. 3. Interlock switch open. 4. Sequencing delay too short. 5. Wrong throttle type selected.

LED DIAGNOSTICS

A Status LED is built into the 1297 controller. It is visible through a window in the label on top of the controller. This Status LED displays fault codes when there is a problem with the controller or with the inputs to the controller. During normal operation, with no faults present, the Status LED flashes steadily on and off. 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”—main contactor welded—appears as:

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

The codes are listed in Table 6.

Table 6 STATUS LED FAULT CODES

LED CODES		EXPLANATION
LED off	▬ (solid black bar)	no power or defective controller
solid on	▭ (solid white bar)	controller or microprocessor fault
0,1	■ ¤	controller operational; no known faults
1,1	¤ ¤	traction motor current sensor error
1,2	¤ ¤¤	hardware failsafe
1,3	¤ ¤¤¤	traction motor M- shorted
1,4	¤ ¤¤¤¤	Lowering valve fault
2,0	¤¤	battery below 20% state of charge
2,1	¤¤ ¤	traction throttle fault
2,2	¤¤ ¤¤	pump motor current sensor error
2,3	¤¤ ¤¤¤	traction sequencing error
2,4	¤¤ ¤¤¤¤	pump motor M- shorted
3,1	¤¤¤ ¤	emerg. rev. wiring or tiller multiplexer error
3,2	¤¤¤ ¤¤	main contactor welded
3,3	¤¤¤ ¤¤¤	traction motor field open or shorted
3,4	¤¤¤ ¤¤¤¤	main contactor open
4,0	¤¤¤¤	expired disable timer
4,1	¤¤¤¤ ¤	expired maintenance monitor
4,2	¤¤¤¤ ¤¤	over-/under-voltage
4,3	¤¤¤¤ ¤¤¤	over-/under-temperature
4,4	¤¤¤¤ ¤¤¤¤	hydraulic throttle fault

NOTE: Only one fault is indicated at a time, and faults are not queued up. Refer to the troubleshooting chart (Table 5) for suggestions about possible causes of the various faults.

SPYGLASS DIAGNOSTICS

The eight-character LCD on the Spyglass displays a continuous sequence of hourmeter, battery state-of-charge, and fault messages.

Fault messages are displayed using the same codes that are flashed by the LED. For example, the LED flashes 3,2 for a welded main contactor:

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

and the corresponding Spyglass message is `CODE 32`.

8 MAINTENANCE

There are no user serviceable parts in the Curtis PMC 1297 controller. **No attempt should be made to open, repair, or otherwise modify the controller.** Doing so may damage the controller and will void the warranty.

It is recommended that the controller be kept **clean and dry** that its diagnostics history file be checked and cleared periodically.

CLEANING

Periodically cleaning the controller exterior will help protect it against corrosion and possible electrical control problems created by dirt, grime, and chemicals that are part of the operating environment and that normally exist in battery powered systems.

CAUTION

When working around any battery powered system, proper safety precautions should be taken. These include, but are not limited to: proper training, wearing eye protection, and avoiding loose clothing and jewelry.

Use the following cleaning procedure for routine maintenance. Never use a high pressure washer to clean the controller.

1. Remove power by disconnecting the battery.
2. Discharge the capacitors in the controller by connecting a load (such as a contactor coil) across the controller's **B+** and **B-** terminals.
3. Remove any dirt or corrosion from the power and signal connector areas. The controller should be wiped clean with a moist rag. Dry it before reconnecting the battery.
4. Make sure the connections are tight. Refer to Section 2, page 7, for maximum tightening torque specifications for the battery and motor connections.

DIAGNOSTIC HISTORY

The 13XX programmer can be used to access the controller's diagnostic history file. The programmer will read out all the faults the controller has experienced since the last time the diagnostic history file was cleared. Faults such as contactor faults may be the result of loose wires; contactor wiring should be carefully checked. Faults such as overtemperature may be caused by operator habits or by overloading.

After a problem has been diagnosed and corrected, it is a good idea to clear the diagnostic history file. 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 fixed.

For instructions on accessing and clearing the diagnostic history file, see the Curtis PMC 13XX programmer manual.

APPENDIX A

GLOSSARY OF FEATURES AND FUNCTIONS

Acceleration rate

The acceleration rate is the time required for the controller to increase PWM output from zero to the maximum allowed. There are four major programmable acceleration rates for the 1297 controller: the Mode 1 and Mode 2 acceleration rates *(see Section 3A, page 24)*, which set how quickly the traction motor accelerates; the pump acceleration rate *(see Section 3B, page 47)*, which sets how quickly the pump motor accelerates during Lift operation; and the lowering valve current acceleration rate *(see Section 3B, page 49)*, which sets how quickly the lowering valve aperture opens during Lower operation.

In addition, there is a separate acceleration rate for emergency reverse—see *Section 3A, page 43*.

Access rights

Each programmable parameter is assigned an access level (OEM or User) that defines who is allowed to adjust it. On generic 1297 models, all the programmable parameters are assigned OEM access levels; see Table D-1. On OEM-specified models, the OEM designates the access level for each parameter. Restricting access rights to the OEM reduces the likelihood of important performance characteristics being changed by someone unfamiliar with the vehicle's operation. In some cases, it may be necessary to restrict a parameter's access to ensure that it is not set to a value in violation of EEC or other safety regulations.

Curtis PMC programmers are available in OEM and User models; the User programmer can adjust only those parameters with User access rights, while the OEM programmer can adjust all the parameters. Typically, OEMs supply User programmers to their dealers and distributors for setting the User-access parameters (if any) to each customer's liking, and also for testing and diagnostics.

Anti-tiedown

The anti-tiedown feature is designed to discourage operators from taping or otherwise "tying down" the mode switch in order to operate permanently in Mode 2—*see Section 3A, page 44*.

BDI

The 1297 controller has a built-in battery discharge indicator (BDI) that constantly calculates the battery state-of-charge whenever KSI is on—*see Section 3C, page 63*.

Bidirectional throttle

A bidirectional (wigwag) throttle allows the operator to control vehicle speed and direction by rotating the throttle mechanism clockwise and counterclockwise. The Curtis ET-XXX is an example of this throttle type.

Braking rate

The braking rate is the time required for the controller to increase from 0% braking output to 100% braking output when a new direction is selected—*see Section 3A, page 26.*

Boost

The boost feature can provide a burst of extra torque when the controller detects that the traction motor is about to stall—*see Section 3A, page 25.*

Coast and pick

The coast and pick feature can be used to drive the vehicle a short distance forward while the Pick switch is activated. When the Pick switch is released, the vehicle coasts to a stop—*see Section 2, page 18, and Section 3A, page 26.*

Creep speed

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). This feature helps to prevent rollback when starting uphill with low throttle—*see Section 3A, page 31*.

