Manual

Model 1229

Permanent Magnet Motor Speed Controller

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Read Instructions Carefully!

Specifications are subject to change without notice.

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The Curtis Difference

You feel it when you drive it

CONTENTS

FIGURES

TABLES

1 OVERVIEW

The Curtis Model 1229 is a sealed, heavy-duty permanent magnet motor speed controller intended for demanding traction applications in hostile environments. It utilizes an advanced, powerful dual-microprocessor, logic architecture for maximum functional safety and accurate speed control.

This controller is designed for large industrial permanent magnet motor applications, such as floor care machines, utility tugs/pushers, burden carriers small material handling vehicles and AGVs.

Fig. 1 *Curtis 1229 motor speed controller.*

Like all Curtis controllers, the 1229 offers superior operator control of motor drive performance.

High power capability

- ✓ Class-leading power density gives maximum power output from smallest possible package
- ✓ Models available from 200–250 A output at 24–36 V, and 200 A at 48V; short-term boost provides current 10% above these limits
- ✓ Insulated Metal Substrate (IMS) power base provides superior heat transfer for increased reliability and highest possible continuous current ratings
- ✓ Uses a heavy-duty external power isolation contactor to provide maximum safety and performance, eliminating the overheating and reliability problems often found with other manufacturers' high-current controllers that use internal board-mounted isolation relays.

Rugged construction

- ✓ Heavy duty threaded M6 busbars for battery and motor connectors eliminate reliability issues often found with push-on power connectors
- ✓ All logic connections via reliable, IP65 sealed 23-pin AMPSEAL connector
- ✓ Robust IP65 sealed polycarbonate enclosure provides excellent chemical resistance and protection from harsh environments
- ✓ Designed to withstand high levels of bump, shock and vibration.

Powerful, flexible I/O

- ✓ Four 10A rated PWM-control auxiliary outputs allow bidirectional control of up to two linear actuators or uni-directional control of up to four other small motor loads
- ✓ Two 2A rated PWM-control auxiliary outputs for line contactor, EM brake, solenoid valves or other relay and contactor coils
- ✓ Integrated fly-back diodes on all auxiliary outputs
- ✓ Highly programmable analog and digital inputs, including a motor speed sensor input for max speed limiting
- ✓ Short circuit protection and integral ESD protection on all I/O
- ✓ CANopen compatible CANbus connection allows use as a ‘CANopen slave’ on any CANopen system, plus limited CANopen ‘master’ capability
- ✓ Compatible with the inexpensive Curtis 3100R CANopen gauge for monitoring battery state-of-charge, service interval timers, and diagnostic information
- ✓ CANopen EDS (Electronic Data Sheets) available.

Flexibility and safety

- ✓ Dual-microprocessor architecture cross-checks critical circuits, logic, and software functions to ensure the highest possible functional safety performance level is achieved
- ✓ Advanced Pulse Width Modulation (PWM) techniques minimize heating losses and torque ripple, resulting in high efficiency and ensuring that EMC emissions are within EN12895 limits
- ✓ Logic I/O mapping function allows vehicle developers to write powerful combinational and sequential logic functions
- ✓ Curtis handheld or PC Windows programming tools provide easy programming and powerful system diagnostic tools

- ✓ Simple motor set-up programming
- ✓ Field-upgradeable software
- ✓ Integrated battery state-of-charge algorithm, plus hours-run and service interval timers
- ✓ Integrated overvoltage, undervoltage and thermal cutback protection.

Complies with relevant U.S. and international regulations

- ✓ EMC: Designed to the requirements of EN12895:2000
- ✓ Safety: Designed to the requirements of
    - EN1175-1:1998+A1:2010
    - EN (ISO) 13849-1:2008
- ✓ IP65 rated per IEC529
- ✓ UL recognized per UL583
- ✓ Regulatory compliance of the complete vehicle system with the controller installed is the responsibility of the vehicle OEM.

Familiarity with your Curtis 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

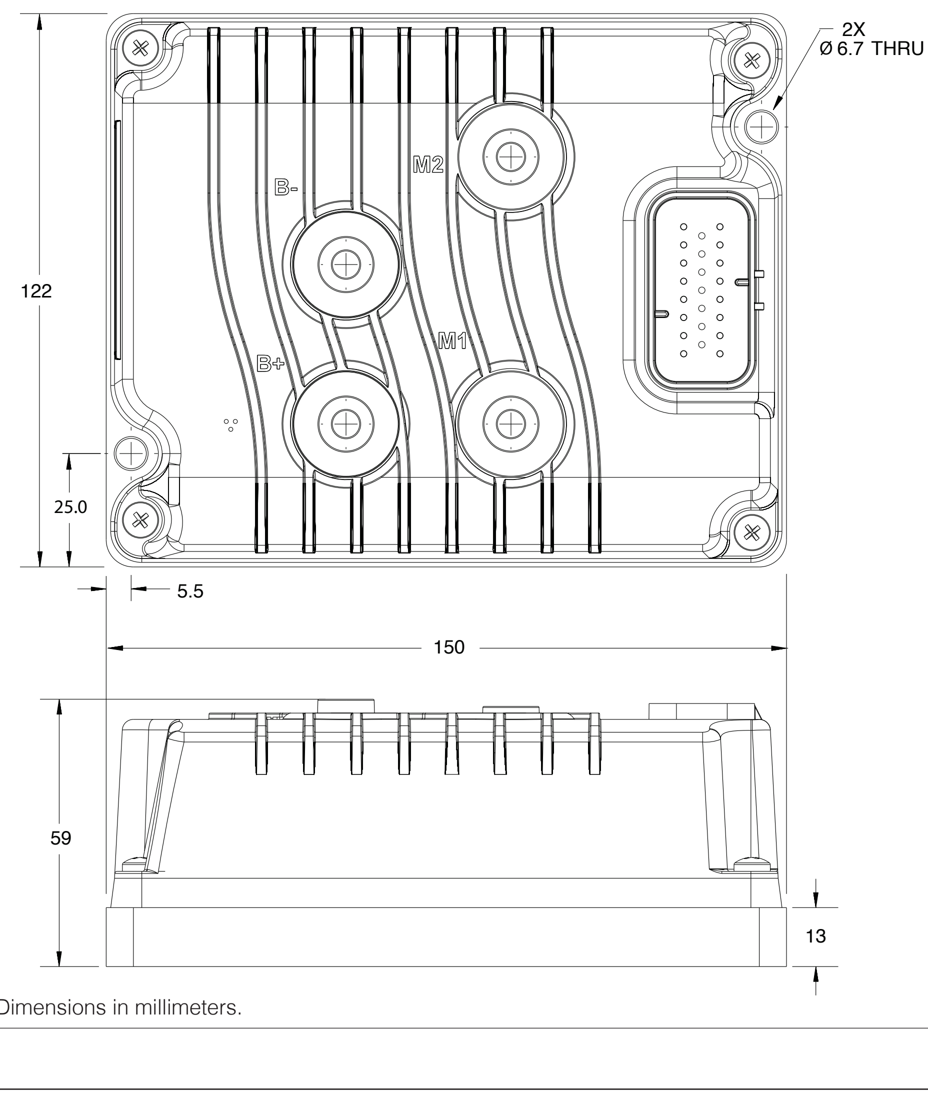
INSTALLATION AND WIRING

MOUNTING THE CONTROLLER

The outline and mounting hole dimensions for the 1229 controller are shown in Figure 2. When an Ampseal plug housing is mated with the 23-pin logic receptacle, the 1229 meets the IP65 requirements for environmental protection against dust and water. Nevertheless, in order to prevent external corrosion and leakage paths from developing, the mounting location should be carefully chosen to keep the controller as clean and dry as possible.

It is recommended that the controller be fastened to a clean, flat metal surface with two M6 mounting bolts, using the holes provided. A thermal joint compound can be used to improve heat conduction from the controller heatsink to the mounting surface. Additional heatsinking or fan cooling may be necessary to meet the desired continuous ratings.

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 B.



Dimensions in millimeters.

Fig. 2 *Mounting dimensions, Curtis 1229 motor controller.*

The 1229 controller contains **ESD-sensitive components**. Use appropriate precautions in connecting, disconnecting, and handling the controller. See installation suggestions in Appendix B for protecting the controller from ESD damage.

CAUTION

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

UNCONTROLLED OPERATION — Some conditions could cause the motor to run out of control. Disconnect the motor or jack up the vehicle and get the drive wheels off the ground before attempting any work on the motor control circuitry.

HIGH CURRENT ARCS — Batteries can supply very high power, and arcing 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.

HIGH CURRENT CONNECTIONS

There are four high-current terminals, identified on the controller housing as **B+**, **B-**, **M1**, and **M2**.

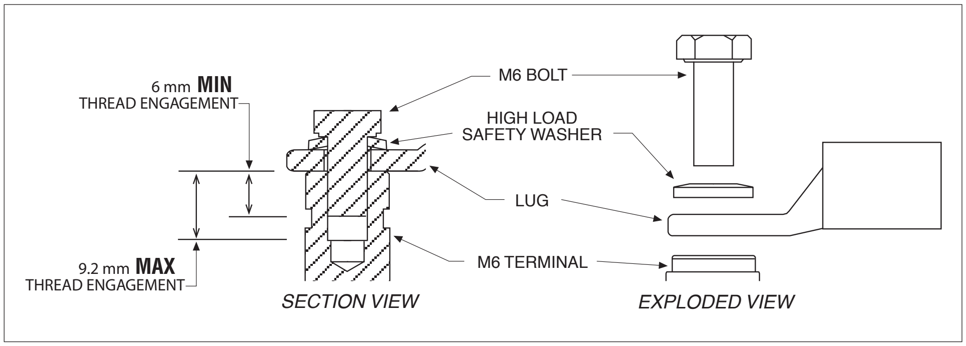
Table 1 High Current Connections

TERMINAL	FUNCTION
B+	Positive battery to controller (after main contactor).
B-	Negative battery to controller.
M1	Motor terminal 1.
M2	Motor terminal 2.

Lug assembly: high current connections

Four aluminum M6 terminals are provided. Lugs should be installed as follows, using M6 bolts sized to provide proper engagement (see diagram):

- Place the lug on top of the aluminum terminal, followed by a high-load safety washer with its convex side on top. The washer should be a SCHNORR 416320, or equivalent.
- If two lugs are used on the same terminal, stack them so the lug carrying the least current is on top.
- Tighten the assembly to 10.2 ±1.1 N·m (90 ±10 in-lbs).



High current wiring recommendations

Battery cables (**B+**, **B-**)

These two cables should be run close to each other between the controller and the battery. Use high quality copper lugs and observe the recommended torque ratings. For best noise immunity the cables should not run across the center section of the controller. With multiple high current controllers, use a star ground from the battery **B-** terminal.

Motor wiring (**M1**, **M2**)

The two motor wires should be close to the same length and bundled together as they run between the controller and the motor. The cable lengths should be kept as short as possible. Use high quality copper lugs and observe the recommended torque ratings. For best noise immunity the motor cables should not run across the center section of the controller. In applications that seek the lowest possible emissions, a shield can be placed around the bundled motor cables and connected to the **B-** terminal at the controller. Typical installations will readily pass the emissions standards without a shield. Low current signal wires should not be run parallel to the motor cables. When necessary they should cross the motor cables at a right angle to minimize noise coupling.

LOW CURRENT WIRING

All low power connections are made through a single 23-pin AMPSEAL connector. The mating plug housing is p/n 770680-1 and the contact pins are p/n 770520-1. The connector will accept 20 to 16 AWG wire with a 1.7 to 2.7mm diameter thin-wall insulation.

The 23 individual pins are characterized in Table 2.

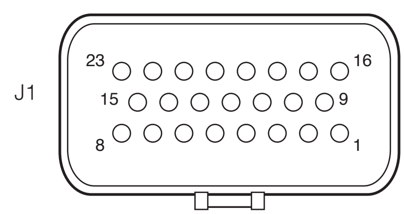


Table 2 Low Current Connections

PIN	NAME	DESCRIPTION	SPECIFICATIONS
1	**CAN H**	CAN bus high output.	
2	**CAN L**	CAN bus low output.	
3	**Switch 3**	Digital input #3.	• Input current: 2.7 mA at 60 V. • Input voltage range: 10 V to 60 V. • Threshold: <10 V.
4	**Driver 2**	Digital output #2. Typically used for brake.	• Output current: 2 A max. • Frequency range: 200 Hz – 1 kHz. • KSI coil return.
5	**Switch 5**	Generic digital input #5. Typically used for speed sensor input. For applications without a speed sensor, can be used as an active-low general purpose digital input (pull to GND).	• Frequency: 30 kHz max. • Logic high threshold: 2.4 V. • Logic low threshold: 1.6 V. • Input voltage range: +60 V to -10 V.
6	**Analog GND**	Analog ground for analog inputs.	• B+ short protection. • Pot fault detection.
7	**Pot 3**	Analog input #3.	• Input voltage range: 0 – 5.0 V. • B+ short protection.
8	**KSI**	Keyswitch input. Provides logic power for the controller and power for Drivers 1&2 coil return.	• Input voltage range: 10 V to 60 V. • Controller will not turn on if battery voltage is below 12 V (all models) or above: 48 V (24–36V models) 64 V (48V models). • Micro reset if KSI voltage is at or below 4 V.
9	**TXD**	Data output to programmer.	• Serial TXD.
10	**Switch 2**	Digital input #2.	• Input current: 2.7 mA at 60 V. • Input voltage range: 10 V to 60 V. • Threshold: <10V .
11	**Switch 4**	Digital input #4.	• Input current: 2.7 mA at 60V. • Input voltage range: 10 – 60V. • Threshold: <10 V.
12	**RXD**	Data input from programmer.	• Serial RXD.
13	**Pot 1**	Analog input #1; typically used for throttle.	• Input voltage range: 0 – 5.0 V. • B+ short protection.
14	**Pot 2**	Analog input #2.	• Input voltage range: 0 – 5.0 V. • B+ short protection.
15	**Driver 5**	Digital output #5. Can be configured as an independent low-side driver, or can be paired with Driver 6 for independent bidirectional actuator control. Can also be combined with Drivers 3&4 to provide two bidirectional speed and direction dependent drivers (see Fig. 3a).	• 10 A driver, with B+ short protection. • Vcap (B+ after contactor) is coil return for low-side driver. • Output short protection.

Table 2 Low Current Connections, cont'd

PIN	NAME	DESCRIPTION	SPECIFICATIONS
16	**GND**	Logic ground for programmer or other external devices.	• Logic ground.
17	**+17V Out**	External +17V output for programmer or speed sensor.	• Short to B+ or GND protection.
18	**+5V Out**	External +5V output for throttle pot or speed sensor.	• Short to B+ or GND protection.
19	**Switch 1**	Digital input #1.	• Input current: 2.7 mA at 60 V. • Input voltage range: 10 V to 60 V. • Threshold: <10 V.
20	**Driver 1**	Digital output #1, dedicated output for the main contactor.	• Output current: 2 A max. • Frequency range: 200 Hz to 1 kHz. • KSI coil return. • Coil short protection.
21	**Driver 6**	Digital output #6. Can be configured as an independent low-side driver, or can be paired with Driver 5 for bidirectional actuator control.	• 10 A low-side driver, with B+ short protection. • Vcap (B+ after contactor) is coil return for low-side driver. • Output short protection.
22	**Driver 3**	Digital output #3. Can be configured as an independent low-side driver, or can be paired with Driver 4 for bidirectional actuator control.	• 10 A low-side driver, with B+ short protection. • Vcap (B+ after contactor) is coil return for low-side driver. • Output short protection.
23	**Driver 4**	Digital output #4. Can be configured as an independent low-side driver, or can be paired with Driver 3 for bidirectional actuator control.	• 10 A low-side driver, with B+ short protection. • Vcap (B+ after contactor) is coil return for low-side driver. • Output short protection.

CONTROLLER WIRING: BASIC CONFIGURATION

Two wiring diagrams are shown in Figures 3a and 3b. The throttle is shown in the diagrams as a 3-wire potentiometer; other types of throttle inputs are easily accommodated, and are discussed in the following throttle wiring section.

The main contactor coil must be wired directly to the controller as shown in Figures 3a and 3b to meet EEC safety requirements. 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 motor

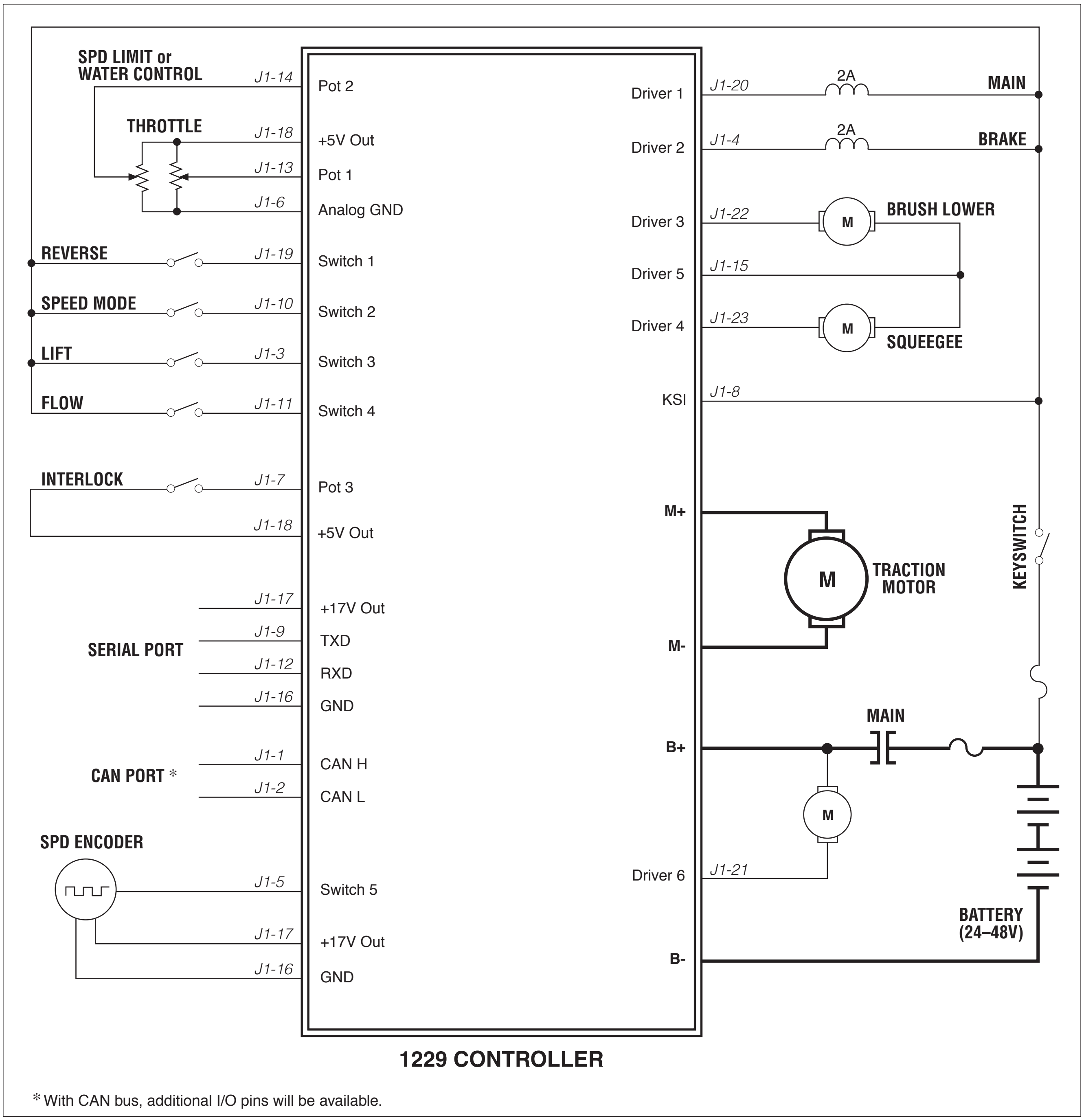


Fig. 3a *Basic wiring, example A: floor care vehicle.*

in the event of various other faults. **If the main contactor coil is not wired to Pin 20 of the 23-pin connector as shown, 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.**

Note that the two wiring diagrams shown are examples only. The 1229 controller can be used in many different wiring configurations and applications via programmable I/O and mapping functions. You may wish to contact your local Curtis representative to discuss your particular application.