Current limiting

Curtis PMC controllers limit the traction motor's drive current and the pump motor current to their programmed maximum values—*see Section 3A, page 24, and Section 3B, page 46*. Current limiting protects the controller from damage that might result if the current were limited only by motor demand. PWM output is reduced until the motor current falls below the set limit.

In addition to protecting the controller, the current limit feature also provides some protection to the rest of the system. By eliminating high current surges during acceleration, stress on the motors and batteries is reduced and their efficiency enhanced.

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.

Current ratio

The 1297 controller's traction motor current limit increases linearly with increased throttle. The current ratio parameter allows adjustment of the amount of current available at low throttle requests in order to maximize startup torque while maintaining smooth vehicle starts—*see Section 3A, page 25.*

Deceleration rate

The deceleration rate is the time required for the controller to decrease PWM output from the maximum allowed to zero, in response to reduced throttle. There are four major programmable deceleration rates for the 1297 controller: the Mode 1 and Mode 2 deceleration rates *(see Section 3A, page 26)*, which set how quickly the traction motor decelerates; the pump deceleration rate *(see Section 3B, page 47)*, which sets how quickly the pump motor decelerates during Lift operation; and the lowering valve current deceleration rate *(see Section 3B, page 50)*, which sets how quickly the lowering valve aperture closes during Lower operation.

See *Coast and pick* and *Throttle deceleration* for two additional deceleration rates for the traction motor.

Emergency reverse

Emergency reverse is activated when the emergency reverse switch is pressed. After the emergency reverse switch is released, normal controller operation is not resumed until the requirements set by the emergency reverse direction interlock parameter are satisfied—*see Section 3A, page 43.*

Environmental protection

The 1297 controller is housed in a rugged ABS plastic case providing environmental protection that meets the requirements of IP53. The controller should be kept clean and dry to ensure long life. Additional protection is recommended if the controller is mounted in a location exposed to dirt or water splash.

ET-series electronic throttle

The ET-XXX is a wigwag-style throttle control assembly providing a 0–5V signal in both directions (Forward/Reverse or Lift/Lower). Use of this throttle control assembly requires that the controller's throttle input be configured for a Type 2 (single-ended 0–5V) throttle.

Fault codes

The 1297 controller provides coded fault information. When a fault occurs, the fault code can be read directly from the Status LED built into the top of the controller's case, or from the Spyglass data display. The fault codes are defined in Table 6—*see Section 7, page 87.*

Fault detection and response

An internal microcontroller automatically maintains surveillance over the functioning of the controller. When a fault is detected, the appropriate fault code is signalled. If the fault is critical, the controller is disabled. More typically, the fault is a remediable condition and temporary. The faults covered by the 1297 controller's automatic fault detection system are listed in Table 5—*see Section 7, page 85.*

Fault recording

Fault events are recorded in the controller's diagnostic history file. Multiple occurrences of the same fault are recorded as one occurrence. This fault event list can be loaded into the programmer for readout. The programmer's 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 keyswitch or interlock switch to reset the controller and enable operation. The only exceptions are these:

FAULT	RECOVERY
anti-tiedown	when mode switch is released
emerg. rev. wiring	when wiring fault is corrected
HPD/SRO	when proper sequence is followed
overvoltage	when battery voltage drops below overvoltage threshold
thermal cutback	when temperature returns to the acceptable range
throttle faults	when input signal returns to the acceptable range
undervoltage	when battery voltage rises above undervoltage threshold
(all other faults)	*(cycle keyswitch or interlock switch)*

Field map

The field map parameter determines the relationship between the traction motor's shunt field winding current and armature current. The field map parameter affects vehicle acceleration and midrange torque characteristics—*see Section 3A, page 41.*

Field map start

The field map start parameter defines the armature current at which the traction motor's field map starts to increase. The field map start parameter is used to help equalize the motor's maximum speed when loaded and unloaded—*see Section 3A, page 41*.

Field current values

The maximum and minimum field current limit values have a powerful influence on the vehicle's maximum speed and torque—*see Section 3A, page 41*. Tuning the maximum and minimum field current limits is described in detail in Section 5: Vehicle Performance Adjustment.

Full bridge

The 1297 controller uses a full bridge design for control of the traction motor's field winding. This eliminates the need for external direction contactors. The result is a higher reliability product that is smaller and simpler to install.

Half bridge

The 1297 controller uses a half bridge topology for the traction motor's armature drive. This provides reliable and highly efficient vehicle control with full all-electronic regenerative braking to zero speed.

High-pedal-disable (HPD)

The HPD feature prevents the vehicle from driving if the controller is turned on when greater than 25% throttle is applied—*see Section 3A, page 44*.

Hourmeters

The 1297 has three built-in hourmeters: the total hourmeter (measuring KSI-on hours), the traction motor hourmeter (measuring drive hours), and the pump motor hourmeter (measuring pump hours)—*see Section 3C, page 59*.

Hydraulic inhibit

The hydraulic inhibit feature prevents Lift or Lower operation if the hydraulic throttle request is greater than 25% when the interlock switch is closed—*see Section 3B, page 48.*

Interlock braking

If the interlock switch is opened while the vehicle is being driven, the 1297 controller sends braking current to the motor—*see Section 3A, page 27.*

Interlock switch

The interlock switch is a controller-enable input intended to provide a secondary operational interlock for the controller in addition to the keyswitch input. If an interlock switch is used, it must be closed in order for the controller to operate. This safety interlock is used on most material handling vehicles, typically in the form of a tiller switch, deadman footswitch, or seatswitch.

Cycling the interlock switch or the keyswitch clears most faults and re-enables operation.

KSI

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

Lift lockout features

Lift operation can be prevented when the pump motor current is too high, when the battery state-of-charge is below 20%, or when more than 25% throttle is requested at the time the interlock switch is closed—*see Section 3B, page 48*.

Load compensation

The load compensation feature adjusts the applied motor voltage as a function of motor load current. Load compensation results in more constant vehicle speeds over variations in motor loading due to ramps and cargo weights, without the operator having to constantly adjust the throttle position—*see Section 3A, page 32.*

Lowering valve

The aperture of the hydraulic line's lowering valve determines the speed of Lower operation; the lowering valve can be either a proportional valve or a simple open/closed valve—*see Section 3B, page 49.*

M- fault detection

This feature determines if the M- power connection is being held low (to B-) by an internal or external fault condition. If an M- fault is detected at the traction motor or pump motor M- power connection, the controller will inhibit PWM output and release the main contactor. External M- fault detection is not performed if greater than 50% throttle is being requested. No M- fault detection is performed if emergency reverse is activated.