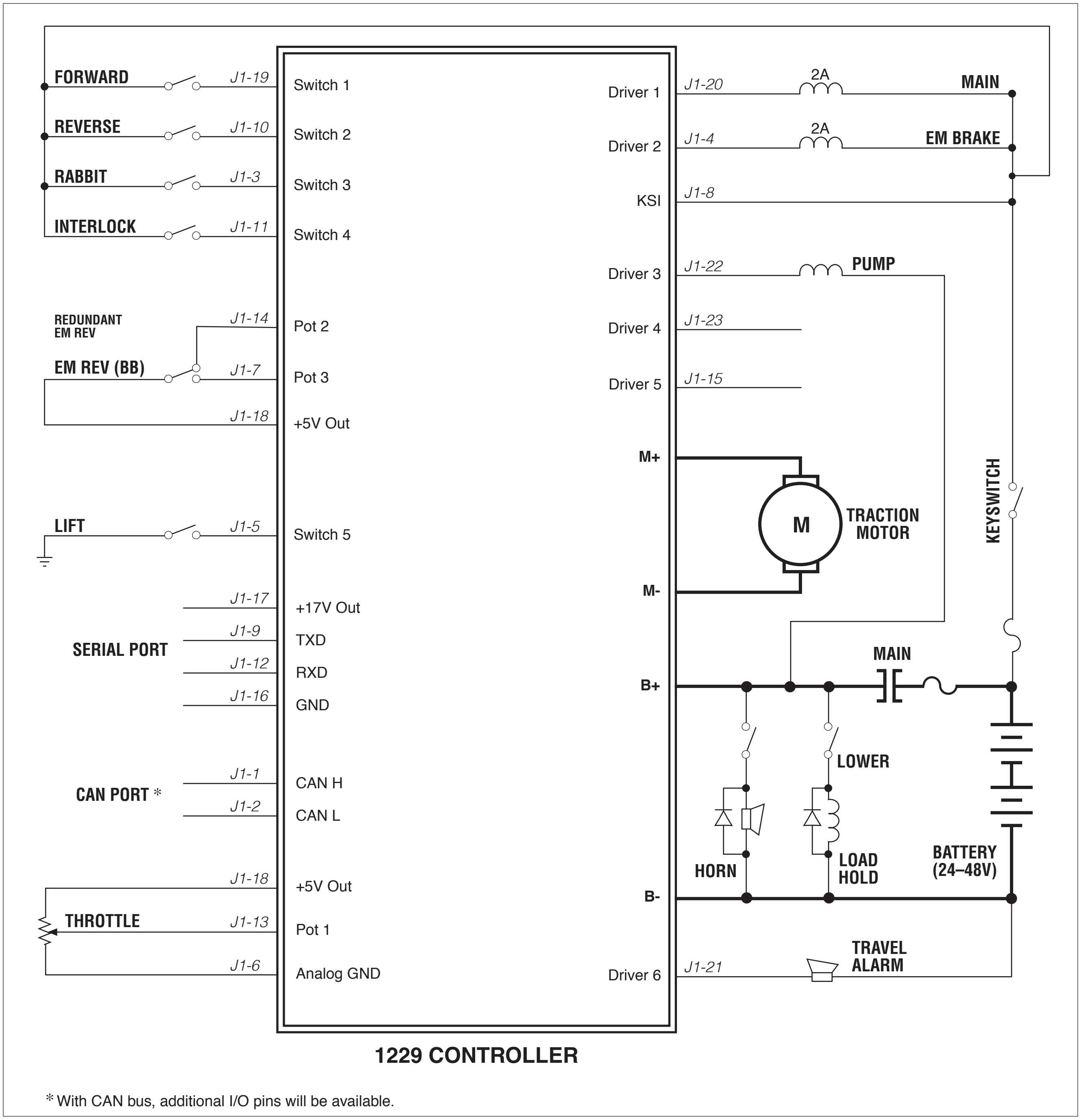


Fig. 3b *Basic wiring, example B: pallet mover.*

ANALOG AND DIGITAL INPUTS

The 1229 has both analog and digital inputs. These inputs are flexible and programmable for multiple uses.

There are three analog inputs: Pot 1–3. They are typically used for devices such as throttles and speed or brake potentiometers, or may be used for switch inputs.

There are five digital inputs: Switch 1–5. Switch 5 is a high speed input that can be used to connect a motor speed sensor, or as a basic switched input to ground. The other four digital inputs (Switch 1–4) should be connected to KSI.

All the inputs, analog and digital, are programmable for multiple functions; the options are described in the Programmable Parameters section of the manual. The following section describes typical input wiring schemes that are used in many vehicle applications.

The 1229 is capable of accepting inputs on the CANbus. This means that if a CAN device, such as a throttle, is used in place of a conventional potentiometer or 0–5V throttle, an additional input will be available for another purpose.

Wiring: Analog inputs

Throttles

A 3-wire potentiometer or a 0–5V source can be used for throttle inputs on the 1229 controller. The throttle can be wired into any of the three analog inputs or via the CAN bus. In the examples shown in Figures 4 and 5 below (as well as in Figures 3a and 3b) the throttle is wired into Pot 1 (pin J1-13).

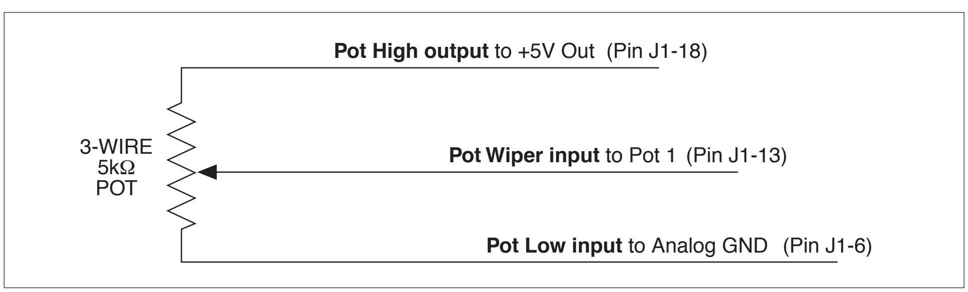
A single reverse switch, or individual forward and reverse switches, can be used for direction control. See Section 4: Programmable Parameters.

Note: If the throttle you are planning to use is not covered in this manual, contact the Curtis office nearest you.

5kΩ, 3-wire potentiometer throttle

With the potentiometer wired as shown below, the controller supplies 5 V (on pin J1-18) with respect to ground (pin J1-6) across the potentiometer. The voltage produced on the wiper is used as the throttle signal to Pot 1 (pin J1-13).

Fig. 4 *Wiring for 5kΩ, 3-wire potentiometet throttle.*

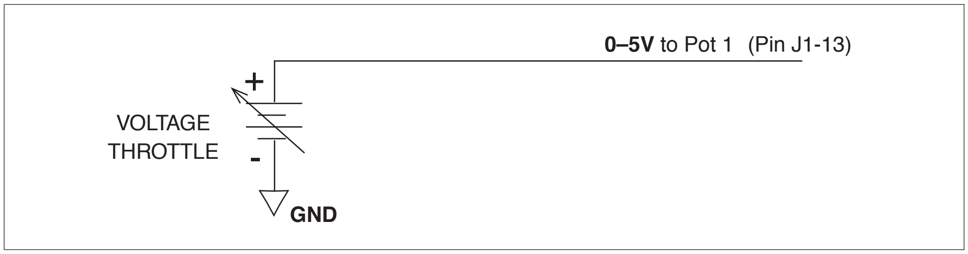


The controller provides full pot fault protection against open or shorted wires anywhere in the throttle potentiometer assembly. If a pot fault occurs while the vehicle is moving, the controller will decelerate the vehicle to a smooth stop using the deceleration rate set by the E Stop Decel parameter. If the fault is corrected while the throttle is still applied, an HPD fault is issued and driving is disabled until throttle is returned to neutral.

Voltage throttle

Wiring for an external voltage throttle is shown below in Figure 5. In this example, the 0–5V signal is wired to Analog 1 (pin J1-13).

Fig. 5 *Wiring for 0–5V voltage throttle.*



Note: Because the throttle input voltage is referenced to GND, and no throttle connections are made to the pot high (pin J1-18) and pot low (pin J1-6) inputs, throttle fault protection is lost with 0–5V throttles. The only throttle fault that will be detected by the controller is a broken wire to the pot wiper input (pin J1-13), which will cause a normal deceleration to zero speed (loss of voltage on pin J1-13). The controller will not recognize out-of-range throttle inputs as faults, and applying excessive voltages to the throttle wiper input may damage the controller. **It is the responsibility of the vehicle manufacturer to provide throttle fault detection for 0–5V throttles.**

Other uses for the analog inputs

Instead of being used for a throttle input, Pot 1, 2, or 3 can be configured for a speed limit, brake pedal, or other potentiometer/voltage input. These inputs can also be programmed and wired as switched inputs for various functions. Switched analog inputs must be referenced to +5V Out (pin J1-18). Analog inputs are programmable for multiple functions; active low option available.

Wiring: Digital inputs

All five digital inputs are programmable for multiple functions; see Section 3: Programmable Parameters. Here we describe typical wiring options that are seen in many vehicle applications

Switches 1–4

Switches 1–4 are typically used to trigger a specific function of the controller, such as forward, reverse, interlock, mode, lift, lower, etc. (see basic wiring diagrams in Figures 3a and 3b). These inputs are wired to the KSI line after the keyswitch and are activated when the input switch is opened or closed. These programmable inputs can be set up to function as normally open or normally closed.

Switch 5

Switch 5 is a high speed digital input capable of accepting a signal from a motor speed sensor. The frequency of this input is programmable, up to 30 kHz. This input is also multi-purpose and can be used as an active low switch input. **This input must be wired via a switch to ground (B-) when it is used as a switch input.** As with the other digital inputs, this input is programmable as normally open or normally closed.

COMMUNICATION PORTS

Separate CAN and serial ports provide complete communications and programming capability for all user-available controller information.

Serial port

The Curtis 1313 handheld and 1314 PC programmers plug into a connector wired to pins J1-9 and J1-12, along with ground (J1-16) and the +5V power supply (J1-17); see Figures 3a and 3b.

CAN port

It is recommended that CAN H (pin J1-1) and CAN L (pin J1-2) be run as a twisted pair. However, many successful applications at 125 kBaud are run without twisting, simply bundling the two lines with the rest of the low current wiring. CAN wiring should be kept away from the high current cables and cross them at right angles when necessary.

DIGITAL OUTPUTS

The 1229 has six digital outputs total: Drivers 1–6. Driver 1 is dedicated for the main contactor. The remaining five are flexible and programmable.

Driver 1

Digital Output 1 is a dedicated 2 A output. It is recommended that the 1229 use an external main contactor, and Driver 1 is reserved for this purpose. However, fault detection on Driver 1 can be disabled for vehicles where a system master controls the main contactor.

Driver 2

Digital Output 2 is also a 2 A output, and is typically used for a brake (as shown in the wiring diagrams in Figures 3a and 3b). However, because some systems do not use a brake, this output is programmable and considered general purpose. The OEM or system designer should keep in mind that this output is 2 A and size the load accordingly.

Drivers 3–6

Drivers 3–6 are 10 A multipurpose outputs. Drivers 3–5 are low side drivers; Driver 6 is programmable as low side or high side. Each output can function independently as a half-bridge driver, meaning that it can operate independently and run a small motor, for example, in a single direction.

These outputs can also be combined to create two full-bridge bidirectional drivers. An example of this is shown in Figure 3a, where Drivers 3, 4, and 5 are combined to run two separate bidirectional motors.

It is also possible to combine Drivers 3&4 (or 5&6) to drive a single motor bidirectionally.

The total continuous current of combined drivers is dependent on the number of drivers used.

NUMBER OF DRIVERS USED	CONTINUOUS CURRENT ALLOWED
1	4.0 A
2	2.5 A
3	2.0 A
4	1.5 A

3

I/O MAPPING

The 1229 controller allows customization of I/O by means of a system of mapping inputs to outputs, through various signal conditioning functions.

Inputs represent physical pins like switches or pot inputs, or inputs from the CANopen interface.

Outputs include Drivers 1–6, half-bridge drivers combined to form full bridges, the traction bridge (which is controlled through "virtual" outputs such as throttle, brake, forward, reverse, emergency reverse, etc.), outputs to the CANopen interface, or virtual functions such as charger inhibit, push, or interlock.

Signal conditioning functions include debouncing, filtering, timers, analog maps, combinatorial logic, toggle functions, etc.

Each input, output, and signal conditioning function is represented in the I/O Map menu by a name prefixed with a unique object number, as follows:

0-Always Off 0%
1-Switch 1
2-Switch 2
3-Switch 3
4-Switch 4
5-Switch 5
6-Toggle 1
7-Toggle 2
8-Toggle 3
9-Toggle 4
10-Toggle 5
11-Pot 1
12-Pot 2
13-Pot 3
14-Threshold 1
15-Threshold 2
16-Threshold 3
17-Threshold 4
18-Debounce 1
19-Debounce 2
20-Debounce 3
21-Debounce 4
22-Timer 1
23-Timer 2
24-Timer 3
25-Timer 4
26-Bit Mask 1
27-Bit Mask 2
28-Bit Mask 3
29-Bit Mask 4
30-Bit Mask 5
31-Bit Mask 6
32-Bit Mask 7
33-Bit Mask 8
34/35-Wig Wag 1
36/37-Wig Wag 2
38/39-Wig Wag 3
40-Vehicle Speed
41-Logic Gate 1
42-Logic Gate 2
43-Logic Gate 3
44-Logic Gate 4
45-Logic Gate 5
46-Logic Gate 6
47-Logic Gate 7
48-Logic Gate 8
49-Logic Gate 9
50-Logic Gate 10
51-Low-Pass 1
52-Low-Pass 2
53-Low-Pass 3
54-Map 1
55-Map 2
56-Map 3
57-PWM Generator 1
58-PWM Generator 2
59-PWM Generator 3
60-PWM Generator 4
61-PWM Generator 5
70-Correlate
71-Inhibit
72-PI
73-Slew Limit 1
74-Slew Limit 2
75-Slew Limit 3
76-Slew Limit 4
77-Voltage Comp 1
78-Voltage Comp 2
79-Voltage Comp 3
80-Voltage Comp 4
81-Driver 2
82-Driver 3
83-Driver 4
84-Driver 5
85-Driver 6
86-Driver 3/4 Actuator
87-Driver 5/6 Actuator
88/89-Driver 3/4/5 Dual Actuator
90-Push
91-Throttle
92-Forward
93-Reverse
94-Speed Mode
95-Speed Limit
96-Brake Pedal
97-Interlock
98-Emergency Reverse
99-Constant Value
100-Always On 100%
111-User 1
112-User 2
113-User 3
114-User 4
115-User 5
116-User 6
117-User 7
118-User 8
119-User Fault Estop
120-User Fault Severe

In addition, these items in the Monitor menu allow vehicle status signals to control I/O Map objects:

101-Main Contactor Engaged
102-Neutral
103-Brake Engaged
104-Brake Not Engaged
105-Rev Beep
106-KSI
107-BDI
108-Traction Active
109-[reserved]
110-[reserved]

Each object in the I/O map can take values from 0–100%. On/off digital objects such as switches take a value of 0% when off and 100% when on. Analog objects can take a value anywhere between 0% and 100%. If an analog object is mapped into an object expecting a digital value, it is interpreted as 0% = off and any non-zero value = on. An analog value when mapped into an output object could represent duty cycle or, if programmed for voltage compensation, a percentage of max voltage.

The following examples illustrate some of the customization possibilities available through I/O mapping.

Example 1: Basic mapping of digital and analog inputs to controller functions

Example 2: Using pot inputs for switches

Example 3: Using logic gates and vehicle status functions

Example 4: Configuring outputs to drive loads

Example 5: More sophisticated use of the Enable Input parameter

Example 6: Use of the analog maps

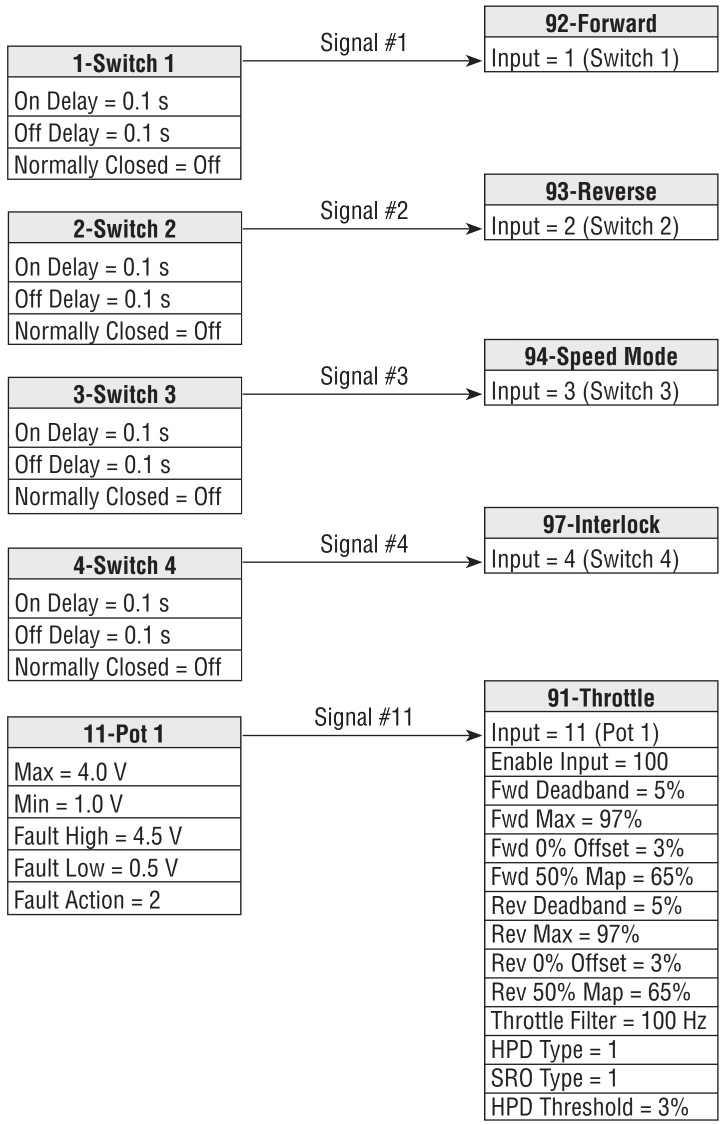
Example 7: Handling wigwag throttles

Example 8: Configuring an actuator

Example 9: Configuring CANopen to operate with a CANopen compliant tiller head

Example 1: Basic mapping of digital and analog inputs to controller functions

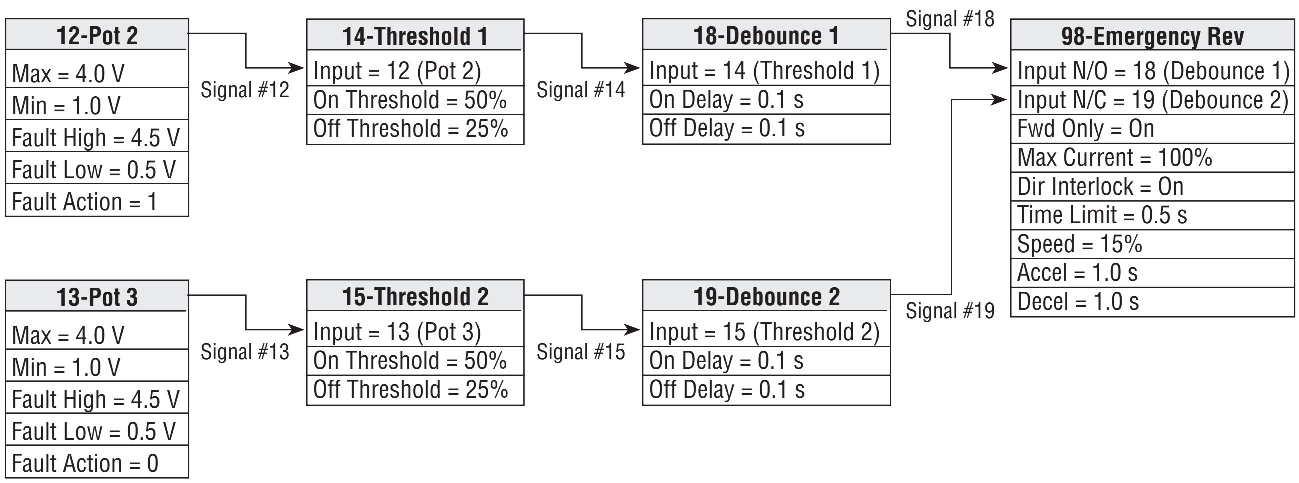
In this example, a vehicle is configured as shown in Figure 3b, with switches on Switch 1 (pin J1-19) for forward, Switch 2 (pin J1-10) for reverse, Switch 3 (pin J1-3) for speed mode, and Switch 4 (pin J1-11) for interlock, and a potentiometer on Pot 1 (pin J1-13) for throttle.



Mapping is accomplished by setting a function's input parameter to the number of the signal you want to map. Setting "92-Forward Input = 1" maps Switch 1 into the Forward function; setting "93-Reverse Input = 2" maps Switch 2 into the Reverse function; etc.

Example 2: Using pot inputs for switches

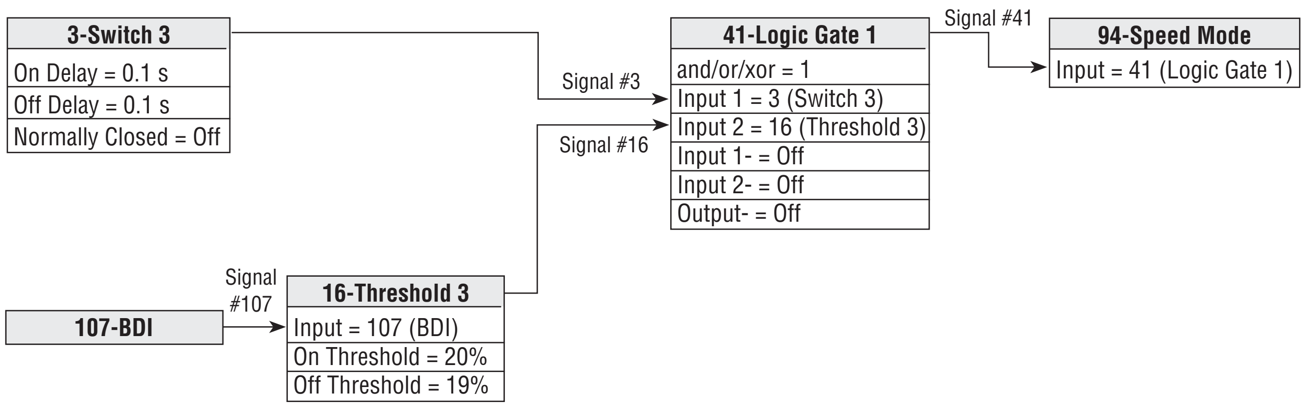
Here a vehicle is configured as shown in Figure 3b, with an SPDT switch connected to Pots 2 & 3 for use as a redundant Emergency Reverse input.



The Threshold functions convert analog signals (0–100%) to digital (on/off) with programmable thresholds, allowing pots to be used for switches. The switch signals are then mapped to Debounce functions, before being eventually mapped to the Emergency Reverse function.

Example 3: Using logic gates and vehicle status functions

A vehicle is configured as shown in Figure 3b. Here the I/O mapping is modified to force the vehicle to use Speed Mode 1 when BDI is below 20%.

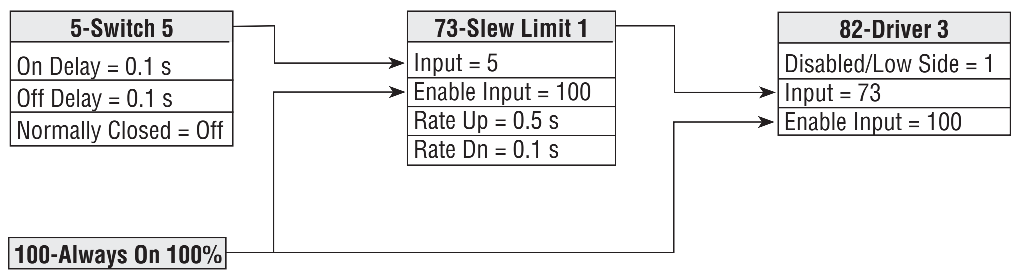


In this example, the Threshold 3 function is used to detect the 20% threshold on signal #107 (BDI). Threshold 3 is used, because Thresholds 1 & 2 are already being used for Emergency Reverse, as shown in Example 2. The Threshold 3 function configured as shown above will generate a signal that is On (100%) when its input (BDI) is above 20%, and Off (0%) when its output is below 20%.

41-Logic Gate 1 is then used to “and” this signal with Switch 3. The resulting signal on Logic Gate 1 will reflect the state of Switch 3 when BDI is above 20%, and will be forced to Off when BDI is below 20%. Setting 94-Speed Mode to 41 completes the mapping.

Example 4: Configuring outputs to drive loads

A vehicle is configured as shown in Figure 3b, with Driver 3 running a pump. Here the I/O mapping is such that the switch on Switch 5 will drive this pump at 100% duty cycle with 0.5 s soft start.



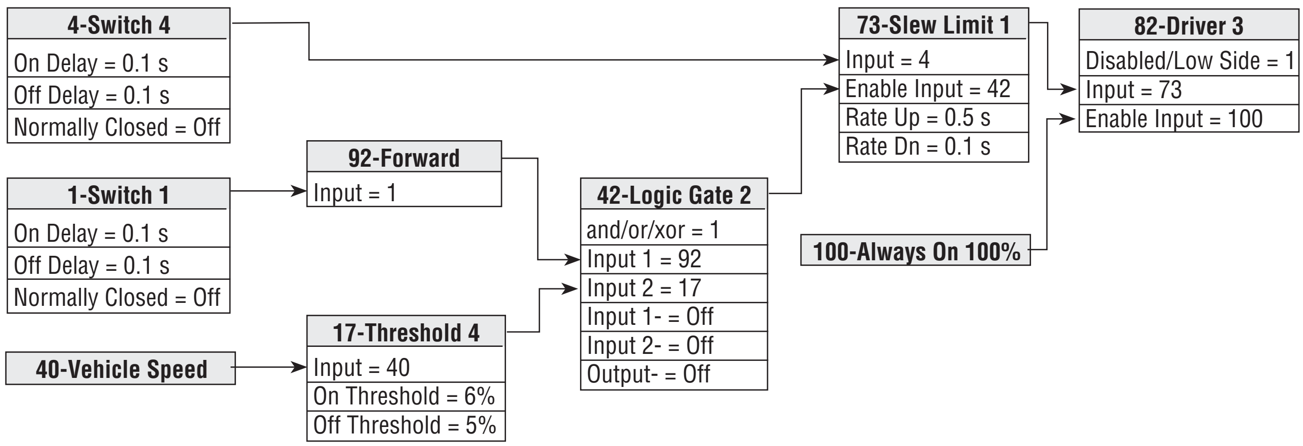
For Switch 5 to function as a switch input, the Encoder Enable parameter under 40-Vehicle Speed must be set to Off. For Driver 3 to be used as a low-side driver, 86-Driver 3/4 Actuator and 88/89-Driver 3/4/5 Actuator must be disabled, and 82-Driver 3 Disabled/Low Side must be set to 1 (Low Side).

Switch 5, like all digital signals in the I/O map, takes a value of 0% when Off, and 100% when On, so this signal already generates the specified duty cycle for Driver 3, except for the soft start requirement—which is generated by inserting the 73-Slew Limit 1 function into the signal chain. If a duty cycle other than 100% is required, it can be generated by inserting one of the PWM functions (objects 57-61) into the signal chain before the slew limiter.

Both 73-Slew Limiter 1 and 82-Driver 3 have an Enable Input parameter as well as an Input parameter. For both of these, the Input parameter specifies the duty cycle, and the Enable Input parameter will force the output to 0% whenever the mapped signal is 0% (in the case of the slew limiter, by applying the Rate Down parameter). Because the example does not specify any criteria to enable the output, these are both mapped to Object 100, which is Always On 100%.

Example 5: More sophisticated use of the Enable Input parameter

A vehicle is configured as in Example 4, with Driver 3 running a pump from Switch 5 at 100% duty cycle with 0.5 s soft start. Now we will modify this mapping so that the pump will only run when Switch 5 is On **and** the vehicle is driving forward at greater than 5% speed.



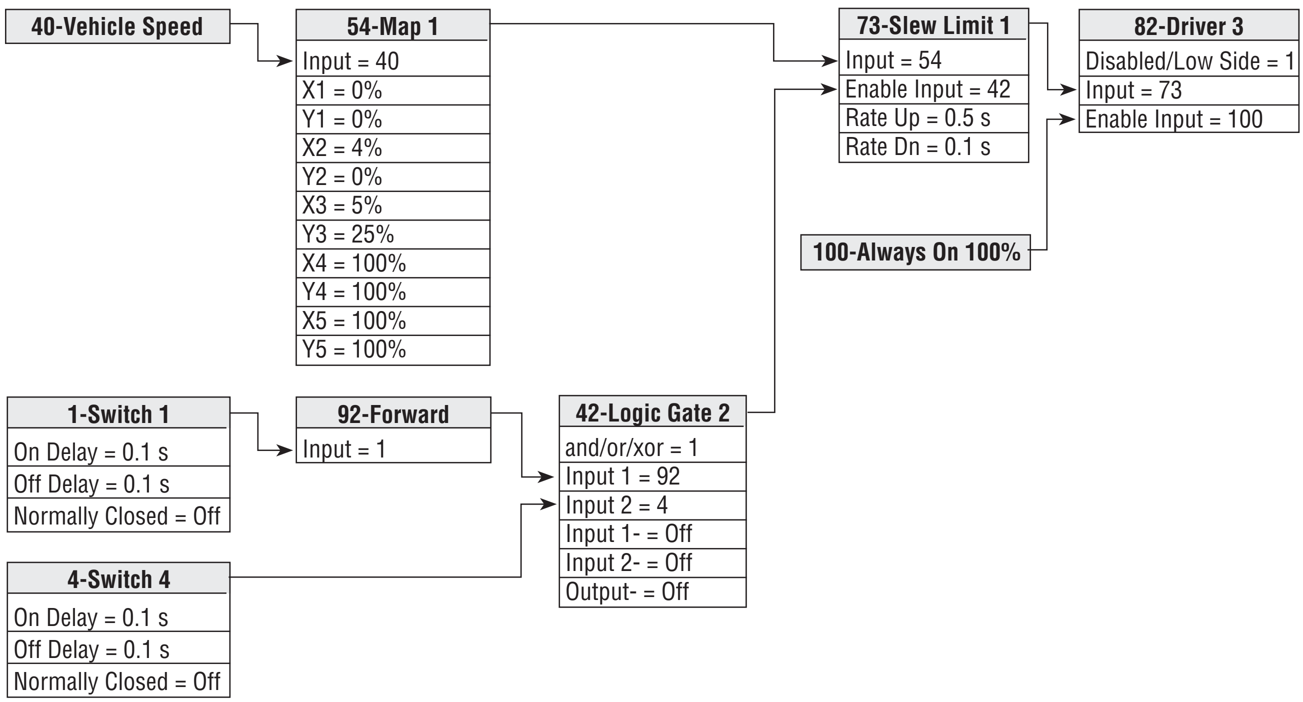
The 73-Slew Limit 1 Enable Input parameter now uses a sophisticated vehicle status function mandating that the pump on Driver 3 will run only when Switch 4 is On and the vehicle is moving forward at greater than 5% speed.

The 92-Forward function uses the signal from 1-Switch 1 as the forward switch, and because 92-Forward is itself also a function, it is available as a vehicle status and can be mapped to other functions in the 1/O map. The preference in this situation is to use 92-Forward to indicate forward rather than 1-Switch 1, because 92 will always indicate forward regardless of other mapping. In fact, the function 92-Forward will indicate the vehicle is commanded in the forward direction even in applications with no forward switch (for example, in applications with wigwag throttles or in applications with a single direction switch mapped to 93-Reverse).

The 40-Vehicle Speed function is where the encoder input is configured, but when an encoder input is not used (as in this example, where Switch 4, which is the encoder input, is configured as a switch input) this function becomes a vehicle status that indicates vehicle speed based on the motor's back-EMF, as a percentage of the Speed Scaler parameter. This signal is mapped to a threshold function to detect the specified 5% speed, and then into a logic gate where it is ANDed with the 92-Forward signal, resulting in a signal that indicates driving forward at greater than 5% speed, which is then mapped into the Enable Input parameter of the slew limiter.

Example 6: Use of the Map functions

A vehicle is configured as in Example 5, with Driver 3 running a pump from Switch 4 at 100% duty cycle, when the vehicle is running forward at greater than 5% speed. Now we will modify this mapping so that the pump will run at a duty cycle proportional to forward speed, such that duty cycle is 0% when the vehicle is running at less than 5% forward speed, is 25% when the vehicle is at 5% forward speed, and ramps to 100% when the vehicle is at 30% forward speed, and remains at 100% for speeds above 30%.



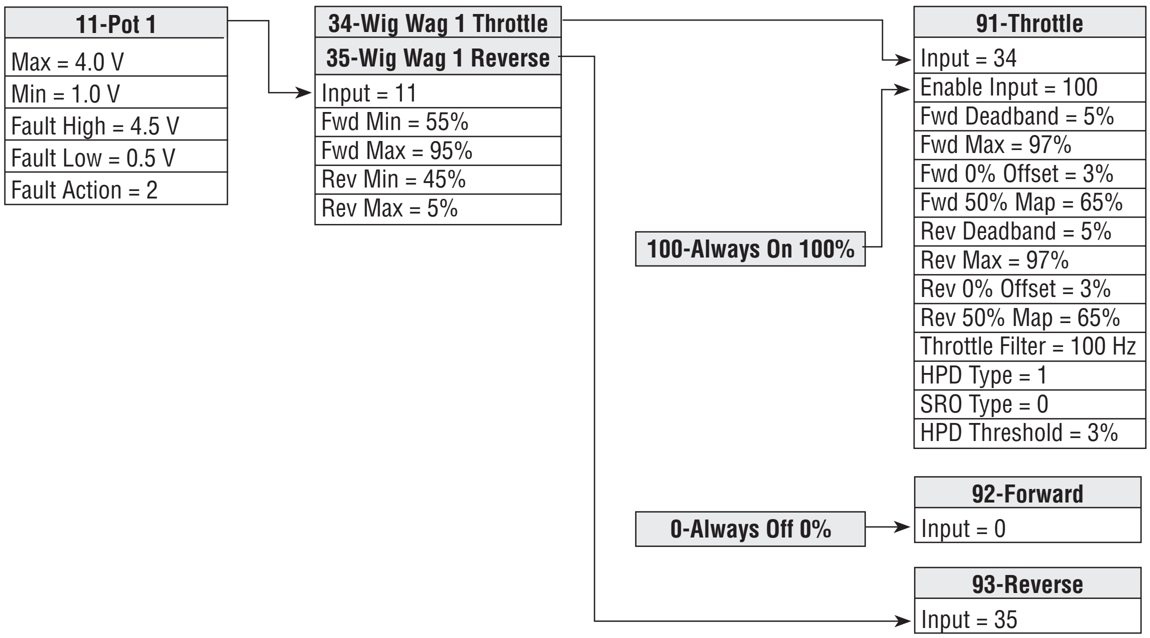
Because of the added requirement that Driver 3 be run at a variable duty cycle, Switch 4 is no longer adequate to generate Driver 3's duty cycle.Instead, duty cycle is generated from 40-Vehicle Speed, with the requirement that duty cycle is variable from 25%–100% over vehicle speeds from 5%–30%. This function is accomplished by mapping 40-Vehicle Speed through one of the analog Map functions. This map is configured to generate 0% output below 5% speed, so the threshold speed detection in the previous example is no longer necessary.

Switch 4 must still control the pump on Driver 3, and the requirement of running only in the Forward direction is still in place. These signals are ANDed using 42-Logic Gate 2, and this signal is used as the Enable Input for 73-Slew Limit 1.

Because vehicle speed is already generating a slew-limited duty cycle, it could be argued that 73-Slew Limit 1 is no longer necessary. However, it's used here to prevent the duty cycle from slamming on if Switch 4 is applied while the vehicle is already at speed.

Example 7: Handling wigwag throttle types

This example shows how to configure a wigwag throttle input on Pot 1.



Wigwag throttle functions are unusual in the I/O map in that they generate two signals from a single input, which is why they are assigned two numbers in the map. These functions take an input, and generate signals to mimic a single-ended throttle and reverse switch. These signals can then be mapped to any function expecting this type of signal, such as 91-Throttle and 93-Reverse, or an actuator.

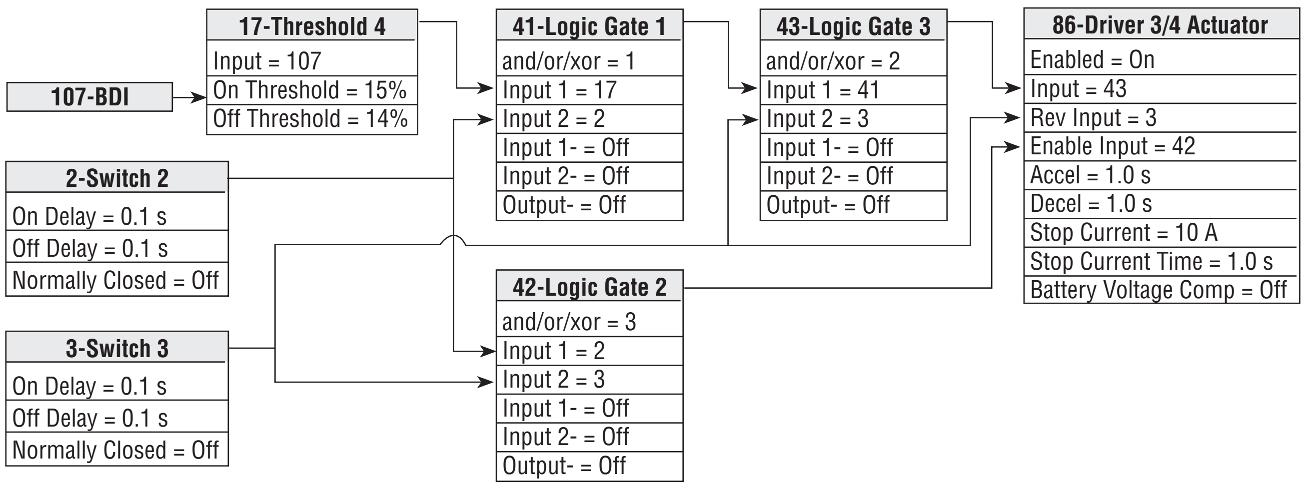
The wigwag functions generate an even-numbered signal as throttle, and an odd-numbered signal as reverse switch. The Reverse signal could be inverted and mapped into the 92-Forward function, but this is not necessary. The 92-Forward function recognizes a special case when 0-Always Off 0% is mapped, and automatically assumes the opposite of the 93-Reverse function. (93-Reverse does the same if it's mapped to 0-Always Off 0%.)