MOSFET

A MOSFET (metal oxide semiconductor field effect transistor) is a type of transistor characterized by its fast switching speeds and very low losses.

MultiMode™

The MultiMode™ feature of the 1297 controller allows the vehicle to be operated with two distinct sets of characteristics. Typically, Mode 1 is programmed for slow precise indoor maneuvering and Mode 2 for faster, long distance, outdoor travel. The following six parameters can be set independently in the two modes:

— acceleration rate
— braking current limit
— braking rate
— deceleration rate
— drive current limit
— maximum speed.

The operator uses the mode switch to select Mode 1 (switch open) or Mode 2 (switch closed).

Multiplexer (MUX)

The Curtis PMC 1312 tiller multiplexer provides a 4-wire serial interface for all tiller functions. The typical wiring configuration for applications using the multiplexer is shown in Figure 4, page 10.

OEM (= Original Equipment Manufacturer)

Overtemperature

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. The 1297 controller constantly monitors its internal heatsink temperature. Starting at 85°C, the armature current is linearly decreased from full set current down to zero at 95°C. NOTE: Braking current limits are not reduced in overtemperature; this ensures that full vehicle braking is available under all thermal conditions.

Full current and performance return automatically after the controller cools down. Although occasional overtemperature operation is usually not damaging to the controller, it does suggest a mismatch. If thermal cutback occurs often in normal operation, the controller is probably undersized for the application and a higher current model should be used. Continuous operation in overtemperature will overstress the power components and reduce the lifetime and reliability of the controller.

Overvoltage protection

The overvoltage protection feature protects the controller if the voltage exceeds the factory-set limit. Overvoltage can result during battery charging or from an improperly wired controller. As soon as the voltage rises above the overvoltage threshold, the armature current is cut back linearly until it reaches zero at the cutoff point; normal controller operation resumes when the voltage drops below the threshold.

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—in this case, 16 kHz—which permits silent, efficient operation.

Regenerative braking

The 1297 controller uses regenerative braking to slow the vehicle to a stop and to reduce speed when traveling downhill. Regenerative braking means that the energy used to slow the vehicle is channeled back into the batteries, resulting in longer vehicle range between charges.

Reset

Some faults require a cycling of the KSI or interlock switch input to reset the controller and enable operation; see *Fault recovery* for exceptions.

Restraint

When the vehicle speed exceeds the requested throttle, the restraint feature causes the motor to apply a braking force and “restrain” the vehicle to the requested speed—*see Section 3, page 27*.

Reverse polarity protection

The 1297 controller is protected against reverse polarity by an internal diode. If the battery’s B+ and B- connections to an otherwise properly wired controller are reversed, the main contactor will not engage—thus protecting the controller from being damaged.

Safe commutation region

The safe commutation region includes all the combinations of field current and armature current that allow proper commutation between the traction motor’s brushes and the armature. If the motor operates outside this region, arcing and severe heating and brush wear will occur. The motor manufacturer should be able to provide curves defining the safe combinations of field and armature current. We highly recommend that you obtain these curves and use them when tuning the 1297 controller to a particular motor—*see Section 5*.

Sequencing delay

The sequencing delay feature allows the interlock switch to be cycled within a set time (the sequencing delay), thus preventing inadvertent activation of various lockout features—*see Section 3C, page 57*.

Smooth, stepless operation

Like all Curtis PMC 1200 Series controllers, the 1297 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 cycle) of the controller's power MOSFET transistors. This technique—pulse width modulation (PWM)—permits silent, stepless operation.

Speed limiting

The maximum traction motor speed can be limited in two ways: through the maximum speed parameter *(see Section 3A, page 31)* and through the minimum field current limit parameter *(see Section 3A, page 41).* The latter (Field Min) is the primary means of adjusting vehicle top speed.

The maximum pump motor speed can be limited through the maximum pump speed parameter *(see Section 3B, page 46)*.

Spyglass display

The Curtis 840 Spyglass display sequences between hourmeter, BDI, and fault code messages—*see Section 2, page 19*.

Static-return-to-off (SRO)

The programmable SRO feature prevents the vehicle from being started when "in gear" (i.e., with a direction already selected)—*see Section 3A, page 45*.

Status LED

A built-in Status LED (Light Emitting Diode) is visible through the label located on top of the 1297 controller. The Status LED flashes a 2-digit fault identification code when a fault is detected by the controller. The fault code continues to flash until the fault has been corrected and the fault condition has been cleared. Clearing the fault condition typically requires cycling KSI for faults detected during startup, and cycling the interlock switch for faults detected during operation. The fault codes are defined in Table 6—*see Section 7, page 87*.

Taper rate

The taper rate determines how quickly the vehicle changes direction when the opposite direction is selected—*see Section 3A, page 26.*

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 that regulates the current limits is also used to calculate the heatsink temperature displayed by the programmer.

Throttle deadband (neutral deadband)

The throttle deadband is the pot wiper voltage range that the controller interprets as neutral. The traction throttle amd hydraulic throttle have separate deadband parameters—*see Section 3A, page 34, and Section 3B, page 51.*

Throttle deceleration

The throttle deceleration rate applies when the traction throttle is first reduced and stays in effect until the armature current goes negative, at which point the normal deceleration rate takes over—*see Section 3A, page 26.*

Throttle map

The throttle map parameter modifies the controller's PWM output relative to the requested throttle amount. The traction throttle and hydraulic throttle have separate throttle map parameters—*see Section 3A, page 38, and Section 3B, page 54.*

Throttle maximum

The throttle maximum parameter allows accommodation of throttles that do not provide the standard full range of voltage or resistance variation at the throttle input. The traction throttle and hydraulic throttle have separate throttle maximum parameters—*see Section 3A, page 36, and Section 3B, page 54.*

Throttle types

The 1294 controller accepts a variety of throttle inputs. The most commonly used single-ended and wigwag throttles (5kΩ–0 and 0–5kΩ pots, 3-wire pots, 0-5V throttles, and the Curtis ET-XXX electronic throttle) can be used simply by selecting the appropriate throttle type in the programmer's Program Menu—*see Section 3A, page 33, and Section 3B, page 51.*

Tuning

The 1297 controller provides a variety of programmable parameters to assist in tuning the vehicle to meet the customer's needs. Section 5: Vehicle Performance Adjustment presents information and procedures for tuning specific operating characteristics on any vehicle.