With one of the direction functions mapped to 0, take care that SRO Type is set to 0 (Off), because otherwise this configuration would force an SRO fault.

11-Pot 1's Fault Action parameter is set to 2, which commands an emergency stop in the event of an out-of-range fault on Pot 1; this setting is recommended for most throttle inputs.

Example 8: Configuring an actuator

In this example, a vehicle is configured to operate a bidirectional actuator using Driver 3 & 4 as an H-bridge, from pushbuttons on Switch 2 (“Lift” = Fwd) and Switch 3 (“Lower” = Rev). If both buttons are pushed simultaneously, the actuator does not move. “Lift” is not allowed if BDI is below 15%.



Function 86-Driver 3/4 Actuator is used here to make an H-bridge for bidirectional motor control using Drivers 3 & 4. Setting the function’s Enable parameter to On automatically disables functions 82-Driver 3 and 83-Driver 4. The actuator function also has programmable Accel/Decel, Stop Current (stall detect), and Battery Voltage Compensation parameters. The signal mapped to the Input parameter specifies the duty cycle, the signal mapped to Rev Input specifies the direction, and the signal mapped to Enable Input enables the H-bridge.

In this example, the duty cycle is generated using 43-Logic Gate 3 to “or” Switch 3 (Lower), with another signal generated from 41-Logic Gate 1, which says Switch 2 (Lift) is pressed and BDI is >15%.

The Reverse Input signal is taken directly from Switch 3.

The Enable Input is generated using 42-Logic Gate 2 to “xor” Switches 2 & 3. This will result in 100% (On) if one button is pressed, and 0% (Off) if both buttons or neither button is pressed.

This example provides a good opportunity to discuss the movement of signals through the I/O map.

The controller firmware scans the entire map every 8 ms, in the order that the functions are numbered (i.e., it calculates function 0, then function 1, then function 2, etc.). This means that signal chains that always propagate forward (from lower numbered functions to higher numbered functions) will be completely calculated every 8 ms. Every time a signal propagates backward (from a higher number to a lower number) there is an 8 ms delay in that signal reaching its destination. For this reason, the I/O map functions are ordered such that inputs are first, followed by conditioning functions, and outputs last. (Note: This does not apply to vehicle status functions, those numbered 100 or above, which are scanned at a lower rate because they don’t change this quickly.)

In example 8, logic gates 41 & 43 are chained in an order that allows the signal to propagate forward. If the two logic gates (and their parameter settings) were swapped, the backwards propagation would cause an 8 ms delay. In this example, that would not be a problem; but in an application chaining all ten logic gates, backwards propagation could create a delay as long as 80 ms.

Example 9: Configuring CANopen to operate with a CANopen compliant tiller head

This example shows how to configure a walkie with a CANopen compliant tiller head that includes a wigwag throttle, rabbit button, neutral detect switch, redundant belly button switch, horn button, and additional wigwag and button controls for lift/lower.

Configuration for use with a CANopen tiller head requires that PDO1 RX mapping is set so that data from the tiller controls are mapped into the User functions in the I/O map, where they can then be mapped into other I/O functions as in the other examples. The factory-set default values are appropriate for most applications; if you require a different arrangement, contact your local Curtis office.

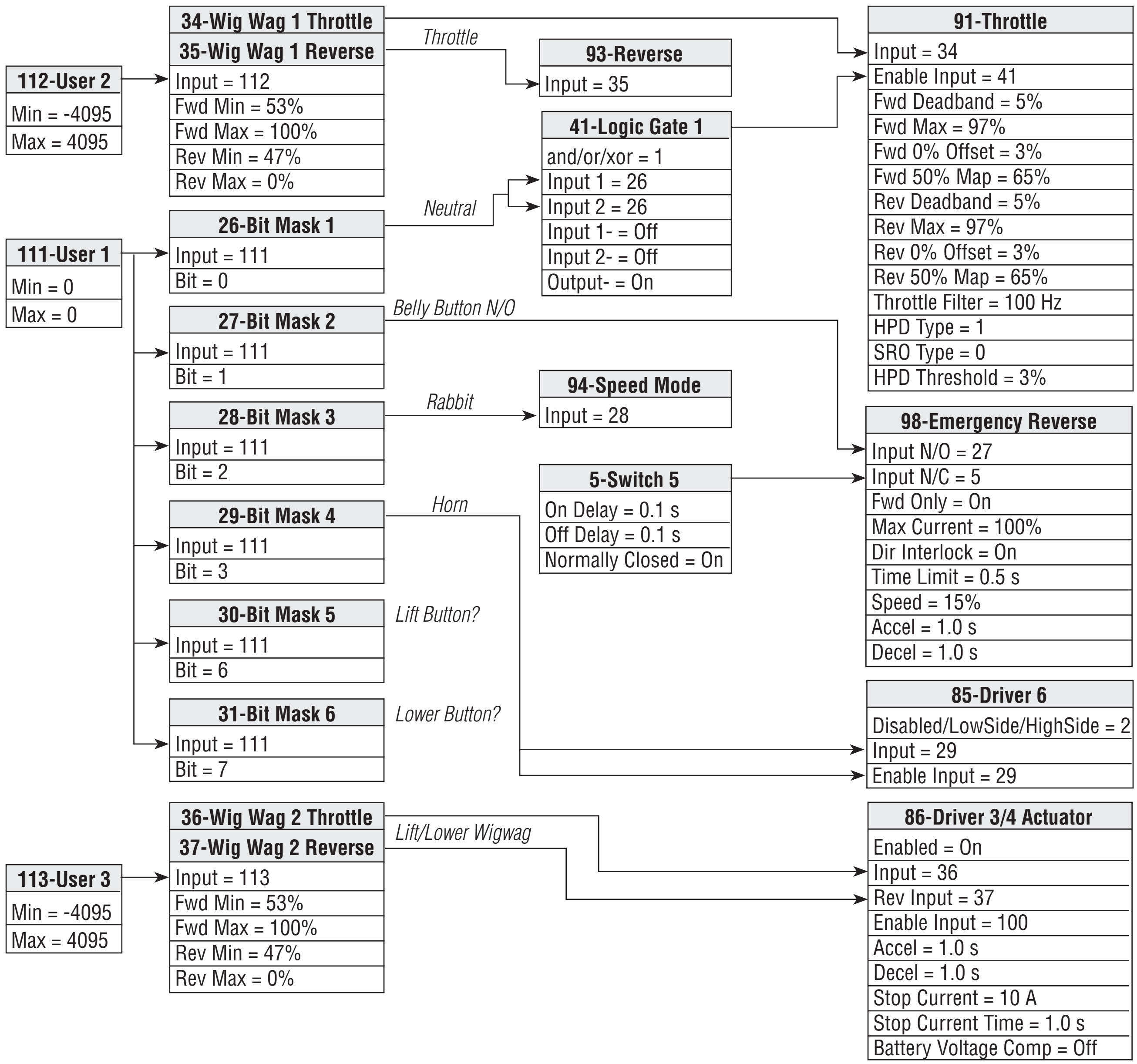
CAN Interface
    Slave Mode
        Operational on KSI = On
        PDO1 RX
            COB Id = 480

The default PDO mapping will cause CANopen data from the tiller head to be mapped into User objects in the I/O map in this way:

111-User 1
    Bit 0 = Neutral Switch
    Bit 1 = Belly Button Switch Normally Open
    Bit 2 = Rabbit Switch
    Bit 3 = Horn Switch
    Bit 6 = Lower Switch
    Bit 7 = Lift Switch
112-User 2
    Wigwag throttle with range from -4095 in full reverse to 4095 full forward
113-User 3
    Auxitiary wigwag throttle to control lift/lower

Additionally there is a redundant belly button switch (normally closed) that is hard-wired to pull to ground; this switch is wired to Switch 5. (Note: Switches 1-4 are pull to B+ only, so they are not able to accept this switch input. If a speed encoder makes Switch 5 unavailable, a Pot input can be used, with a threshold detect function, as shown in earlier examples.)

The User functions have parameters for min and max, to scale CANopen values into the I/O map's normal 0–100%. If min and max are both set to 0, the value enters the map without any scaling, which is intended for situations such as 111-User 1 where data from multiple switches are packed into one piece of data. These will be unpacked using the Bit Mask functions.



The PDO mapping delivers the data into User functions 1-3.

The wigwag throttle data in 112-User 2 is scaled into the I/O map's normalized 0-100% and processed just as a wigwag on one of the Pot inputs would be.

The Lift/Lower wigwag data in 113-User 3 is configured to drive an actuator motor on Drivers 3 & 4, as in Example 8.

The switch data in 111-User 1 is unpacked using Bit Mask functions and mapped into appropriate functions. 41-Logic Gate 1 is unsed to invert the "neutral" signal for use as a throttle enable, providing a redundant check on throttle. The belly button n/o switch is used for Emergency Reverse, along with the n/c input on Switch 5. The horn button is mapped to drive a buzzer, using Driver 6 as a high-side driver.

With a few logic gates, the I/O map could be configured to require pressing the Lift/Lower buttons along with the Lift/Lower wigwag to operate the actuator. The example is truncated here for the sake of brevity.

4 PROGRAMMABLE PARAMETERS

The 1229 controller has a number of parameters that can be programmed using a Curtis 1313 handheld programmer or 1314 Programming Station. The programmable parameters allow a high level of customization designed to fit the needs of multiple applications. In addition to basic controller setup, the 1229 provides a high level of flexibility through I/O mapping and logic functions.

PROGRAMMING MENUS

The programmable parameters are grouped into nested hierarchical menus, as shown in Tables 3 and 4.

We strongly urge you to read Section 6, Initial Setup and Section 7: Tuning Guide before adjusting any of the parameters.

CAUTION

Even if you opt to leave most of the parameters at their default settings, **it is imperative that you perform the procedures outlined in these sections to set up the basic system characteristics for your application**.

Table 3 Programmable Parameter Menus: 1313/1314 Programmer

- **SPEED MODE MENU** .... p. 32
  - **Mode 1** .... p. 32
    - Max Speed
    - Min Speed
    - Rev Max Speed
    - Rev Min Speed
    - Accel High Speed
    - Accel Low Speed
    - Decel High Speed
    - Decel Low Speed
    - Brake Decel High Speed
    - Brake Decel Low Speed
  - **Mode 2** .... p. 32
    - Max Speed
    - Min Speed
    - Rev Max Speed
    - Rev Min Speed
    - Accel High Speed
    - Accel Low Speed
    - Decel High Speed
    - Decel Low Speed
    - Brake Decel High Speed
    - Brake Decel Low Speed
  - **[Other]** .... p. 33
    - Interlock Decel High Speed
    - Interlock Decel Low Speed
    - Quick Stop Decel
    - Quick Stop Pause
    - E Stop Decel
    - Soft Start
    - Soft Stop Decel
  - **Fine Tuning** .... p. 33
    - High Speed
    - Low Speed
    - Soft Stop Speed

- **I/O MAP MENU** .... p. 35
  - **Switch** .... p. 35
    - **1-Switch 1**
      - On Delay
      - Off Delay
      - Normally Closed
    - **2-Switch 2** *(same)*
    - **3-Switch 3** *(same)*
    - **4-Switch 4** *(same)*
    - **5-Switch 5** *(same)*
  - **Toggle** .... p. 36
    - **6-Toggle 1**
      - Input
      - Enable Input
    - **7-Toggle 2** *(same)*
    - **8-Toggle 3** *(same)*
    - **9-Toggle 4** *(same)*
    - **10-Toggle 5** *(same)*
  - **Pots** .... p. 37
    - **11-Pot 1**
      - Max
      - Min
      - Fault High
      - Fault Low
      - Fault Action
    - **12-Pot 2** *(same)*
    - **13-Pot 3** *(same)*
  - **Thresholds** .... p. 38
    - **14-Threshold 1**
      - Input
      - On Threshold
      - Off Threshold
    - **15-Threshold 2** *(same)*
    - **16-Threshold 3** *(same)*
    - **17-Threshold 4** *(same)*
  - **Debounce** .... p. 39
    - **18-Debounce 1**
      - Input
      - On Delay
      - Off Delay
    - **19-Debounce 2** *(same)*
    - **20-Debounce 3** *(same)*
    - **21-Debounce 4** *(same)*
  - **Timers** .... p. 40
    - **22-Timer 1**
      - Time
      - Trigger Input
      - Enable Input
    - **23-Timer 2** *(same)*
    - **24-Timer 3** *(same)*
    - **25-Timer 4** *(same)*
  - **Bit Masks** .... p. 41
    - **26-Bit Mask 1**
      - Input
      - Bit
    - **27-Bit Mask 2** *(same)*
    - **28-Bit Mask 3** *(same)*
    - **29-Bit Mask 4** *(same)*
    - **30-Bit Mask 5** *(same)*
    - **31-Bit Mask 6** *(same)*
    - **32-Bit Mask 7** *(same)*
    - **33-Bit Mask 8** *(same)*
  - **Wig Wag** .... p. 42
    - **34/35-Wig Wag 1**
      - Input
      - Forward Min
      - Forward Max
      - Reverse Min
      - Reverse Max
    - **36/37-Wig Wag 2** *(same)*
    - **38/39-Wig Wag 3** *(same)*
  - **Speed Sensor** .... p. 44
    - **40-Vehicle Speed**
      - Encoder Enable
      - Limit Max Speed
      - Pulses/Rev
      - Max Speed

Table 3 Programmable Parameter Menus, cont'd

- **Logic Gates** .... p. 45
  - **41-Logic Gate 1**
    - and/or/xor
    - Input 1
    - Input 2
    - Input 1-
    - Input 2-
    - Output-
  - **42-Logic Gate 2** *(same)*
  - **43-Logic Gate 3** *(same)*
  - **44-Logic Gate 4** *(same)*
  - **45-Logic Gate 5** *(same)*
  - **46-Logic Gate 6** *(same)*
  - **47-Logic Gate 7** *(same)*
  - **48-Logic Gate 8** *(same)*
  - **49-Logic Gate 9** *(same)*
  - **50-Logic Gate 10** *(same)*
- **Filters** .... p. 46
  - **51-Low-Pass 1**
    - Input
    - Frequency
  - **52-Low-Pass 2** *(same)*
  - **53-Low-Pass 3** *(same)*
- **Maps** .... p. 47
  - **54-Map 1**
    - Input
    - X1
    - Y1
    - X2
    - Y2
    - X3
    - Y3
    - X4
    - Y4
    - X5
    - Y5
  - **55-Map 2** *(same)*
  - **56-Map 3** *(same)*
- **PWM** .... p. 48
  - **57-PWM 1**
    - Input
    - Pull-in
    - Pull-in Time
    - Holding
  - **58-PWM 2** *(same)*
  - **59-PWM 3** *(same)*
  - **60-PWM 4** *(same)*
  - **61-PWM 5** *(same)*
- **70-Correlate** .... p. 49
  - Input 1
  - Input 2
  - Tolerance
- **71-Inhibit** .... p. 49
- **PI Controller** .... p. 50
  - **72-PI**
    - Input+
    - Input-
    - Kp
    - Ki
- **Slew Limiters** .... p. 50
  - **73-Slew Limit 1**
    - Input
    - Enable Input
    - Rate Up
    - Rate Dn
  - **74-Slew Limit 2** *(same)*
  - **75-Slew Limit 3** *(same)*
  - **76-Slew Limit 4** *(same)*
- **Voltage Comp** .... p. 51
  - **77-Voltage Comp 1**
    - Input
    - Max Voltage
  - **78-Voltage Comp 2** *(same)*
  - **79-Voltage Comp 3** *(same)*
  - **80-Voltage Comp 4** *(same)*
- **Outputs** .... p. 52
  - **81-Driver 2**
    - Input
    - Enable Input
    - Fault Check
  - **82-Driver 3**
    - Disabled/Low Side
    - Input
    - Enable Input
  - **83-Driver 4** *(same)*
  - **84-Driver 5** *(same)*
  - **85-Driver 6**
    - Disabled/Low Side/High Side
    - Input
    - Enable Input
  - **86-Driver 3/4 Actuator**
    - Enabled
    - Input
    - Rev Input
    - Enable Input
    - Accel
    - Decel
    - Stop Current
    - Battery Voltage Comp
    - Stop Current Time
  - **87-Driver 5/6 Actuator** *(same)*
  - **88/89-Driver 3/4/5 Dual Actuator**
    - Enabled
    - Input A
    - Input B
    - Rev Input
    - Enable A Input
    - Enable B Input
    - Accel
    - Decel
    - Simultanesous Enable
    - Stop Current
    - Battery Voltage Comp
    - Stop Current Time
- **Push** .... p. 56
  - 90-Push Input

Table 3 Programmable Parameter Menus, cont'd

- **Throttle and Interlock** ...... p. 57
  - **91-Throttle**
    - Input
    - Enable Input
    - Forward Deadband
    - Forward Max
    - Forward 0% Offset
    - Forward 50% Map
    - Reverse Deadband
    - Reverse Max
    - Reverse 0% Offset
    - Reverse 50% Map
    - Throttle Filter
    - HPD Type
    - SRO Type
    - HPD Threshold
    - HPD Latch
    - Sequencing Delay
    - PotL Current Check
  - **92-Forward Input**
  - **93-Reverse Input**
  - **94-Speed Mode Input**
  - **95-Speed Limit Input**
  - **96-Brake Pedal Input**
  - **97-Interlock Input**
  - **98-Emergency Reverse**
    - Input N/O
    - Input N/C
    - Fwd Only
    - Max Current
    - Dir Interlock
    - Time Limit
    - Speed
    - Accel
    - Decel
- **Constants** .... p. 61
  - 99-Constant Value
  - 100-Always On 100%
- **User Inputs** .... p. 62
  - **111-User 1**
    - Min
    - Max
  - **112-User 2** *(same)*
  - **113-User 3** *(same)*
  - **114-User 4** *(same)*
  - **115-User 5** *(same)*
  - **116-User 6** *(same)*
  - **117-User 7** *(same)*
  - **118-User 8** *(same)*
- **User Faults** .... p. 62
  - **119-User Fault Estop**
    - Input
    - Delay
  - **120-User Fault Severe** *(same)*

MAIN CONTACTOR MENU .... p. 63
- Main/Brake Frequency
- Pull-in
- Holding
- Battery Voltage Compd
- Fault Check
- Open Delay

EM BRAKE MENU .... p. 64
- Enable
- Pull In
- Holding
- Battery Voltage Comp
- Fault Check
- Open Delay

BATTERY MENU .... p. 65
- Nominal Voltage
- Full Voltage
- Empty Volts
- Full Charge Voltage
- Start Charge Voltage
- Reset Voltage
- Discharge Factor
- Charge Factor

MOTOR MENU .... p. 66
- System Resistance
- Test Mode
- Speed Scaler
- Current Rating
- Max Current Time
- Open Detect