Undertemperature

If the controller heatsink temperature falls below -25°C, the armature current is cut back to 50%. At this reduced current, the controller will quickly heat up without damage. When its heatsink temperature rises above -25°C, full current will become available.

Undervoltage protection

Undervoltage protection automatically cuts back the controller output if battery voltage is detected below the undervoltage threshold at startup, or when the battery voltage is pulled below the threshold by an external load. As soon as the voltage falls below the undervoltage threshold, the armature current is cut back linearly until it reaches zero at the cutoff point; normal controller operation resumes when the voltage rises above the threshold.

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

Variable braking

The variable braking feature allows the operator to use the throttle to control the amount of braking force applied to a moving vehicle—*see Section 3A, page 28.*

Variable Lift and Lower

The variable Lift and variable Lower features allow the operator to use the throttle to control the speed of Lift and Lower operation—*see Section 3B, page 56.*

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 15–20 msec and turns off the controller. The external watchdog also 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 held in reset. In addition the main contactor, armature PWM, field, and pump sections are disabled.

Welded contactor check

The 1297 controller checks for a welded main contactor at startup. If a welded contactor is detected, the controller inhibits its output until the fault is removed and the keyswitch power is cycled.

APPENDIX B

MOUNTING DIMENSIONS FOR CURTIS THROTTLES

Fig. B-1 *Mounting dimensions, Curtis PMC standard 5kΩ, 3-wire potentiometer, p/n 98191.*