CURRENT LIMITS MENU .... p. 67
- Main Current Limit
- Regen Current Limit
- Boost Current
- Boost Time

COMPENSATION MENU .... p. 68
- IR Comp
- Anti-Rollback Comp

MISCELLANEOUS MENU .... p. 68
- Sleep

CAN INTERFACE MENU .... p. 69
- Operational on KSI
- Node ID
- Baud Rate
- **Slave Mode** .... p. 69
  - Interlock on KSI
  - CANopen Interlock
  - Heartbeat Rate
  - PDO Timeout Period
  - Emergency Message Rate
  - PDO1 TX
  - PDO1 RX
  - PDO2 TX
  - PDO2 RX
- **3100R Master** .... p. 70
  - Enable
  - Device ID
  - Backlight
  - 0/1 Icons
  - Low BDI Alert
  - Service Interval Alert

SPEED MODE MENU: Mode 1, Mode 2		
PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Max Speed	0–100 %	The Max Speed and Min Speed parameters, combined with 95-Speed Limit Input (see page 59) define the speed command at 100% throttle, as a percentage of Speed Scaler (Motor menu » Speed Scaler). Max Speed applies when the Speed Limit input is 100%; Min Speed when it is 0%.
Min Speed	0–100 %	See Max Speed parameter.
Rev Max Speed	0–100 %	See Max Speed parameter.
Rev Min Speed	0–100 %	See Max Speed parameter.
Accel High Speed	0.1–30.0 s	Forward acceleration when speed or throttle input is above the high speed set point; see Figure 6. Acceleration is defined as the time it takes the controller output to reach Max Speed.
Accel Low Speed	0.1–30.0 s	Forward acceleration when speed or throttle input is below the high speed set point; see Figure 6. Higher values (and slower response) can help low speed maneuverability.
Decel High Speed	0.1–30.0 s	Forward deceleration when speed or throttle input is above the high speed set point; see Figure 6. Deceleration is defined as the time it takes the controller output to reach 0% when throttle is released.
Decel Low Speed	0.1–30.0 s	Forward deceleration when speed or throttle input is below the high speed set point; see Figure 6. Deceleration is defined as the time it takes the controller output to reach 0% when throttle is released.
Rev Accel High Speed	0.1–30.0 s	Acceleration when the vehicle is traveling in reverse and speed or throttle input is above the high speed set point; see Figure 6. Acceleration is defined as the time it takes the controller output to reach Max Speed.
Rev Accel Low Speed	0.1–30.0 s	Acceleration when the vehicle is traveling in reverse and speed or throttle input is below the high speed set point; see Figure 6. Acceleration is defined as the time it takes the controller output to reach Max Speed.
Rev Decel High Speed	0.1–30.0 s	Deceleration when the vehicle is traveling in reverse and speed or throttle input is above the high speed set point; see Figure 6. Deceleration is defined as the time it takes the controller output to reach 0% when throttle is released.
Rev Decel Low Speed	0.1–30.0 s	Deceleration when the vehicle is traveling in reverse and speed or throttle input is below the high speed set point; see Figure 6. Deceleration is defined as the time it takes the controller output to reach 0% when throttle is released.
Brake Decel Max	0.1–30.0 s	Deceleration rate when 96-Brake Pedal is 100% (see page 59).
Brake Decel Min	0.1–30.0 s	Deceleration rate when 96-Brake Pedal is 0.1% (see page 59).

SPEED MODE MENU: Other		
PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Interlock Decel High Speed	0.1–30.0 s	Rate (in seconds) at which the speed command decreases when interlock is off and vehicle speed is above the set High Speed.
Interlock Decel Low Speed	0.1–30.0 s	Rate (in seconds) at which the speed command decreases when interlock is off and vehicle speed is below the set Low Speed.
Quick Stop Decel	0.1–30.0 s	Rate (in seconds) at which the speed command decreases when throttle is reversed in either direction.
Quick Stop Pause	0–1.0 s	Duration of pause at zero speed after a Quick Stop has been executed, before direction is reversed.
E Stop Decel	0.1–30.0 s	Rate (in seconds) at which the speed command decreases when a fault is present that requires vehicle to stop. E Stop Decel allows a controlled deceleration.
Soft Start	0–100 %	Softens the bump caused by gear train slack when starting from neutral.
Soft Stop Decel	0.1–30.0 s	Rate (in seconds) when vehicle is stopping in neutral and vehicle speed drops below Soft Stop Speed.

SPEED MODE MENU: Fine Tuning		
PARAMETER	ALLOWABLE RANGE	DESCRIPTION
High Speed	0–100 %	Defines the speed above which the high speed accel/decel parameters are used; see Figure 6.
Low Speed	0–100 %	Defines the speed below which the low speed accel/decel parameters are used; see Figure 6.
Soft Stop Speed	0–100 %	Defines the speed below which a gentler deceleration is applied; see Figure 6.

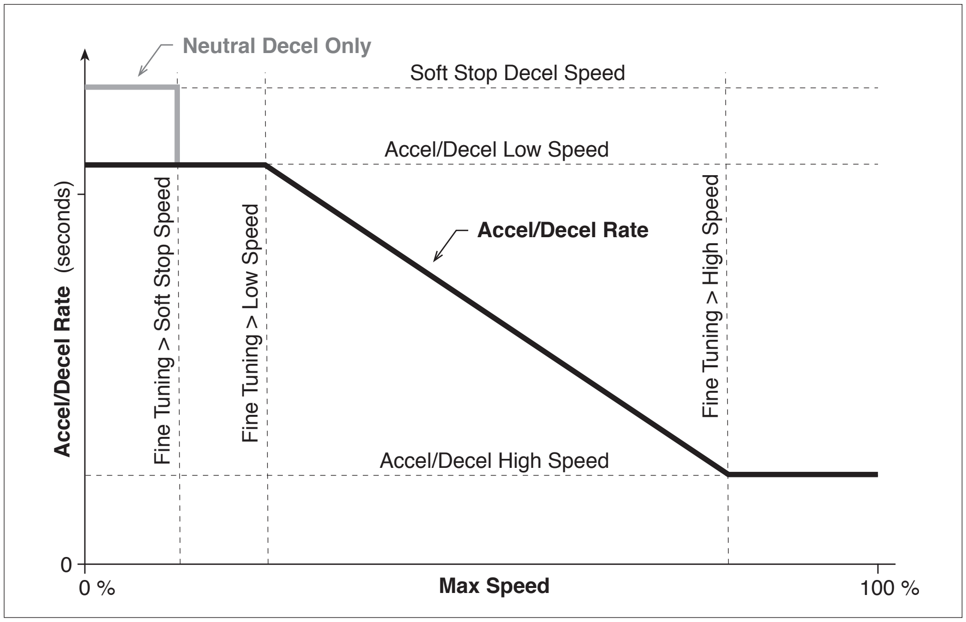


Fig. 6 *Accel/Decel Rate diagram.*

I/O MAP: SWITCH SUBMENU		
PARAMETER	ALLOWABLE RANGE	DESCRIPTION
On Delay	0–30 s	To debounce the rising edge, the input must be On for the programmed seconds before Object = 100%.
Off Delay	0–30 s	To debounce the falling edge, the input must be Off for the programmed seconds before Object = 0%.
Normally Closed	On/Off	Setting this parameter to On inverts the signal.

The three Digital In parameters can be set for these five objects:

1-Switch 1	Pin J1-19	Pull to B+ results in Object 1 = 100%.
2-Switch 2	Pin J1-10	Pull to B+ results in Object 2 = 100%.
3-Switch 3	Pin J1-3	Pull to B+ results in Object 3 = 100%.
4-Switch 4	Pin J1-11	Pull to B+ results in Object 4 = 100%.
5-Switch 5	Pin J1-5	Pull to B- (not B+) results in Object 5 = 100% (applicable only when pin J1-5 is not being used for speed encoder).

I/O MAP: TOGGLE SUBMENU		
PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Input	0–120	This parameter specifies the object that is to be the toggle object.
Enable Input	0–120	The signal mapped to this parameter enables the toggle object if its value is non-zero, and disables the toggle object if its value is zero.

Five toggle objects are available:

6-Toggle 1

7-Toggle 2

8-Toggle 3

9-Toggle 4

10-Toggle 5.

In its simplest application, you would set the object you want to toggle as the toggle input, and then set the enable input to be always On (always on has the object name 100-Always On 100%).

More often, you will want the toggle enable to be based on some other condition. For example, suppose you want to use a momentary pushbutton to select between Mode 1 and Mode 2, and you want the vehicle to always be in Mode 1 when exiting neutral, and then while driving to toggle beween Modes 1&2 with momentary presses of the button. Suppose you wire the button to Switch 4, which has the object name 4-Switch 4. You could then set one of the toggle object inputs = 4. In this example, let's use the first toggle object:

6-Toggle 1 Input = 4.

Next, you want to force the toggle to take effect only when the vehicle is driving. To do this, you would set the 6-Toggle 1 Enable Input parameter to the Brake Not Engaged object, which has the object name 104-Brake Not Engaged.

6-Toggle 1 Enable Input = 104.

When the brake is engaged, 104=100%, which disables 6-Toggle 1 and forces its output to 0% regardless of what 4-Switch 4 is doing. Once the brake is not engaged, 104=100% and 6-Toggle 1 will toggle between 0% and 100% (i.e., between Mode 1 and Mode 2) on every rising edge of 4-Switch 4.

I/O MAP: POT SUBMENU		
PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Max	0–5.0 V	Sets the input voltage above which this object will have a value of 100%.
Min	0–5.0 V	Sets the input voltage below which this object will have a value of 0%.
Fault High	0–5.5 V	Sets the input voltage above which a fault will be generated.
Fault Low	0–5.5 V	Sets the input voltage below which a fault will be generated.
Fault Action	0–3	Defines the action to take when a fault is generated: 0 = no action 1 = force analog 0% on this object 2 = stop vehicle, using controlled decel 3 = drop main or drop brake (as appropriate).

Pot objects read a voltage from a physical input (pins J1-13, J1-14, J1-7) and create a normalized (0–100%) analog signal in the I/O map based on the five Pot parameters. The five Pot parameters can be set for the following inputs:

11-Pot 1 Pin J1-13

12-Pot 2 Pin J1-14

13-Pot 3 Pin J1-7.

I/O MAP: THRESHOLDS SUBMENU		
PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Input	0–120	The signal mapped to this input will cause this object to be On or Off based on the Threshold settings.
On Threshold	0–100 %	Defines the On Threshold. When the programmed On Threshold > programmed Off Threshold, the object is On when the signal is > On Threshold, and Off when the signal is < Off Threshold. When the programmed On Threshold < programmed Off Threshold, the output is inverted: On when the signal is < On Threshold, and Off when the signal is > Off Threshold.
Off Threshold	0–100 %	Defines the Off Threshold. When the programmed On Threshold > programmed Off Threshold, the object is On when the signal is > On Threshold, and Off when the signal is < Off Threshold. When the programmed On Threshold < programmed Off Threshold, the output is inverted: On when the signal is < On Threshold, and Off when the signal is > Off Threshold.

Threshold objects convert an analog signal (0–100%) in the I/O map to a digital signal (0%/100%), based on the settings of the Threshold parameters. Hysteresis is included. The Threshold objects operate in normal or inverted mode, as described above.

The three Threshold parameters apply to these four objects:

14-Threshold 1

15-Threshold 2

16-Threshold 3

17-Threshold 4.

For example, to set up thresholds for 12-Analog In 2, you would enter “12” as the Input value on one of the Threshold objects.

Note: There are mappable analog values besides the three analog inputs—such as BDI% and vehicle speed. So, for example, if you want to force low speed based on low BDI, you could map BDI (object 107-BDI) into 14-Threshold 1 by setting its input parameter to 107. Then, if you set 95-Speed Limit Input to 14 (14-Threshold 1) you force Min Speed when the BDI is below the programmed threshold.

I/O MAP: DEBOUNCE SUBMENU		
PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Input	0–120	The signal mapped to this input will be debounced according to the setpoints defined by the On Delay and Off Delay parameters.
On Delay	0–30 s	To debounce the rising edge, the input must be On for the programmed seconds before Object = On.
Off Delay	0–30 s	To debounce the falling edge, the input must be Off for the programmed seconds before Object = Off.

Debounce objects allow debouncing of digital objects in the I/O map. Note that these are not needed for the physical switches (objects 1–5) because their debouncing is set up directly by the parameters for those objects.

The three Debounce parameters apply to these four objects:

18-Debounce 1

19-Debounce 2

20-Debounce 3

21-Debounce 4.

I/O MAP: TIMERS SUBMENU

PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Time	0–240 s	Defines how long the object will be On after there is a rising edge on the Trigger Input.
Trigger Input	0–120	The rising edge on the signal mapped to this input will cause the timer object to be On for the programmed Time.
Enable Input	0–120	When the signal from the object specified by this parameter is non-zero, the timer is enabled.

Timer objects will be On for a programmed amount of time, when the programmed Enable Input is On and a rising edge occurs on the programmed Trigger Input.

The three Timer parameters apply to these four objects:

22-Timer 1

23-Timer 2

24-Timer 3

25-Timer 4.

I/O MAP: BIT MASKS SUBMENU

PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Input	0–120	Specifies the object mapped to this input.
Bit	0–15	Specifies which bit is to be masked.

The two Bit Masks parameters apply to these eight objects:

26-Bit Mask 1

27-Bit Mask 2

28-Bit Mask 3

29-Bit Mask 4

30-Bit Mask 5

31-Bit Mask 6

32-Bit Mask 7

33-Bit Mask 8.

Bit Mask functions take a value of On (100%) when the specified bit in the mapped Input signal is On, and Off (0%) when the specified bit is Off. These are intended for use when a single value containing multiple switch states is written into the User objects over CANopen.

I/O MAP: WIG WAG SUBMENU		
PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Input	0–120	Specifies the signal to be mapped to this object.
Forward Min	0–100 %	Defines the forward edge of the neutral deadband.
Forward Max	0–100 %	Defines the forward value beyond which the throttle value will be 100%.
Reverse Min	0–100 %	Defines the reverse edge of the neutral deadband.
Reverse Max	0–100 %	Defines the reverse value beyond which the throttle value will be 100%.

The five Wig Wag parameters apply to these three objects:

34/35-Wig Wag 1

36/37-Wig Wag 2

38/39-Wig Wag 3.

All functions expecting directional throttle input, like H-bridges and the Throttle function that drives the traction bridge, expect single-ended throttle, plus signal(s) indicating direction.

Up to three wigwag throttles can be processed using the Wig Wag functions into single-ended throttle and reverse signals which can then be mapped to those output functions. The "throttle" (even) functions will have an analog value of 0–100% based on wigwag position defined by the parameters. The "reverse" (odd) functions will take a value of On (100%) to indicate reverse direction, and Off (0%) to indicate forward direction.

The setting of the min/max parameters must be monotonic for the Wig Wag functions to operate: i.e., Reverse Max < Reverse Min < Forward Min < Forward Max **-or-** Forward Max < Forward Min < Reverse Min < Reverse Max (programming the latter case will effectively invert the value of the reverse function); see Figure 7.

Fig. 7a *34/35-Wig Wag 1 diagram, standard setup.*

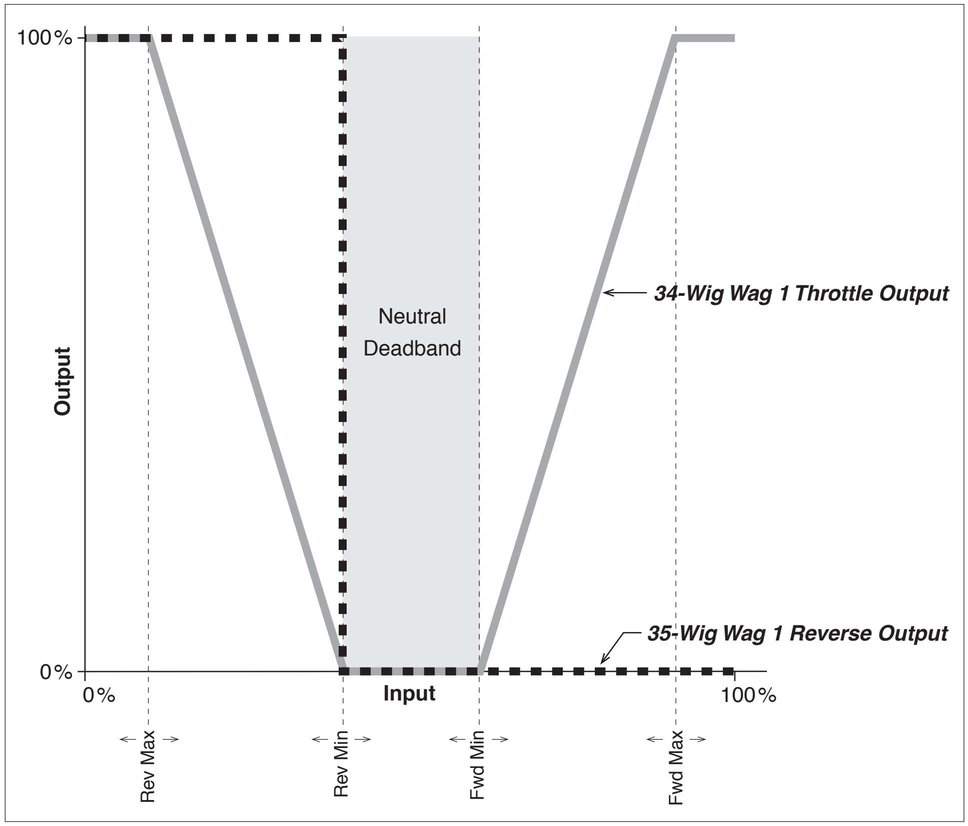
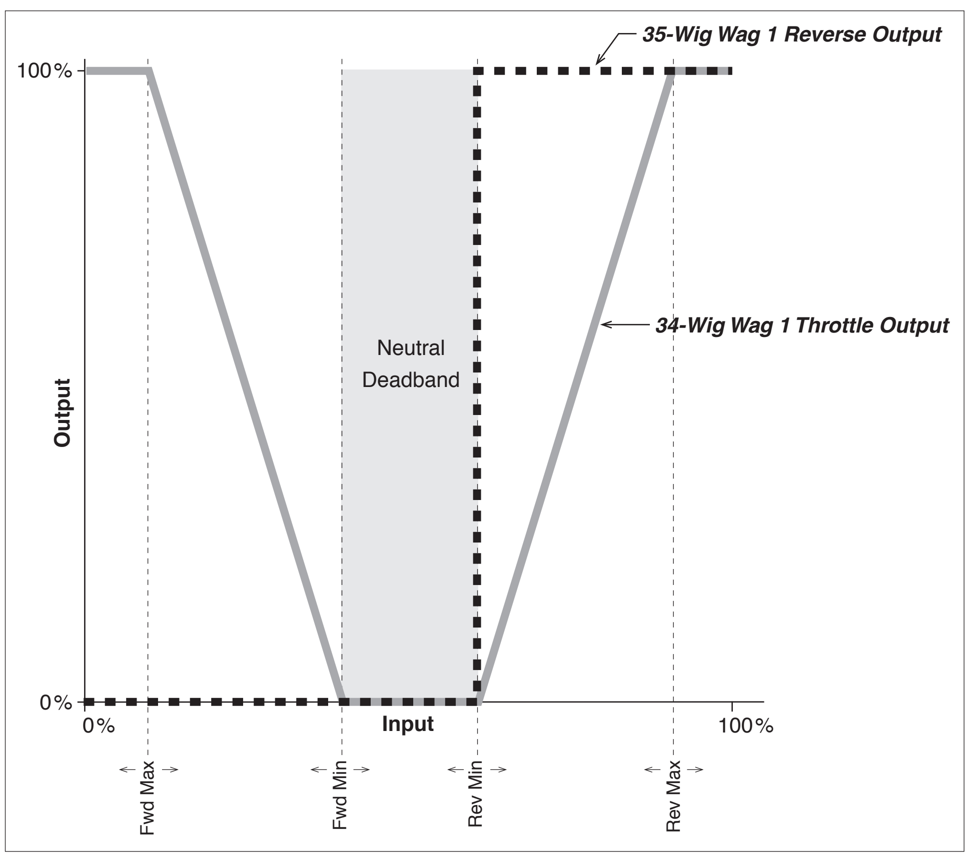


Fig. 7b *34/35-Wig Wag 1 diagram, inverted setup.*



I/O MAP: SPEED SENSOR SUBMENU		
PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Encoder Enable	On / Off	When programmed On, J1-5 will be used as an encoder input; in other words, Switch 5 will be forced to Off.
Limit Max Speed	On / Off	When programmed On, the encoder input will be used to limit the vehicle's maximum speed.
Pulses/Rev	1 – 1024	Sets the encoder pulses per revolution.
Max Speed	100 – 20000 rpm	When Limit Max Speed is programmed On, this parameter sets the maximum speed of the motor.

This menu is used to configure the encoder input at pin J1-5.

The four Speed Sensor parameters apply to only one object:

40-Vehicle Speed.

If Encoder Enable is programmed Off, 40-Vehicle Speed will reflect the vehicle speed estimate based on the motor's back EMF, as a percentage of the Speed Scaler parameter (Motor menu » Speed Scaler). For example, if back EMF is 6 V and Speed Scaler is set to 24 V, 40-Vehicle Speed will have a value of 25%.

I/O MAP: LOGIC GATES SUBMENU		
PARAMETER	ALLOWABLE RANGE	DESCRIPTION
and/or/xor	1–3	Defines the gate type: 1 = AND 2 = OR 3 = XOR.
Input 1	0–120	Specifies the object mapped to Input 1 of this gate.
Input 2	0–120	Specifies the object mapped to Input 2 of this gate.
Input 1-	On/Off	When programmed On, inverts the Input 1 signal.
Input 2-	On/Off	When programmed On, inverts the Input 2 signal.
Output-	On/Off	When programmed On, inverts the output of the gate.

Logic Gate objects allow combining digital and analog signals in the I/O map using logical functions. And/or/xor functions are set explicitly. Nand/nor/xnor are built by selecting the "Output-" option. Inverters can be accomplished by mapping both inputs of a nand/nor gate to the same signal. Inputs may be inverted as well. Note that when the three "invert" parameters are set to Off, the AND gate is actually an analog "Min" function, and the OR gate is actually an analog "Max" function. Therefore analog signals may be mapped to inputs of and/or gates, and combined with digital signals. This allows, for example, an AND gate to be used as an analog switch: if one input of an AND gate is mapped to an analog signal and the other to a digital signal, the digital signal will switch the analog signal on/off in the signal chain.

The six Logic Gate parameters apply to these ten objects:

41-Logic Gate 1

42-Logic Gate 2

43-Logic Gate 3

45-Logic Gate 4

46-Logic Gate 5

47-Logic Gate 6

48-Logic Gate 7

49-Logic Gate 8

43-Logic Gate 9

44-Logic Gate 10.

I/O MAP: FILTERS SUBMENU		
PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Input	0–120	Specifies the analog signal that will be filtered.
Cutoff Frequency	2–125 Hz	Defines the cut-off frequency of the filter.

Filter objects provide a low-pass filter for analog signals.

The two Filter parameters apply to these three objects:

51-Low-Pass Filter 1

52-Low-Pass Filter 2

53-Low-Pass Filter 3.

I/O MAP: MAPS SUBMENU		
PARAMETER	ALLOWABLE RANGE	DESCRIPTION
X1	0–100 %	Sets the input value for the first point on the map.
Y1	0–100 %	Sets the output value for the first point on the map.
X2	0–100 %	Sets the input value for the second point on the map.
Y2	0–100 %	Sets the output value for the second point on the map.
X3	0–100 %	Sets the input value for the third point on the map.
Y3	0–100 %	Sets the output value for the third point on the map.
X4	0–100 %	Sets the input value for the fourth point on the map.
Y4	0–100 %	Sets the output value for the fourth point on the map.
X5	0–100 %	Sets the input value for the fifth point on the map.
Y5	0–100 %	Sets the output value for the fifth point on the map.

Maps allow a gain to be applied to analog signals based on a 5-point map. The ten Maps parameters apply to these three objects:

54-Map 1

55-Map 2

56-Map 3.

I/O MAP: PWM SUBMENU		
PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Input	0–120	Specifies the digital signal that will be mapped to this input. A rising edge on this signal will trigger the Pull-In value on this object for the time set by the Pull-In Time, after which the value will drop to the programmed Holding value.
Pull-In	0–100 %	Defines the analog value this object will have on a rising edge of the input signal.
Pull-In Time	0–30.0 s	Defines the time for which this object will output the Pull-In value before dropping to the Holding value.
Holding	0–100 %	Defines the analog value this object will have after the programmed Pull-In Time has expired.

PWM objects generate an analog signal typical of what would drive a coil. From a rising edge on the digital input signal, this object will have the Pull-In value for a specified amount of time (Pull-In Time), then drop to the Holding value. These objects could also be used as a digital-to-analog converter, since they generate an analog signal from a digital input.

The four PWM parameters apply to these five objects:

57-PWM 1

58-PWM 2

59-PWM 3

60-PWM 4

61-PWM 5.

I/O MAP: CORRELATE SUBMENU

PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Input 1	0–120	Specifies the first object to be mapped to the correlation check.
Input 2	0–120	Specifies the second object to be mapped to the correlation check.
Tolerance	0–50 %	Defines the allowed difference between Inputs 1 & 2.

If the functions mapped to the two inputs differ by more than the programmed Tolerance, a correlation check fault is raised and an E Stop decel occurs.

The value of function 70-Correlate is 100% when the inputs correlate and is 0% when they differ, so this function is appropriate to drive other functions' Enable Input.

These three parameters apply to only one object:

70-Correlate.

I/O MAP: INHIBIT SUBMENU

OBJECT	ALLOWABLE RANGE	DESCRIPTION
71-Inhibit	0–120	If the signal mapped to this object is non-zero, traction and all outputs are disabled and the BDI battery charge tracking is activated.

I/O MAP: PI CONTROLLER SUBMENU

PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Input +	0–120	Specifies the object to be mapped to the non-inverting input.
Input -	0–120	Specifies the object to be mapped to the inverting input.
Kp	0–100 %	Defines the proportional gain.
Ki	0–100 %	Defines the integral gain.

The PI Controller allows closed-loop control of an output, with proportional and integral terms. This could be used, for example, to control pressure on a brush deck, using feedback from a sensor wired to an analog input.

These four parameters apply to only one object:

72-PI.

I/O MAP: SLEW LIMITERS SUBMENU

PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Input	0–120	Specifies a analog signal to be slew rate limited.
Enable Input	0–120	Enables or disables the slew limiter. If the signal mapped to this input has a value of 0%, the slew limiter will ramp to 0% regardless of the state of the input signal.
Rate Up	0.1–30.0 s	Sets the minimum time for the slew limiter to ramp from 0% to 100%.
Rate Dn	0.1–30.0 s	Sets the minimum time for the slew limiter to ramp from 100% to 0%.

Slew Limiters limit the ramp rate at which an analog signal can change.

The four Slew Limiters parameters apply to these four objects:

73-Slew Limit 1

74-Slew Limit 2

75-Slew Limit 3

76-Slew Limit 4.

I/O MAP: VOLTAGE COMP SUBMENU		
PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Input	0–120	Specifies the analog signal object to be voltage compensated.
Max Voltage	0–64 V	Defines the voltage compensation point. The voltage comp object outputs a PWM duty cycle of Max Voltage / Battery Voltage.

The physical output drivers are controlled by mapping signals into objects 81–89, depending on the configuration of coil drivers or actuators. An analog signal mapped to the Input of these objects will be interpreted directly as a PWM duty cycle, i.e. an analog value of 35% mapped to a driver will result in a 35% duty cycle. Driver output can be voltage compensated by mapping the analog signal through a Voltage Compensate object.

Voltage Compensate objects allow a PWM value to vary to create a constant output voltage. For example, if Driver 3 Input is mapped to an analog signal at 50%, it will output 50% duty cycle. If a voltage compensate object is set to 48V max, and its input is mapped to an analog signal at 50%, the object will output a PWM value which represents 24V (50% of 48V) based on the capacitor bank voltage.

The two Voltage Comp parameters apply to these four objects:

77-Voltage Comp 1

78-Voltage Comp 2

79-Voltage Comp 3

80-Voltage Comp 4.

I/O MAP: OUTPUTS SUBMENU > Driver 2

PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Input	0–120	The analog value of the object mapped to the Input parameter will set the duty cycle for Driver 2.
Enable Input	0–120	When the object mapped to the Enable Input parameter is in a non-zero state, output on Driver 2 is enabled.
Fault Check	On / Off	When programmed On, the controller will issue a Driver 2 fault and disable the driver if the coil is missing or shorted to B-.

Driver 2 is normally used for an EM brake. Vehicles with no EM brake may use Driver 2 as a 2A low-side driver by disabling EM brake control in the EM Brake Control menu.

These three parameters apply to only this one object:

81-Driver 2.

I/O MAP: OUTPUTS SUBMENU > Drivers 3 – 5

PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Disabled/Low Side	0–1	Enables this output to be used as a low-side driver. A coil must be present and pulled to B+ or a fault will occur. See additonal conditions below. 0 = disabled 1 = low-side driver enabled.
Input	0–120	The analog value of the object specified by the Input parameter will set the duty cycle for the driver.
Enable Input	0–120	When the object mapped to the Enable Input parameter is in a non-zero state, output on the driver is enabled.

For Drivers 3 and 4, Driver 3/4 Actuator and Driver 3/4/5 Dual Actuator must be disabled first.

For Driver 5, Driver 5/6 Actuator and Driver 3/4/5 Dual Actuator must be disabled first.

These three parameters apply to these three objects:

82-Driver 3

83-Driver 4

84-Driver 5.

I/O MAP: OUTPUTS SUBMENU > Driver 6

PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Disabled/Low Side/ High Side	0–2	Enables this output to be used as either a low-side driver or a high-side driver. A coil must be present and pulled to B+ or a fault will occur. In addition, Driver 5/6 Actuator must be disabled first. 0 = disabled 1 = low-side driver enabled 2 = high-side driver enabled.
Input	0–120	The analog value of the object mapped to the Input parameter will set the duty cycle for Driver 6.
Enable Input	0–120	When the object mapped to the Enable Input parameter is in a non-zero state, output on Driver 6 is enabled.

These three parameters apply to this object:

85-Driver 6.

I/O MAP: OUTPUTS SUBMENU > 3/4 and 5/6 Actuators		
PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Enabled	On / Off	Enables drivers 3 and 4 (or drivers 5 and 6) in an H-bridge configuration, and automatically disables the low-side option on those drivers.
Input	0 – 120	The analog signal of the object mapped to the Input parameter will set the PWM duty cycle for this actuator.
Rev Input	0 – 120	If the signal of the object mapped to the Rev Input parameter has a value of zero, the bridge operates in the forward direction. If the signal has a value of non-zero, the bridge operates in the reverse direction.
Enable Input	0 – 120	When the object mapped to the Enable Input parameter is in a non-zero state, output on the bridge is enabled. If the signal is zero, the bridge will decelerate to a stop.
Accel	0.1 – 30.0 s	Defines the acceleration rate.
Decel	0.1 – 30.0 s	Defines the deceleration rate.
Stop Current	1 – 10 A	The bridge will stop once this current is reached.
Battery Voltage Compensated	On / Off	When programmed On, the output will be compensated so that a 100% input signal will result in the programmed Nominal Voltage on the bridge (Battery menu > Norminal Voltage).

These eight parameters apply to these two objects:

86-Driver 3/4 Actuator

87-Driver 5/6 Actuator.

I/O MAP: OUTPUTS SUBMENU > Driver 3/4/5 Dual Actuator		
PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Enabled	On/Off	Enables Drivers 3, 4, and 5 in a dual-H bridge configuration, with Driver 5 as the common leg. The low-side option is automatically disabled on these drivers. The actuators are limited to 10A total, and if run simultaneously must be in the same direction and at the same speed.
Input A	0–120	The analog signal of the object mapped to the Input A parameter will set the PWM duty cycle for the driver 3/5 actuator. If Simultaneous Enable is On and both bridges are enabled, both actuators will operate at the lesser of Input A and Input B speeds.
Input B	0–120	The analog signal of the object mapped to the Input B parameter will set the PWM duty cycle for the driver 4/5 actuator. If Simultaneous Enable is On and both bridges are enabled, both actuators will operate at the lesser of Input A and Input B speeds.
Rev Input	0–120	If the signal of the object mapped to the Rev Input parameter has a value of zero, the bridges operate in the forward direction. If the signal has a value of non-zero, the bridges operate in the reverse direction.
Enable A Input	0–120	If the signal of the object mapped to the Enable A Input parameter is non-zero, the driver 3/5 bridge will be operational. If the signal is zero,the bridge will decelerate to a stop. If Enable A and Enable B are both active and Simultaneous Enable is Off, both actuators are disabled.
Enable B Input	0–120	If the signal of the object mapped to the Enable B Input parameter is non-zero, the driver 4/5 bridge will be operational. If the signal is zero, the bridge will decelerate to a stop. If Enable A and Enable B are both active and Simultaneous Enable is Off, both actuators are disabled.
Accel	0.1–30.0 s	Defines the acceleration rate.
Decel	0.1–30.0 s	Defines the deceleration rate.
Simultaneous Enable	On–Off	When programmed On, both actuators can operate simultaneously. When programmed Off, only one actuator can be enabled at a time.
Stop Current	1–10 A	The bridge will stop once this current is reached.
Battery Voltage Compensated	On/Off	When programmed On, the output will be compensated so that a 100% input signal will result in the programmed Nominal Voltage on the bridge (Battery menu » Norminal Voltage).

These eleven parameters apply to this one object:

88/89-Driver 3/4/5 Dual Actuator.

I/O MAP: PUSH INPUT SUBMENU		
OBJECT	ALLOWABLE RANGE	DESCRIPTION
90-Push Input	0–120	If the signal mapped to this object is non-zero, the brake will drop and the traction bridge will be open to facilitate pushing the vehicle.

I/O MAP: THROTTLE AND INTERLOCK SUBMENU > Throttle		
PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Input	0–120	The analog signal of the object mapped to the Input parameter will be interpreted as the throttle value.
Enable Input	0–120	When the object mapped to the Enable Input parameter is in a non-zero state, throttle output is enabled.
Forward Deadband	0–100%	Sets the forward throttle input value below which the throttle is in neutral; see Figure 8.
Forward Max	0–100%	Sets the forward throttle input value above which the throttle is at 100%; see Figure 8.
Forward 0% Offset	0–100%	Sets the minimum forward throttle output value when throttle is just out of neutral; see Figure 8.
Forward 50% Map	0–100%	Sets the minimum forward throttle output value when throttle input is 50%; see Figure 8.
Reverse Deadband **Reverse Max** **Reverse 0% Offset** **Reverse 50% Map**		These four parameters have the same ranges as their Forward counterparts, but apply to Reverse throttle.
Throttle Filter	2–125 Hz	Applies a low-pass filter to the throttle.
HPD Type	0–2	Defines the HPD Type: 0 = HPD disabled 1 = HPD checked on interlock 2 = HPD checked on KSI.
SRO Type	0–2	Defines the SRO Type: 0 = SRO disabled 1 = SRO checked on interlock 2 = SRO checked on KSI.
HPD Threshold	1–25 %	Sets the minimum throttle value that will trigger an HPD fault.
HPD Latch	0.0–10.0 s	This parameter will set a Wiring fault if an HPD Sequencing fault is present for longer than the programmed time; a KSI cycle is required to clear the fault. A default value of 0.0 s disables the latch.
Sequencing Delay	0.0–5.0 s	The sequencing delay feature allows the interlock switch to be cycled within a set time (the programmed sequencing delay), thus preventing inadvertent activation of HPD or SRO. This feature is especially useful in applications where the interlock switch may bounce or be momentarily cycled during operation.
PotL Current Check	On/Off	For use with voltage throttles; enables/disables the PotL (pin J1-6) current check. See voltage throttle, page 13. Note: This parameter should be disabled (Off) for voltage throttles **only**.

These seventeen parameters apply to this one object:

91-Throttle.

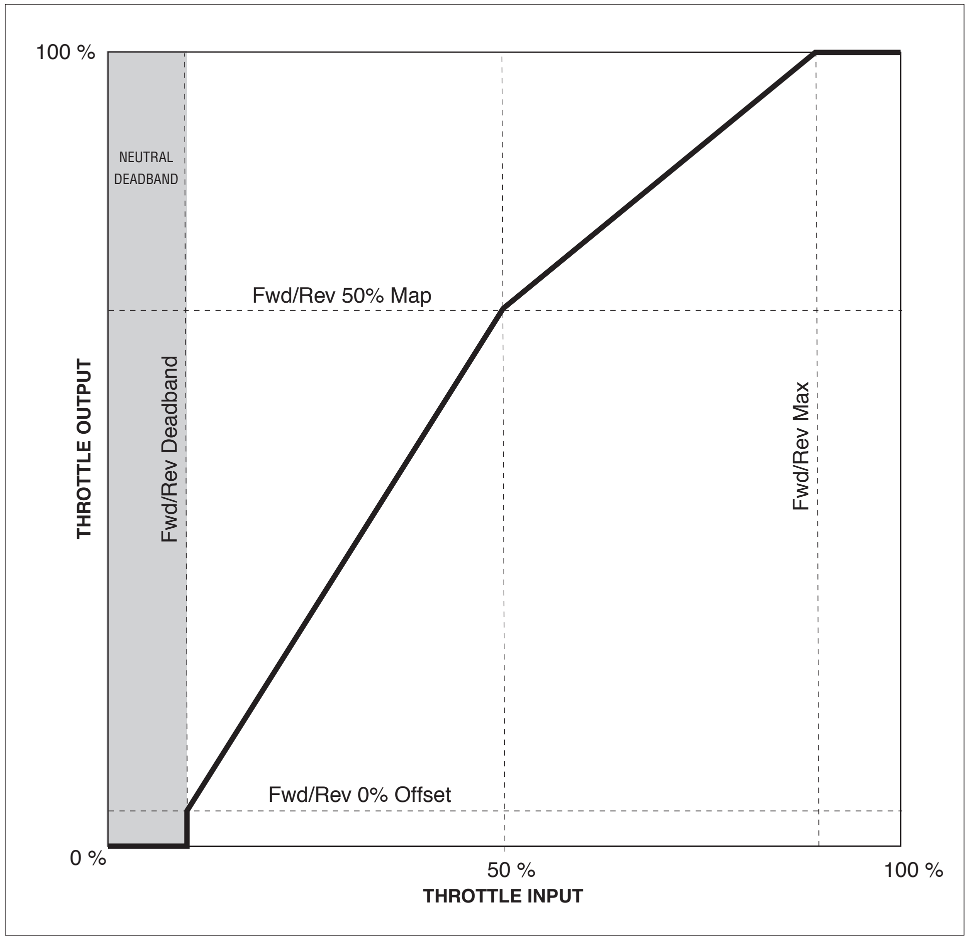


Fig. 8 *Throttle diagram.*

I/O MAP: THROTTLE AND INTERLOCK SUBMENU > Misc.