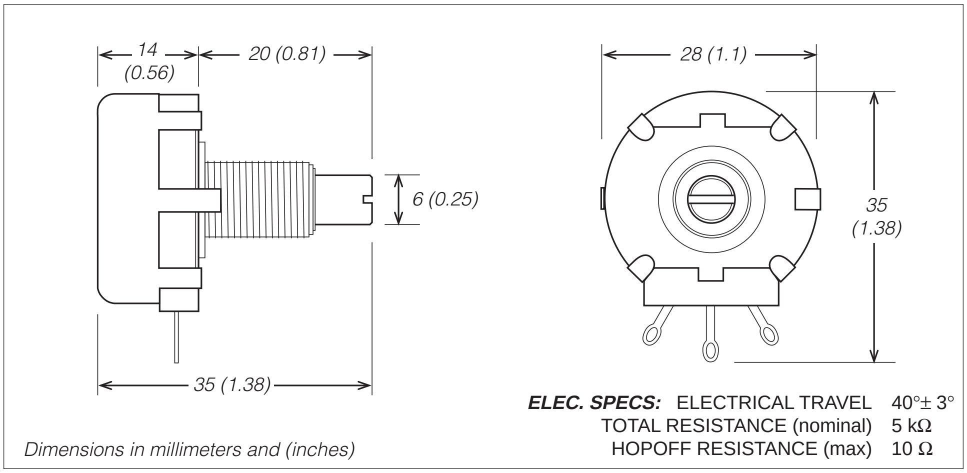


Fig. B-2 *Mounting dimensions, Curtis PMC potboxes.*

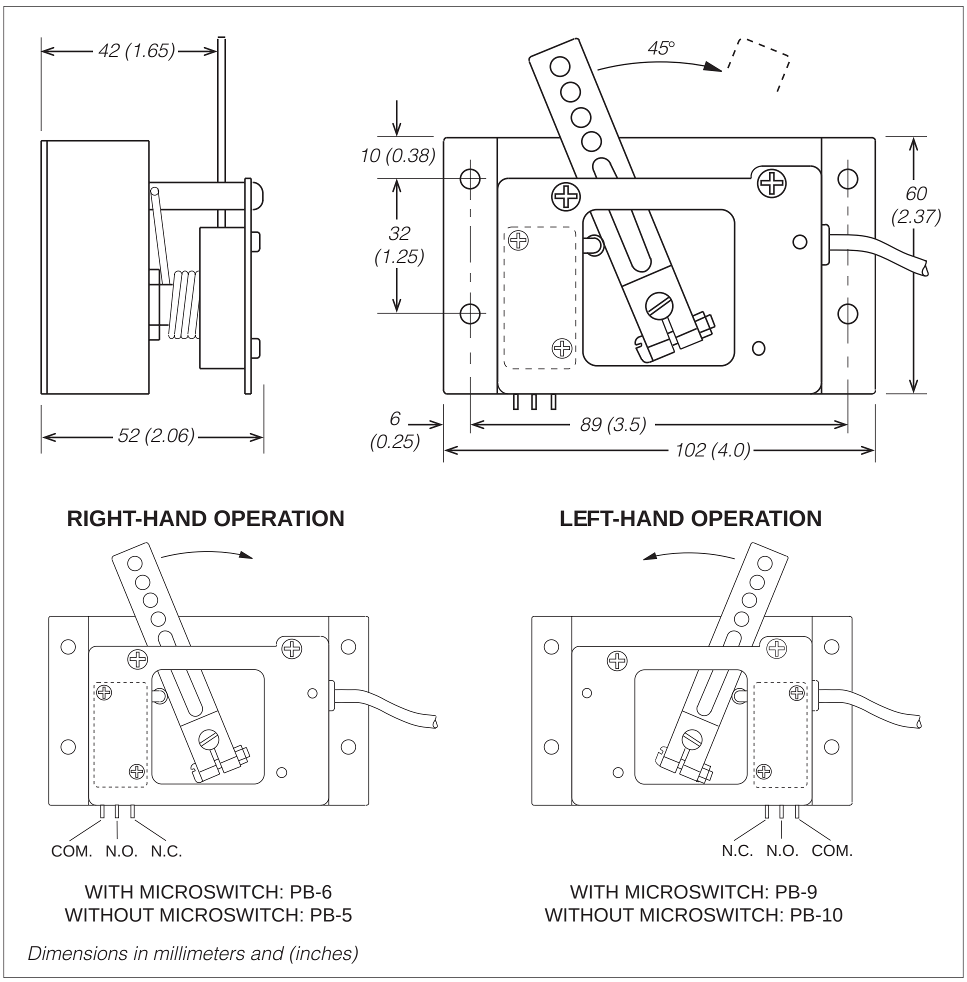


Fig. B-3 *Mounting dimensions, Curtis PMC footpedal FP-2.*

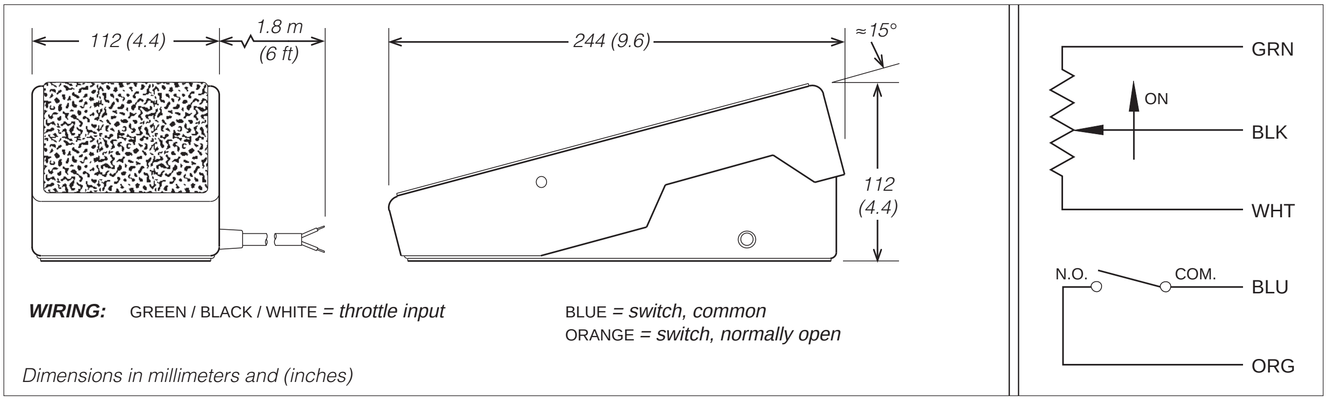


Fig. B-4 *Mounting dimensions, Curtis potentiometer WP-45 CP.*

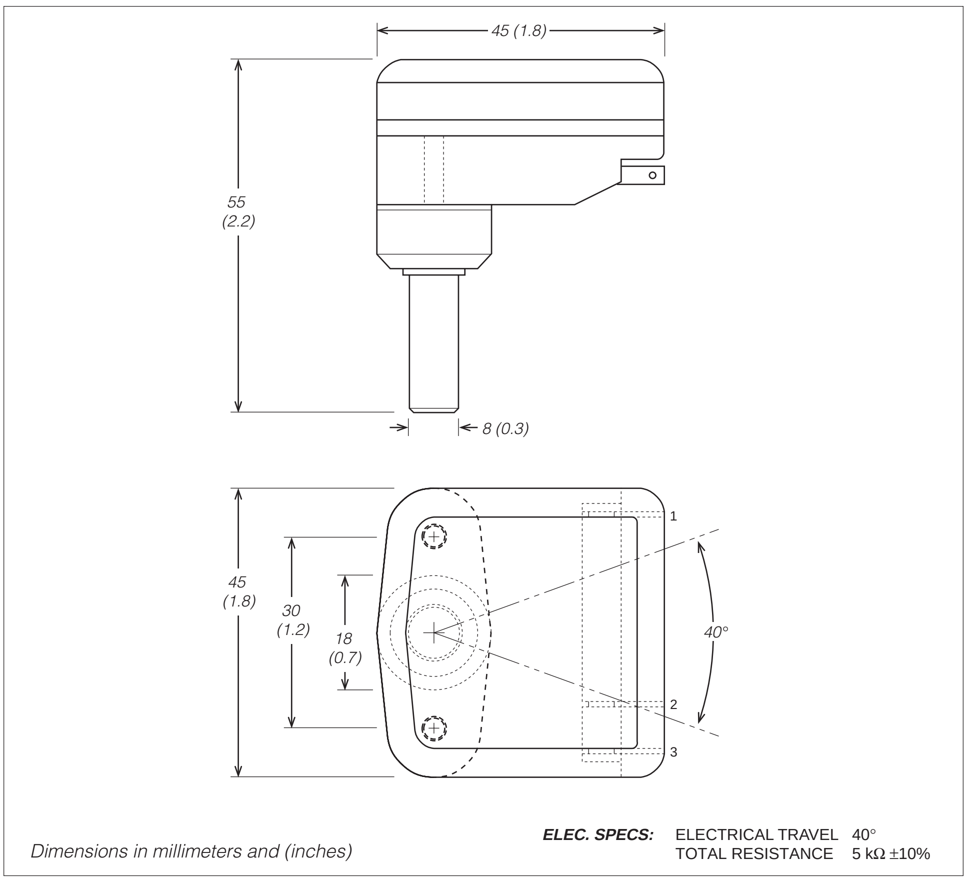
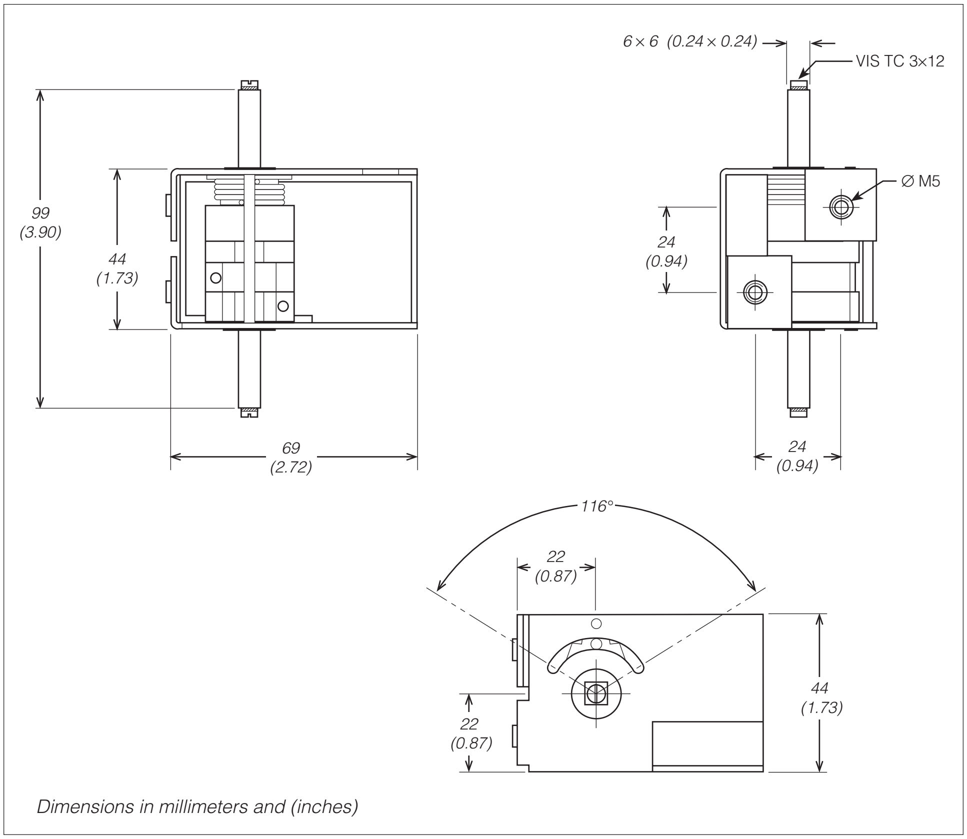