OBJECT	ALLOWABLE RANGE	DESCRIPTION
92-Forward	0–120	When the signal mapped to this object is non-zero, the traction will drive forward. If this and 93-Reverse Input are both mapped, drive is disabled when both are non-zero. If this input is not mapped, the forward function will always be the opposite of the reverse function.
93- Reverse	0–120	When the signal mapped to this object is non-zero, the traction will drive reverse. If this and 92-Forward Input are both mapped, drive is disabled when both are non-zero. If this input is not mapped, the reverse function will always be the opposite of the forward function.
94-Speed Mode	0–120	When the signal mapped to this object is zero, Speed Mode 1 parameters are used. When the signal is non-zero, Speed Mode 2 parameters are used.
95-Speed Limit	0–120	The signal mapped to this object will set the maximum forward and reverse speeds by interpolating between the Min/Max setpoints for the selected Speed Mode. If a speed limiter is not used, map to object 100-Always On 100%; the programmed Max Speed parameters will then be used.
96-Brake Pedal	0–120	When the signal mapped to this object is non-zero, the traction bridge will decelerate according to the rates set by the Brake Decel Min/Max setpoints. To disable this function, map to object 0-Always Off 0%.
97-Interlock	0–120	When the signal mapped to this object is non-zero, it enables the main contactor and the outputs. For vehicles with no interlock, map to object 100-Always On 100% or to object 106-KSI. Sequencing delay is accomplished using the Sequencing Delay parameter in the 91-Throttle object.

I/O MAP: THROTTLE AND INTERLOCK SUBMENU > Emergency Reverse		
PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Input N/O	0–120	This is a normally open input. When the signal mapped to Input N/O is non-zero, and the signal mapped to Input N/C is zero, emergency reverse will be activated. Mapping this input to object 0-Always Off 0% disables emergency reverse.
Input N/C	0–120	This is a normally closed input. When Input N/C is mapped to an object other than 0-Always Off 0%, this signal must be the inverse of the Input N/O signal or an EMR Redundancy fault will be issued. For vehicles without redundant contacts in the Emergency Reverse switch, Input N/C can be mapped to object 0-Always Off 0%—but the safety of the system is reduced.
Fwd Only	On/Off	When programmed On, Emergency Reverse can be activated only when the vehicle is traveling forward. When programmed Off, Emergency Reverse can be activated regardless of vehicle direction.
Max Current	0–100 %	Sets the current limit during Emergency Reverse operation, as a percentage of the maximum Boost Current (see Current Limits menu).
Dir Interlock	On/Off	Determines whether the interlock switch must be turned off after Emergency Reverse before the vehicle can be driven again. On = Interlock and throttle and direction must all be cleared. Off = Only throttle and direction must be cleared.
Time Limit	0–30.0 s	Sets the maximum time the vehicle will operate with the Emergency Reverse inputs active.
Speed	0–100 %	Sets the maximum speed of the vehicle during Emergency Reverse operation, as a percentage of the programmed Motor menu » Speed Scaler.
Accel	0.1–30.0 s	Sets the rate (in seconds) at which the vehicle accelerates in the opposite direction after it has been brought to a stop in an Emergency Reverse operation.
Decel	0.1–30.0 s	Sets the rate (in seconds) at which the vehicle brakes to a stop when Emergency Reverse is activated.

The nine Emergency Reverse parameters apply to this one object:

98-Emergency Reverse.

I/O MAP: CONSTANTS SUBMENU

OBJECT	ALLOWABLE RANGE	DESCRIPTION
99-Constant Value	0–100 %	Allows a constant analog value to be used in the I/O map, most commonly as the non-inverted term for the PI loop control.
100-Always On 100%	100 %	This value is always 100%. It can be mapped to enable inputs which need to be automatically enabled.

I/O MAP: VEHICLE STATUS OBJECTS
(not programmable; displayed in Monitor menu)

OBJECT	ALLOWABLE RANGE
101-Main Contactor Engaged	0% / 100%
102-In Neutral	0% / 100%
103-Brake Engaged	0% / 100%
104-Brake Not Engaged	0% / 100%
105-Rev Beep	0% / 100%
106-KSI	0% / 100%
107-BDI	0–100%
108-Traction Active	0% / 100%
109-[reserved for future use]	
110-[reserved for future use]	

I/O MAP: USER INPUTS SUBMENU

PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Min	-32767–32767	User Inputs are entry points into the I/O map for values written using CANopen. For example, a CANopen throttle may be mapped into User Input 1 by a CANopen master controller. The Min and Max parameters will scale any raw CANopen value into the I/O map's normalized 0–100%. If Min and Max are both zero, the value is written directly without any scaling. This is intended for CANopen devices which pack multiple switch states into a single value. These switches can be unpacked using the Bit Mask objects.
Max	-32767–32767	

These two User Inputs parameters apply to these eight objects:

111-User Input 1

112-User Input 2

113-User Input 3

114-User Input 4

115-User Input 5

116-User Input 6

117-User Input 7

118-User Input 8.

Values are written into these objects using CANopen. Each User Input has a unique CANopen ID, and a master controller must write to these IDs. The signals then get mapped into other functions such as throttle, interlock, etc.

I/O MAP: USER FAULTS SUBMENU

PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Input	0–120	Specifies the object to be mapped to this Input.
Delay	0–5.0 s	Provides a delay before the fault action is initiated.

These two User Inputs parameters apply to these two objects:

119-User Fault Estop

120-User Fault Severe.

When the signal mapped to object 119 is non-zero, the controller performs a controlled deceleration using the E Stop Decel parameter, and issues a User Fault Estop.

When the signal mapped to object 120 becomes non-zero, the controller immediately drops the main contactor and EM brake, shorts the traction bridge, and issues a User Fault Severe.

MAIN CONTACTOR MENU

PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Main/Brake Frequency	0.2–1.0 kHz	Defines the PWM frequency of the main contactor and the EM brake.
Pull In	0–100 %	The main contactor pull-in voltage parameter allows a high initial voltage when the contactor driver first turns on, to ensure contactor closure. After 1 second, this peak voltage drops to the contactor holding voltage. Note: The Battery Voltage Compensated parameter (below) controls whether the pull-in and holding voltages are battery voltage compensated.
Holding	0–100 %	The main contactor holding voltage parameter allows a reduced average voltage to be applied to the contactor coil once it has closed. This parameter must be set high enough to hold the contactor closed under all shock and vibration conditions the vehicle will be subjected to. Note: The Battery Voltage Compensated parameter (below) controls whether the pull-in and holding voltages are battery voltage compensated.
Battery Voltage Compensated	On/Off	This parameter determines whether the main contactor pull-in and holding voltages are battery voltage compensated. When set On, the pull-in and holding voltages are set relative to the set Nominal Voltage (see Battery Menu, page 54). In other words, the output voltage is adjusted to compensate for swings in battery voltage, so the percentage is relative to the set Nominal Voltage—not to the actual voltage. For example, suppose Nominal Voltage is set to 48V and Holding Voltage is set to 75% (36V) to the output driver. Now suppose the bus voltage dips to 40V. If Battery Voltage Compensated = On, the output will still be 36V (Nominal Voltage × Holding Voltage) to the coil. If Battery Voltage Compensated = Off, the output will be 30V (Actual Voltage × Holding Voltage) to the coil.
Fault Check	On/Off	When programmed On, the controller performs a test to make sure the main contactor is open (not welded shut) before it is commanded to close, and another test immediately after it is commanded to close to make sure that it has indeed closed. These tests are not performed if this parameter is Off. The main contactor driver, however, is always protected from short circuits.
Open Delay	0–40 s	The Open Delay can be set to allow the main contactor to remain closed for a period of time (the delay) 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.

EM BRAKE MENU		
PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Enable	On / Off	Enables the EM brake function on Driver 2 (pin J1-4).
Pull In	0 – 100 %	Allows a high initial voltage when the EM brake first turns on, to ensure brake release. After 1 second, this peak voltage drops to the holding voltage. Note: The Battery Voltage Compensated parameter (below) controls whether the pull-in and holding voltages are battery voltage compensated.
Holding	0 – 100 %	Allows a reduced average voltage to be applied to the brake coil once the brake has been released. This parameter must be set high enough to hold the brake released under all shock and vibration conditions the vehicle will be subjected to. Note: The Battery Voltage Compensated parameter (below) controls whether the pull-in and holding voltages are battery voltage compensated.
Battery Voltage Compensated	On / Off	This parameter determines whether the EM brake pull-in and holding voltages are battery voltage compensated. When set On, the pull-in and holding voltages are set relative to the set Nominal Voltage (see Battery Menu, page 65). In other words, the output voltage is adjusted to compensate for swings in battery voltage, so the percentage is relative to the set Nominal Voltage—not to the actual voltage. For example, suppose Nominal Voltage is set to 48V and Holding Voltage is set to 75% (36V) to the output driver. Now suppose the bus voltage dips to 40V. If Battery Voltage Compensated = On, the output will still be 36V (Nominal Voltage × Holding Voltage) to the coil. If Battery Voltage Compensated = Off, the output will be 30V (Actual Voltage × Holding Voltage) to the coil.
Fault Check	On / Off	When set to On, tests are run to ensure the brake coil is connected. An EM Brake Fault is issued if the tests fail.
Open Delay	0.0 – 1.0 s	Sets the time (the delay) after no throttle for the brake to engage.

BATTERY MENU		
PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Nominal Voltage	24–48 V	Must be set to the vehicle's nominal battery voltage.
Full Voltage	0–64 V	Voltage when the battery is fully charged.
Empty Voltage	0–64 V	Voltage when the battery is fully discharged.
Full Charge Voltage	0–64 V	When a charger is attached, the voltage above which the battery is considered fully charged.
Start Charge Voltage	0–64 V	When a charger is attached, the BDI value will not increment unless the battery voltage is above the programmed value. Below this value, the battery is not considered to be charging, even though the Inhibit input indicates a charger is present.
Reset Voltage	0–64 V	Voltage at which the BDI is reset to 100%.
Discharge Factor	0.1–10.0	Discharge rate of the battery; larger batteries require larger values, because they discharge more slowly.
Charge Factor	0.1–10.0	Charge rate of the battery; larger batteries require larger values, because they charge more slowly.

MOTOR MENU		
PARAMETER	ALLOWABLE RANGE	DESCRIPTION
System Resistance	0–800 mΩ	Sets the actual system resistance (motor + brushes + wiring + connections) used for load compensation and motor speed estimation. It is important that the value set here is taken directly from the motor test described below.
Test Mode	On / Off	Puts the system into a reduced current test mode to allow the motor to be stalled and the motor/system resistance to be accurately measured. The resultant value, which is displayed in the Monitor menu, must be used for the System Resistance parameter above. After getting the measurement, be sure to either cycle KSI or set the Test Mode parameter back to Off.
Speed Scaler	0–48 V	Defines the maximum voltage applied to the motor when 100% speed is commanded.
Current Rating	0–250 A	Set this to the current rating of your motor.
Max Current Time	0–120 s	Sets the maximum time that maximum current is allowed.
Open Detect	On / Off	Enables open motor fault detection.

CURRENT LIMITS MENU		
PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Main Current Limit	30–250 A	Sets the maximum current the controller will supply to the motor during drive operation; the maximum allowable current is model-dependent; see specifications in Table D-1.
Regen Current Limit	30–250 A	Sets the maximum current the controller will supply to the motor during regen operation; the maximum allowable current is model-dependent; see specifications in Table D-1.
Boost Current	30–275 A	Sets the current the controller will supply to the motor in boost mode. Boost operation provides an increased current for the duration defined by the Boost Time parameter. The maximum allowable boost current is 10% over the controller's nominal current limit.
Boost Time	0–10 s	Sets the maximum time for boost mode operation.

COMPENSATION MENU		
PARAMETER	ALLOWABLE RANGE	DESCRIPTION
IR Comp	0–100 %	Sets the motor load compensation.
Anti-Rollback Comp	0–125 %	Sets the motor load compensation when the vehicle is in neutral and vehicle speed is below the Speed Mode » Fine Tuning » Soft Stop Speed setpoint. This feature allows a higher compensation level to improve stopping on ramps.

MISCELLANEOUS PARAMETERS MENU		
PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Sleep	0–60 minutes	Sets how long after no activity the controller goes to sleep.

CAN INTERFACE MENU

PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Node ID	0–127	Sets the CAN node ID for this controller.
Baud Rate	-2 – 3	Sets the CAN baud rate for the CANopen system: -2 = 50 Kbps. -1 = 100 Kbps. 0 = 125 Kbps. 1 = 250 Kbps. 2 = 500 Kbps. 3 = 1 Mbps.

CAN INTERFACE MENU: Slave Mode Submenu

PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Operational on KSI	On/Off	When programmed On, the CANopen Slave enters the NMT operational state automatically when KSI is powered on.
CANopen Interlock	On/Off	When programmed On, interlock will be disabled until the CANopen Master sends an NMT operational command.
Heartbeat Rate	16 – 200 ms	Sets the rate at which the 1229 controller sends heartbeat messages.
PDO Timeout Period	0 – 200 ms	Sets the PDO timeout period for the CANopen Slave system. After the slave controller has sent a PDO TX, it will declare a PDO Timeout Fault if the master controller has not sent a reply PDO RX message within the set time. Either PDO1 RX or PDO2 RX will reset the timer. Setting the PDO Timeout Period = 0 will disable this fault check.
Emergency Message Rate	16 – 200 ms	Sets the minimum rate between CAN emergency messages from the CANopen Slave system, in order to prevent quickly changing fault states from flooding the CAN bus.
PDO1 TX, COB Id	0–65535	Set this parameter to match the COB ID of the CANopen Master's PDO1 TX.
PDO1 RX, COB Id	0–65535	Set this parameter to match the COB ID of the CANopen Master's PDO1 RX.
PDO2 TX, COB Id	0–65535	Set this parameter to match the COB ID of the CANopen Master's PDO2 TX.
PDO2 RX, COB Id	0–65535	Set this parameter to match the COB ID of the CANopen Master's PDO2 RX.

CAN INTERFACE MENU: 3100R Master Submenu

PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Enable	On / Off	Enables the 3100R master.
Device ID	0 / 255	Sets the 3100R CAN node ID.
Backlight	On / Off	Enables the backlight on the 3100R, if it has one.
0/1 Icons	On / Off	Enables the 0/1 icons on the 3100R BDI display.
Low BDI Alert	0 – 100 %	When the BDI is below this value, the 3100R battery icon and warning LED will light. A setting of 0 disables this feature.
Service Interval Alert	0 – 10000 hours	When the KSI hour meter is above this value, the 3100R wrench icon and warning LED will light. A setting of 0 disables this feature.

CLONING (for copying parameter settings to multiple controllers)

Once a controller has been programmed to the desired settings, these settings can be transferred as a group to other controllers, thus creating a family of "clone" controllers with identical settings. **Cloning only works between controllers with the same model number and software version.** For example, the programmer can read all the information from a 1229-3101 controller and write it to other 1229-3101 controllers; however, it cannot write that same information to 1229-3102 controllers.

To perform cloning, plug the programmer (1313 or 1314) into the controller that has the desired settings. Select the Program menu and follow the procedure to copy the settings into the programmer.

Plug the programmer into the controller that you want to have these same settings, and follow the Program menu procedure to write these settings into the controller.

5 MONITOR MENU

Through the Monitor menu, the 1313 handheld and 1314 PC programmers provide access to real-time data during vehicle operation. This information is helpful during diagnostics and troubleshooting, and also while adjusting programmable parameters.

Monitor Menu: TRACTION MOTOR

VARIABLE	DISPLAY UNITS	DESCRIPTION
Current	A	Current in the traction motor.
Voltage	V	Traction motor voltage.
Resistance	mΩ	Resistance of the system as measured by the powerbase at the traction motor terminal. This variable displays an accurate resistance reading only when the Motor Test Mode parameter (page 66) is On and the motor is stalled.
PWM	%	Traction motor PWM output.

Monitor Menu: DRIVERS		
VARIABLE	DISPLAY UNITS	DESCRIPTION
Driver 3 Current	A	Current at Driver 3 (pin J1-22).
Driver 3 Stop	On / Off	Driver 3 stopped due to current or temperature limiting.
Driver 4 Current	A	Current at Driver 4 (pin J1-23).
Driver 4 Stop	On / Off	Driver 4 stopped due to current or temperature limiting.
Driver 5 Current	A	Current at Driver 5 (pin J1-15).
Driver 5 Stop	On / Off	Driver 5 stopped due to current or temperature limiting.
Driver 6 Current	A	Current at Driver 6 (pin J1-21).
Driver 6 Stop	On / Off	Driver 6 stopped due to current or temperature limiting.
Driver 3/4 Actuator Current	A	Current at Driver 3/4 Actuator.
Driver 3/4 Actuator Stop	On / Off	Driver 3/4 Actuator stopped due to current or temperature limiting.
Driver 5/6 Actuator Current	A	Current at Driver 5/6 Actuator.
Driver 5/6 Actuator Stop	On / Off	Driver 5/6 Actuator stopped due to current or temperature limiting.
Driver 3/4/5 Dual Actuator Current	A	Current at Driver 3/4/5 Dual Actuator.
Driver 3/4/5 Dual Actuator Stop	On / Off	Driver 3/4/5 Dual Actuator stopped due to current or temperature limiting.

Monitor Menu: INPUTS

VARIABLE	DISPLAY UNITS	DESCRIPTION
Switch 1	On / Off	Status of Switch 1 (pin J1-19).
Switch 2	On / Off	Status of Switch 2 (pin J1-10).
Switch 3	On / Off	Status of Switch 3 (pin J1-3).
Switch 4	On / Off	Status of Switch 4 (pin J1-11).
Switch 5	On / Off	Status of Switch 5 (pin J1-5).
Pot 1	V	Voltage at Pot 1 (pin J1-13).
Pot 2	V	Voltage at Pot 2 (pin J1-14).
Pot 3	V	Voltage at Pot 3 (pin J1-7).

Monitor Menu: BATTERY

VARIABLE	DISPLAY UNITS	DESCRIPTION
KSI	V	Voltage at KSI (pin J1-8).
V Cap	V	Voltage of controller's internal capacitor bank at B+ terminal.
BDI	%	Battery state of charge.

Monitor Menu: I/O MAP

VARIABLE	DISPLAY UNITS	DESCRIPTION
1-Switch 1	%	All the I/O objects are listed in the Monitor Menu. Each object's status is displayed as 0% (Off) or 100% (On), or as a percentage within the 0–100% range.
. . .		
120-User Fault Severe	%	

Monitor Menu: CONTROLLER

VARIABLE	DISPLAY UNITS	DESCRIPTION
KSI Hours	hours	Hours KSI has been active, since the vehicle was serviced.
Drive Time	hours	Hours the vehicle has been moving, since the vehicle was serviced.
IMS Temp	°C	Temperature sensor readout.

Monitor Menu: CANopen

VARIABLE	DISPLAY RANGE	DESCRIPTION
CAN NMT State	0 – 127	Controller CAN NMT State: 0 = initialization 4 = stopped 5 = operational 127 = pre-operational.
User 1	-32767 – 32767	These are the raw values written over CANopen, which are required for scaling CANopen values in the I/O map, as described in the Initial Setup section.
. . .		
User 8	-32767 – 32767	

6

INITIAL SETUP

Before operating the vehicle, carefully complete the following initial setup procedures. If you find a problem during the checkout, refer to the diagnostics and troubleshooting section (Section 8) for further information.

Before starting the setup procedures, **jack the vehicle drive wheels up off the ground so that they spin freely**. Double-check all wiring to ensure that it is consistent with the wiring guidelines presented in Section 2. Make sure all connections are tight.