Fig. B-5 *Mounting dimensions, Curtis electronic speed control device (ET series).*



APPENDIX C

VEHICLE DESIGN CONSIDERATIONS
REGARDING ELECTROMAGNETIC COMPATIBILITY (EMC)
AND ELECTROSTATIC DISCHARGE (ESD)

ELECTROMAGNETIC COMPATIBILITY (EMC)

Electromagnetic compatibility (EMC) encompasses two areas: emissions and immunity. *Emissions* are radio frequency (rf) energy generated by a product. This energy has the potential to interfere with communications systems such as radio, television, cellular phones, dispatching, aircraft, etc. *Immunity* is the ability of a product to operate normally in the presence of rf energy.

EMC is ultimately a system design issue. Part of the EMC performance is designed into or inherent in each component; another part is designed into or inherent in end product characteristics such as shielding, wiring, and layout; and, finally, a portion is a function of the interactions between all these parts. The design techniques presented below can enhance EMC performance in products that use Curtis PMC motor controllers.

Decreasing Emissions

Motor brush arcing can be a significant source of rf emissions. These emissions may be reduced by installing bypass capacitors across the motor wires and/or between each motor wire and the motor frame. If the latter approach is used, the voltage rating and leakage characteristics of the capacitors must be adequate to meet any safety regulations regarding electrical connections between a battery operated circuit and the chassis. The bypass capacitor should be installed as close to the motor as possible, or even inside it, to provide the best performance. Alternatively a ferrite bead can be installed on the wires, as close as possible to the motor. In some instances, capacitors and ferrite beads may both be appropriate. Another option is to choose a motor with a brush material that will result in less arcing to the commutator. Brushes that have been run in for approximately 100 hours will typically generate lower emissions than new brushes because there is less arcing after they are properly seated.

The motor drive output from Curtis PMC controllers can also make a contribution to rf emissions. This output is a pulse width modulated square wave with rather fast rise and fall times that are rich in harmonics. The impact of these switching waveforms can be minimized by making the wires from the controller to the motor as short as possible. Ferrite beads installed on the drive wires can further reduce these emissions. For applications requiring very low emissions, the solution may involve enclosing the controller, interconnect wires, and motor together in one shielded box. The motor drive harmonics can couple to battery supply leads and throttle circuit wires, so ferrite beads may also be required on these other wires in some applications.

Increasing Immunity

Immunity to radiated electric fields can be achieved either by reducing the overall circuit sensitivity or by keeping the undesired signals away from this circuitry. The controller circuitry itself cannot be made less sensitive, since it must accurately detect and process low level signals from the throttle potentiometer. Thus immunity is generally achieved by preventing the external rf energy from coupling into sensitive circuitry. This rf energy can get into the controller circuitry via conducted paths and via radiated paths.

Conducted paths are created by the wires connected to the controller. These wires act as antennas and the amount of rf energy coupled into these wires is generally proportional to their length. The rf voltages and currents induced in each wire are applied to the controller pin to which the wire is connected. Curtis PMC motor controllers include bypass capacitors on the printed circuit board's throttle wires to reduce the impact of this rf energy on the internal circuitry. In some applications, ferrite beads may also be required on the various wires to achieve desired performance levels.

Radiated paths are created when the controller circuitry is immersed in an external field. This coupling can be reduced by enclosing the controller in a metal box. Some Curtis PMC motor controllers are enclosed by a heat sink that also provides shielding around the controller circuitry, while others are unshielded. In some applications, the vehicle designer will need to mount the controller within a shielded box on the end product. The box may be constructed of just about any metal, although steel and aluminum are most commonly used.

Most coated plastics do not provide good shielding because the coatings are not true metals, but rather a mixture of small metal particles in a non-conductive binder. These relatively isolated particles may appear to be good based on a dc resistance measurement but do not provide adequate electron mobility to yield good shielding effectiveness. Electroless plating of plastic will yield a true metal and can thus be effective as an rf shield, but it is usually more expensive than the coatings.

A contiguous metal enclosure without any holes or seams, known as a Faraday cage, provides the best shielding for the given material and frequency. When a hole or holes are added, rf currents flowing on the outside surface of the shield must take a longer path to get around the hole than if the surface was contiguous. As more "bending" is required of these currents, more energy is coupled to the inside surface, and thus the shielding effectiveness is reduced. The reduction in shielding is a function of the longest linear dimension of a hole rather than the area. This concept is often applied where ventilation is necessary, in which case many small holes are preferable to a few larger ones.

Applying this same concept to seams or joints between adjacent pieces or segments of a shielded enclosure, it is important to minimize the open length of these seams. Seam length is the distance between points where good ohmic contact is made. This contact can be provided by solder, welds, or pressure contact. If pressure contact is used, attention must be paid to the corrosion characteristics of the shield material and any corrosion-resistant processes applied to the base material. If the ohmic contact itself is not continuous, the shielding effectiveness can be maximized by making the joints between adjacent pieces overlapping rather than abutted.

The shielding effectiveness of an enclosure is further reduced when a wire passes through a hole in the enclosure. RF energy on the wire from an external field is re-radiated into the interior of the enclosure. This coupling mechanism can be reduced by filtering the wire at the point where it passes through the boundary of the shield. Given the safety considerations involved with connecting electrical components to the chassis or frame in battery powered vehicles, such filtering will usually consist of a series inductor (or ferrite bead) rather than a shunt capacitor. If a capacitor is used, it must have a voltage rating and leakage characteristics that will allow the end product to meet applicable safety regulations.

The B+ (and B-, if applicable) wires that supply power to the throttle control panel—such as for the keyswitch—should be bundled with the remaining throttle wires so that all these wires are routed together. If the wires to the control panel are routed separately, a larger loop area is formed. Larger loop areas produce more efficient antennas which will result in decreased immunity performance.

ELECTROSTATIC DISCHARGE (ESD)

Curtis PMC motor controllers contain ESD-sensitive components, and it is therefore necessary to protect them from ESD damage. Electrostatic discharge (ESD) immunity is achieved either by providing sufficient distance between conductors and the outside world so that a discharge will not occur, or by providing an intentional path for the discharge current such that the circuit is isolated from the electric and magnetic fields produced by the discharge. In general the guidelines presented above for increasing the radiated immunity will also provide increased ESD immunity.

It is usually easier to prevent the discharge from occurring than to divert the current path. A fundamental technique for ESD prevention is to provide adequately thick insulation between all metal conductors and the outside environment so that the voltage gradient does not exceed the threshold required for a discharge to occur. If the current diversion approach is used, all exposed metal components must be grounded. The shielded enclosure, if properly grounded, can be used to divert the discharge current; it should be noted that the location of holes and seams can have a significant impact on the ESD suppression. If the enclosure is not grounded, the path of the discharge current becomes more complex and less predictable, especially if holes and seams are involved. Some experimentation may be required to optimize the selection and placement of holes, wires, and grounding paths. Careful attention must be paid to the control panel design so that it can tolerate a static discharge.

APPENDIX D

PROGRAMMABLE PARAMETERS

The 1297's programmable parameters are listed below in alphabetical order (by display name), along with the default access levels, minimum and maximum allowable values, and default settings that are standard on generic models. Cross references to the main entry in the manual are also provided.

Not included in this alphabetical listing are the hourmeter and battery discharge indicator (BDI) parameters, which are listed separately.

Table D-1 PARAMETER RANGES AND DEFAULT SETTINGS (for Generic 1297 Controllers with Rev. 01 Software)

1297 PARAMETER	DEFAULT ACCESS	MIN VALUE	MAX VALUE	DEFAULT SETTING	UNITS	DESCRIPTION IN MANUAL
ACCEL RATE, M1-M2	OEM	0.1	3.0	**0.5**	seconds	*page 24*
ANTI-TIEDOWN	OEM			**OFF**	—	*page 44*
BOOST ENABLE	OEM			**OFF**	—	*page 25*
BRAKE C/L, M1-M2	OEM	50	RATED CURRENT *1	**RC*1**	amps	*page 25*
BRAKE RATE, M1-M2	OEM	0.1	3.0	**0.5**	seconds	*page 26*
COAST DECEL	OEM	0.1	10.0	**0.3**	seconds	*page 26*
CREEP SPEED	OEM	0	25	**0**	percent	*page 31*
CURRENT RATIO	OEM	1	4	**2**	—	*page 25*
DECEL RATE, M1-M2	OEM	0.1	10.0	**3.0**	seconds	*page 26*
DRIVE C/L, M1-M2	OEM	50	RATED CURRENT *1	**RC*1**	amps	*page 24*
E-M BRAKE DLY	OEM	0.0	30.0	**3.0**	seconds	*page 29*
E-M BRAKE TYPE	OEM	0	5	**1**	—	*page 29*
EMR ACCEL RATE	OEM	0.0	3.0	**0.1**	seconds	*page 43*
EMR DIR INT	OEM			**ON**	—	*page 43*
EMR REV C/L	OEM	50	RATED CURRENT *1	**RC*1**	amps	*page 43*
EMR REV CHECK	OEM			**OFF**	—	*page 43*
EMR TIME LIMIT	OEM			**OFF**	—	*page 43*
FIELD CHECK	OEM			**ON**	—	*page 42*
FIELD MAP	OEM	0	100	**50**	percent	*page 41*
FIELD MAX	OEM	FIELD MIN	RATED CURRENT *2	**RC*2**	amps	*page 41*
FIELD MIN	OEM	2.0	RESTRAINT	**5.0**	amps	*page 41*
FLD MAP START	OEM	25	RATED CURRENT *1	**75** or **100**	amps	*page 41*
H/S LATCH	OEM			**OFF**	—	*page 31*
HPD	OEM	0	2	**1**	—	*page 44*
HYD INHIBIT	OEM			**OFF**	—	*page 48*
HYD THRTL DB	OEM	0	40	**10**	percent	*page 51*
HYD THRTL MAP	OEM	20.0	80.0	**50.0**	percent	*page 54*

*1 The **rated armature current for the traction motor** depends on the controller model: 1297-22XX (150 amps), 1297-23XX (250 amps), 1297-24XX (350 amps); the default setting is the maximum value.

*2 The **rated field current for the traction motor** depends on the controller model: 1297-22XX (25 amps), 1297-23XX (25 amps), 1297-24XX (35 amps); the default setting is the maximum value.

Table D-1, continued

1297 PARAMETER	DEFAULT ACCESS	MIN VALUE	MAX VALUE	DEFAULT SETTING	UNITS	DESCRIPTION IN MANUAL
HYD THRTL MAX	OEM	60	100	**90**	percent	*page 53*
HYD THRTL TYPE	OEM	(see sidebox†)		**2**	—	*page 51*
INT BRAKE C/L	OEM	50	RATED CURRENT*1	**RC*1**	amps	*page 27*
INT BRAKE DLY	OEM	0.0	30.0	**2.0**	seconds	*page 27*
INT BRAKE RATE	OEM	0.0	3.0	**0.1**	seconds	*page 27*
INT OVERRIDE	OEM			**OFF**	—	*page 31*
LOAD COMP	OEM	0.0	25.0	**0.0**	percent	*page 32*
LOAD HOLD DLY	OEM	0.0	1.0	**0.5**	seconds	*page 50*
LV ACCEL	OEM	0.0	3.0	**0.1**	seconds	*page 49*
LV CHECK	OEM			**ON**	—	*page 50*
LV DECEL	OEM	0.0	3.0	**0.1**	seconds	*page 50*
LV DITHER	OEM	0	100	**0**	percent	*page 49*
LV MAX C/L	OEM	LV MIN C/L	3.0	**1.0**	amps	*page 49*
LV MIN C/L	OEM	0.0	LV MAX C/L	**1.0**	amps	*page 49*
MAIN CONT DIAG	OEM			**ON**	—	*page 57*
MAIN CONT INT	OEM			**ON**	—	*page 57*
MAIN OPEN DLY	OEM	0	40	**0**	seconds	*page 57*
MAX SPEED, M1-M2	OEM	CREEP SPEED	100	**100**	percent	*page 31*
MUX ENABLE	OEM			**OFF**	—	*page 58*
NO LOAD C/L	OEM	0	PUMP C/L	**0**	amps	*page 46*
NO LOAD SPEED	OEM	0	100	**100**	percent	*page 46*
POT LOW CHECK	OEM			**OFF**	—	*page 40*
PUMP ACCEL	OEM	0.1	3.0	**0.1**	seconds	*page 47*
PUMP BDI L/O	OEM			**OFF**	—	*page 48*
PUMP BDI WARN	OEM			**OFF**	—	*page 48*
PUMP C/L	OEM	25	RATED CURRENT*3	**RC*3**	amps	*page 46*
PUMP DECEL	OEM	0.1	3.0	**0.1**	seconds	*page 47*
PUMP LOCK C/L	OEM	25	RC*3+50	**RC*3**	amps	*page 48*
PUMP LOCK DLY	OEM	0.1	25.0	**0.5**	seconds	*page 48*
PUMP MAX SPEED	OEM	0	100	**100**	percent	*page 46*
RESTRAINT	OEM	FIELD MIN	RATED CURRENT*2	**5.0** or **8.0**	amps	*page 27*
SEQUENCING DLY	OEM	0.0	3.0	**0.1**	seconds	*page 57*
SRO	OEM	0	3	**0**	—	*page 45*
TAPER RATE	OEM	1	20	**10**	—	*page 26*
THROTTLE DB	OEM	0	40	**10**	percent	*page 34*
THROTTLE DECEL	OEM	0.1	1.0	**0.3**	seconds	*page 26*
THROTTLE MAP	OEM	20.0	80.0	**50.0**	percent	*page 38*
THROTTLE MAX	OEM	60	100	**90**	percent	*page 36*
THROTTLE TYPE	OEM	(see sidebox††)		**2**	—	*page 33*
VARIABLE BRAKE	OEM			**ON**	—	*page 28*
VARIABLE LIFT	OEM			**OFF**	—	*page 56*
VARIABLE LOWER	OEM			**OFF**	—	*page 56*

† Hydraulic throttle types:
2=0–5kΩ
4=0-5V

†† Traction throttle types:
1=5kΩ–0
2=0–5V
3=0–5kΩ
4=wigwag

*3 The **rated armature current for the pump motor** depends on the controller model: 1297-22XX (200 amps), 1297-23XX (200 amps), 1297-24XX (300 amps); the default setting is the maximum value.

Table D-1, continued

The 1297's remaining parameters are listed below. For these lists, Program Menu order is used rather than alphabetical order.

1297 PARAMETER	DEFAULT ACCESS	MIN VALUE	MAX VALUE	DEFAULT SETTING	UNITS	DESCRIPTION IN MANUAL
Hourmeter						
ADJ HRS HIGH	OEM	0	151	**0**	—	*page 59*
ADJ HRS MID	OEM	0	255	**0**	—	*page 59*
ADJ HRS LOW	OEM	0	255	**0**	—	*page 59*
SET TOTL HRS	OEM			**OFF**	—	*page 60*
SET TRAC HRS	OEM			**OFF**	—	*page 60*
SET PUMP HRS	OEM			**OFF**	—	*page 60*
SRVC TOTL HRS	OEM	0.0	50.0	**0.0**	100 hours	*page 60*
SRVC TRAC HRS	OEM	0.0	50.0	**0.0**	100 hours	*page 60*
SRVC PUMP HRS	OEM	0.0	50.0	**0.0**	100 hours	*page 60*
DIS TOTL HRS	OEM	0	250	**10**	hours	*page 61*
DIS TRAC HRS	OEM	0	250	**10**	hours	*page 61*
DIS PUMP HRS	OEM	0	250	**10**	hours	*page 61*
TRAC FAULT SPD	OEM	0	100	**100**	percent	*page 61*
PUMP FAULT SPD	OEM	0	100	**100**	percent	*page 61*
SERVICE TOTL	OEM			**OFF**	—	*page 62*
SERVICE TRAC	OEM			**OFF**	—	*page 62*
SERVICE PUMP	OEM			**OFF**	—	*page 62*
Battery Discharge Indicator (BDI)						
FULL VOLTS	OEM	EMPTY VOLTS	RESET VOLTS	**204**	0.01 VPC	*page 63*
EMPTY VOLTS	OEM	90	FULL VOLTS	**173**	0.01 VPC	*page 63*
RESET VOLTS	OEM	FULL VOLTS	300	**209**	0.01 VPC	*page 63*

APPENDIX E

SPECIFICATIONS

Table E-1 SPECIFICATIONS: 1297 CONTROLLER

Nominal input voltage	24 V
PWM operating frequency	16 kHz
Electrical isolation to heatsink	500 V ac (minimum)
KSI input voltage (minimum)	16.8 V
KSI input current (no contactors engaged)	80 mA without programmer; 120 mA with programmer
Logic input voltage	>7.5 V High; <1 V Low
Logic input current	7.3 mA (nominal)
Throttle control signals	2-wire 5kΩ–0 or 0–5kΩ; 3-wire pot; or 0–5V
Operating ambient temperature range	-40°C to 50°C (-40°F to 122°F)
Storage ambient temperature range	-25°C to 85°C (-13°F to 185°F)
Heatsink overtemperature cutback	linear cutback starts at 85°C (185°F); complete cutoff at 95°C (203°F)
Heatsink undertemperature cutback	50% armature current at -25°C (-13°F); complete cutoff at -40°C (-40°F)
Package environmental rating	IP53
Weight	3.0 kg (6.1 lb)
Dimensions (L×W×H)	158 × 158 × 84 mm (6.2" × 6.2" × 3.3")

		TRACTION							PUMP	
MODEL NUMBER	NOMINAL BATTERY VOLTAGE (volts)	DRIVE CURRENT LIMIT (amps)	BOOST 10 SEC RATING * (amps)	ARMATURE 2 MIN RATING * (amps)	ARMATURE 1 HOUR RATING * (amps)	FIELD 2 MIN RATING (amps)	FIELD 1 HOUR RATING (amps)	BRAKING CURRENT LIMIT (amps)	ARMATURE 2 MIN RATING (amps)	ARMATURE 1 HOUR RATING (amps)
1297-22XX	24	150	180	150	75	25	15	150	200	80
1297-23XX	24	250	300	250	90	25	15	250	200	80
1297-24XX	24	350	420	350	120	35	20	350	300	100

* Controller mounted to 12"×12"×⅛" aluminum plate, with continuous 3 mph airflow perpendicular to back of plate, and 25°C ambient temperature.