① Begin the setup procedures

①-**a**. Put the throttle in neutral, and make sure any connected switches are open.

①-**b**. Turn on the controller and plug in a programming device. The programmer should power up with an initial display. If it does not, check for continuity in the keyswitch circuit and controller ground.

② Set the system's nominal voltage

②-**a**. In the Program » Battery menu, set the Nominal Voltage parameter to match the system voltage of your vehicle.

③ Set up the main contactor output

③-**a**. If the 1229 is not to control the main contactor, ensure that CANopen Interlock is set to On (Program » CAN Interface » Slave Mode sub-menu), so the 1229 will not attempt to drive until the CAN master has signaled that the system is operational. Set Program » Main Contactor » Fault Check to Off. The Main/Brake Frequency should be set to the desired frequency for the EM brake. Skip to step ④.

③-**b**. In the Program » Main Contactor menu, set the desired frequency for the main contactor and EM brake output using the Main/Brake Frequency parameter.

③-**c**. Set the Pull-In Voltage and Holding Voltage appropriately for your main contactor. If Battery Voltage Comp is set to On, these are interpreted as percentages of the Battery » Nominal Voltage parameter and the output will vary duty cycle as the battery voltage fluctuates. If Battery Voltage Comp is set to Off, these are interpreted as duty cycles for the output.

③-**d**. For vehicles where the 1229 controls the main contactor, it is recommended that Program » Main Contactor » Fault Check be set to On.

③-**e**. Set Open Delay to an appropriate time for the contactor to open when the vehicle is idle.

④ **Set up the EM brake output**

④-**a**. If the vehicle does not use an EM brake, set Program » EM Brake » Enabled to Off and skip to step ⑤.

④-**b**. Set the Pull-In Voltage and Holding Voltage appropriately for your EM Brake. If Battery Voltage Comp is set to On, these are interpreted as percentages of the Battery » Nominal Voltage parameter and the output will vary duty cycle as the battery voltage fluctuates. If Battery Voltage Comp is set to Off, these are interpreted as duty cycles for the output.

④-**c**. For vehicles where the 1229 controls the EM brake, it is recommended that Program » EM Brake » Fault Check be set to On.

④-**d**. The Delay parameter sets the maximum time after the vehicle has come to a stop before the EM brake is applied. If the vehicle somtimes sets the EM brake too early during stopping, increasing this setting may help.

⑤ **I/O setup**

For any switches, pots, or CANopen connected I/O devices to perform their intended function, these devices must be mapped to the correct function. Refer to sections 3 and 4 for information on how to configure I/O mapping.

⑤-**a**. Select the Monitor » Inputs menu.

⑤-**b**. Cycle all switches connected to the Switch 1–5 inputs and verify that the inputs are reflected properly in the Monitor menu.

⑤-**c**. If Switch 5 is used for a switch input, be sure it is switched to B- and Encoder Input is disabled in the Program » I/O Map » Speed Sensor » 40-Vehicle Speed submenu.

⑤-**d**. If any switch state is inverted, check the Normally Closed parameter for that input in the Program » I/O Map » Switch submenus.

⑤-**e**. Set an appropriate debounce time for each switch in the Program » I/O Map » Switch submenus.

⑤-**f**. Cycle each pot input through its entire range. Record the min and max voltages displayed in the Monitor » Inputs menu.

⑤-**g**. Enter appropriate Min and Max voltage values for each pot input using the Program » I/O Map » Pots submenus. These voltages should be set so that the input can provide a 0–100% signal over its full range. It is advisable to add some buffer around the absolute full range of the mechanism to allow for resistance variations over time and temperature as well as variations in the tolerance of potentiometer values between individual mechanisms. Generally this means the Min voltage will be set as much as 5% above the measured min, and the Max voltage will be set as much as 5% below the measured max, providing a small deadband to account for sensor variation. If the input is to be used as vehicle throttle, enter the Min and Max voltages directly, because the throttle function provides its own deadbands which will be set later during throttle configuration.

⑤-**h**. Configure fault handling for the pot inputs using the Program » I/O Map » Pots submenus. For the greatest system safety, pots should not use the full 0–5V input range of the 1229 pot input, allowing the controller to detect a broken or disconnected sensor if the signal is out of range. This range is set using the Fault High and Fault Low parameters. Ideally, Fault Low is set greater than 0.0V but less than the valid input range of the sensor, and Fault High is set lower than 5.0V but greater than the valid input range of the sensor. An appropriate Fault Action must be set to allow safe fault handling. Typically throttle inputs will use Fault Action 2 (emergency stop). See section 4 for more information on fault actions.

⑤-**i**. For CANopen inputs, the default PDO mapping will map 8 bytes from PDO1 RX to User Inputs 1–4, and 8 bytes from PDO2 RX to User Inputs 5–8. Configure the baud rate for the system and COB IDs for these messages using the Program » CAN Interface menu. If the default PDO mapping is not adequate for your application, contact your Curtis application engineer.

⑤-**j**. When the CANopen system is operational, use the Monitor » CANopen menu to observe values from CANopen I/O devices in User 1–8. Cycle each analog input through its range and record the min and max values. Enter these values in the Program » I/O Map » User Inputs submenus, giving some room for deadbands as necessary. If a User Input contains multiple switch values, set Min and Max to zero and refer to section 3, example 9, on unpacking the switches using Bit Mask functions. Cycle the keyswitch in order for the programmed Min and Max values to take effect.

⑤-**k**. Using the Monitor » I/O Map » Switches submenu, verify that each switch input registers 0% when the switch is off, and 100% when the switch is on.

⑤-**l**. Using the Monitor » I/O Map » Pots submenu, verify that each pot input ranges from 0% to 100% over the full range of mechanical travel. If the value does not reach 0%, increase the Min setting for that pot. If the pot is at 0% with too much travel remaining, decrease the Min setting for that pot. Perform similar checks at the 100% end of pot travel.

⑤-**m**. For any CANopen analog inputs, use the Monitor » I/O Map » User Inputs submenu to verify that any CANopen analog inputs range from 0% to 100% over the full range of mechanical travel. If the value does not reach 0% or 100%, adjust the Min and Max settings for that User Input.

⑤-**n** For any CANopen switch inputs mapped to bit mask functions, use the Monitor » I/O Map » Bit Masks submenu to verify that each switch input registers 0% when the switch is off, and 100% when the switch is on.

⑤-**o**. All inputs are now configured and functioning, and can be mapped to vehicle functions using the Program » I/O Map submenus. Refer to sections 3 and 4 to complete this mapping. Note that some I/O mapping, expecially to throttle functions, will cause a Parameter Change fault. This is to prevent unintended traction motor movement when changing the throttle configuration, and is cleared by cycling the keyswitch once the I/O mapping is complete.

⑥ **Set up wigwag throttles** *(skip to step ⑦ if the vehicle has no wigwag throttles)*

⑥-**a**. To configure a wigwag throttle, use the Monitor » I/O Map » Pots submenu (or the Monitor » I/O Map » User Inputs submenu for CANopen throttles) and note the number of the function to which the throttle is connected. Note the value of that function when the throttle is in resting position (neutral), in full forward position, and in full reverse position.

⑥-**b**. In the Program » I/O Map » Wig Wag submenu, choose a Wig Wag function that is not currently being used; the I/O map can process up to three wigwag throttles, for control of traction drive and actuators.

⑥-**c**. Set the Wig Wag function's Input parameter to the number of the I/O Map function where the throttle is connected. For example, this would be 11 for Pot 1, or 112 for User Input 2.

⑥-**d**. Set the neutral deadband for the Wig Wag function using the Forward Min and Reverse Min parameters. These should be the value of the throttles resting position noted in step ⑥-a, plus/minus the deadband, typically 5%. For example, if the throttle value is 46% when resting, set Forward Min = 51% and Reverse Min = 41%. If the throttle value increases in reverse and decreases in forward, reverse these settings (Forward Min = 41%, Reverse Min = 51%). If this leaves too much throttle travel in the neutral range, the deadband can be reduced, but this increases the risk of the throttle coming to rest outside the neutral deadband.

⑥-**e**. Set Forward Max so that the throttle can achieve 100% in the full forward position. Use the throttle's Max Forward value as noted in step ⑥-a and set Forward Max 3%–5% inside this value. For example, if the full forward throttle value is 98%, Forward Max would be 93%–95%; if the Full Forward occurs as the pot is decreasing in value, for example at 5%, Forward Max would be 8%–10%. This guarantees that the output of the Wig Wag Throttle Function will reach 100% as the pot nears the edge of mechanical travel.

⑥-**f**. Set Reverse Max similarly to Forward Max.

⑥-**g**. In the Monitor » I/O Map » Wig Wag submenu, observe the values of the Wig Wag function as you apply throttle. At rest, the Wig Wag function should be 0%. As you move the throttle in the forward direction, the Wig Wag function should range from 0–100%, while the Wig Wag Reverse function should remain at 0% (= Off). As you move the throttle in the reverse direction, the Wig Wag function should range 0–100% while the Wig Wag Reverse function will be 100% (= On).

⑥-**h**. This function has converted a wigwag throttle input into functions that mimic a single-ended throttle with a reverse switch, and can now be mapped into the traction throttle or into an actuator input. In step ⑦, use the Wig Wag function numbers as the inputs into the Throttle function: if Wig Wag 1 was used, 91-Throttle Input will be set to 34 (Wig Wag 1 Throttle), 93-Reverse Input will be set to 35 (Wig Wag 1 Rev), and 92-Forward Input will be set to zero. See section 3 for more information on using wigwag throttles to control traction or actuators.

⑦ **Set up single-ended throttles and direction switches**

⑦-**a**. In previous steps you will have observed your connected switches, pots, CANopen devices, and other types of inputs using the Monitor » I/O Map submenus. Note the function numbers where these signals are connected. Step ⑦ will describe how to map throttle, forward, and reverse switches to control the traction drive.

⑦-**b**. If the vehicle has a switch for forward, set Program » I/O Map » Throttle and Interlock » 92-Forward Input to the number of the function where the switch is connected. For example, if the forward switch is connected to Switch 2, set 92-Forward Input to 2. If the vehicle has only a reverse switch, or has a wigwag throttle, set 92-Forward Input to zero and set SRO Type to zero. The controller will recognize Forward Input = 0 as a special case and let the 92-Forward function take a value that is always opposite of 93-Reverse.

⑦-**c**. If the vehicle has a switch for reverse, set Program » I/O Map » Throttle and Interlock » 93-Reverse Input to the number of the function where the switch is connected. If a wigwag throttle is used, the Wig Wag function will provide a "virtual" reverse switch as described in step ⑥. If the vehicle has only a forward switch, set 93-Reverse Input to zero and set SRO Type to zero. The controller will recognize Reverse Input = 0 as a special case and let the 93-Reverse function take a value that is always opposite of 92-Forward.

⑦-**d**. Set Program » I/O Map » Throttle and Interlock » 91-Throttle » Input to the function number where the throttle is connected. For example, if the throttle is connected to 11-Pot 1, set 91-Throttle Input to 11. If this throttle is processed by one of the Wig Wag functions, this will be the number of that function as described in step ⑥.

⑦-**e**. Set the Forward Deadband and Reverse Deadband parameters. The throttle deadband parameters provide a buffer around the mechanical return of the throttle mechanism to allow reliable return to neutral, allowing for resistance variations over time and temperature as well as variations in the tolerance of potentiometer values between individual mechanisms. If the throttle source already has a programmed deadband, for example, from wigwag processing functions, Forward Deadband and Reverse Deadband can be set to 0%; otherwise, a buffer of 3%–5% is recommended. Use Monitor » I/O Map » Throttle and Interlock » 91-Throttle to test the throttle to be sure the throttle return spring reliably returns it to 0% with some slight extra play included. If the deadbands result in too much throttle travel before EM brake release or vehicle movement, decreasing them will improve this performance.

⑦-**f**. Set the Forward Max and Reverse Max parameters. The throttle max parameters provide a buffer around the full mechanical travel of the throttle mechanism to allow reliable full throttle performance. If the throttle source already has a programmed max, for example, from wigwag processing functions, Forward Max and Reverse Max can be set to 100%; otherwise, a buffer of 95%–97% is recommended. Use Monitor » I/O Map » Throttle and Interlock » 91-Throttle to test the throttle to to be sure it reliably generates 100% throttle at full travel with some slight extra play included. If the max settings result in too much throttle remaining when 100% throttle is reached, increasing them will improve this performance.

⑦-**g**. Set the Forward and Reverse 0% Offset parameters. To overcome motor cogging and stalling at very low speeds, the 0% Offset provides a "creep speed" which is the minimum throttle command just out of neutral. If the motor cogs or the vehicle has trouble moving at minimum throttle inputs, increasing these parameters may improve performance.

⑦-**h**. Set the Forward and Reverse 50% Map parameters. To provide greater control with partial throttle movements, the 50% Map parameters allow programming the amount of gain applied to the throttle at 50% travel. Setting these to a value greater than 50% will give more control of low-speed throttle movements. Values of 65%–75% are typical. Test settings on the vehicle to determine optimum feel.

⑦-**i**. Set HPD Type. HPD prevents vehicle movement when throttle is applied before the keyswitch or the interlock. This is critical to preventing a vehicle from moving when it is turned on with a broken or inproperly configured throttle. A setting of 1 requires the throttle to be in neutral when interlock is applied. A setting of 2 requires the throttle to be in neutral only when the keyswitch is turned on. A setting of zero disables HPD and is not recommended for vehicle applications.

⑦-**j**. Set SRO Type. SRO prevents vehicle movement when a forward or reverse switch is applied before the keyswitch or the interlock. Vehicles with a single switch for forward/reverse or with a wigwag throttle should disable this parameter by setting it to zero. Vehicles with separate forward and reverse switches can set this parameter to 1 to check SRO on application of interlock, or set it to 2 to check SRO on keyswitch.

⑦-**k**. Set Sequencing Delay. Sequencing delay helps prevent triggering HPD/SRO checks when the interlock switch vibrates during normal driving. The typical setting is 100–200ms.

7 TUNING GUIDE

This section shows you how to tune the desired drive feel for the vehicle. The procedures should be conducted in the sequence given, because successive steps build upon the ones before. Please follow them carefully and do not skip any steps. Make sure you are in a clear and open area when you start the tuning process. You will need to use a programmer in order to conduct these procedures. The tuning procedures show you how to adjust various programmable parameters to accomplish specific performance goals. Refer to the descriptions of the applicable parameters in Section 4.

1 Tune the 1229 for your vehicle's traction motor

1-**a**. In the Program » Motor menu, set the Speed Scaler to the maximum voltage of the traction motor.

1-**b**. Set the Current Rating to the maximum continuous current rating of the motor, and the Max Current Time to the maximum time the traction motor can sustain the 1229's peak current. This allows the 1229 to estimate when the traction motor might be too hot, and will cause a cutback of maximum drive current to protect the motor. If in operation this cutback seems to be applied too early, these parameters may be increased to allow better vehicle performance, but this increases the risk that the traction motor may become overheated. Tuning these parameters to exceed the motor specification is best done with a temperature monitoring device on the motor.

1-**c**. Open Detect should be set to On for most applications. This allows the 1229 to run a very short burst of current into the traction motor to perform several diagnostic checks. This parameter should only be set to Off for unusual applications where that check may cause problems for the vehicle; however, the safety performance of the system will be reduced.

1-**d**. Measuring the total resistance of the traction system, including the windings of the traction motor and all wiring, is critical to proper performance of the 1229. To measure the System Resistance:

- i. With cool motors, position the vehicle so it is stalled against an immoveable object.
- ii. Set Program » Motor » Test Mode to On.
- iii. Watch Monitor » Traction Motor » Resistance while driving against the immoveable object. With the traction motor stalled, note the resistance.
- iv. Stop driving and enter the resistance into Program » Motor » System Resistance.
- v. Turn Test Mode to Off.

1-**e**. In the Program » Current Limits menu, set appropriate current limits for the application.

1-**f**. In Program » Compensation » IR Comp, set an appropriate compensation level for the motor control algorithm. This is typically in the range of 50%-80%, higher values providing a more aggressive feel, and lower values a more relaxed feel but with less ability to clear obstacles.

2 Set up the speed modes

The 1229 allows up to two speed modes. The operator selects them using a switch mapped to the I/O Mapping function 94-Speed Mode (see section 3.) If the function mapped to 94-Speed Mode has a value of 0, Speed Mode 1 is selected. If it is non-zero, Speed Mode 2 is selected. Vehicles that intend to use only one speed mode should map 94-Speed Mode Input to function 0-Always Off 0% to permanently select Speed Mode 1.

2-**a**. If the vehicle has a speed limit pot, this signal must be mapped to 95-Speed Limit Input. If the vehicle has no speed limit pot, 95-Speed Limit Input should be set to 100-Always On 100%. The Min Speed settings in speed modes 1 and 2 will be ignored and should be set to 0%.

2-**b**. If the vehicle uses a brake pot, this signal must be mapped to 96-Brake Pedal Input. For this configuration, typically the Fwd/Rev Decel parameters will be set to very slow rates to allow the vehicle to "coast" on throttle up, and the Brake Decel High Speed/Low Speed setting will tune the decel rates. Of no brake pot is used, set 96-Brake Pedal Input to 0 and proceed to tune the decel rates.

2-**c**. Start tuning Speed Mode 1 by selecting it using the switch mapped to 94-Speed Mode (or by setting this to 0 if there is no switch).

2-**d**. If a speed pot is used, set this to its maximum value.

2-**e**. Set Program » Speed Mode » Mode 1 » Max Speed to the maximum speed you want to drive in forward in this speed mode.

2-**f**. Set Program » Speed Mode » Mode 1 » Rev Max Speed to the maximum speed you want to drive in reverse in this speed mode.

2-**g**. If a speed pot is used, set it to its minimum value.

2-**h**. Set Program » Speed Mode » Mode 1 » Min Speed to the speed you want to drive in forward with the speed pot at minimum.

2-**i**. Set Program » Speed Mode » Mode 1 » Rev Min Speed to the speed you want to drive in reverse with the speed pot at minimum.

2-**j**. If a speed pot is used, set this to its maximum.

2-**k**. Accelerate forward from a dead stop, and adjust the Accel High Speed parameter for the appropriate feel.

2-**l**. Tune Program » Speed Mode » Soft Start to soften the initial acceleration. This tunes an S-curve contour to the acceleration profile.

2-**m**. From full throttle in forward, release the throttle to neutral. Adjust the Decel High Speed parameter to provide the required stopping distance.

2-**n**. From partial throttle in forward, release the throttle to neutral. Adjust the Decel Low Speed parameter to provide the appropriate feel.

2-**o**. Adjust Program » Speed Mode » Soft Stop Decel to soften the feeling as the vehicle approaches zero speed, much as you'd let off the brake slightly as your car reaches a stop.

2-**p**. Check stopping distance from various speeds and adjust as necessary.

2-**q**. Accelerate in reverse from a dead stop, and adjust the Rev Accel High Speed parameter for the appropriate feel.

2-**r**. From full throttle in reverse, release the throttle to neutral. Adjust the Rev Decel High Speed parameter to provide the required stopping distance.

2-**s**. From partial throttle in reverse, release the throttle to neutral. Adjust the Rev Decel Low Speed parameter to provide the appropriate feel.

2-**t**. Check stopping distance from various speeds and adjust as necessary.

2-**u**. Check the drive performance using various throttle positions and speed pot settings and tune as necessary.

2-**v**. Repeat these steps for Speed Mode 2, if used.

3 Set up Quick Stop Decel

Quick Stop Decel provides the option for a more aggressive decel rate if direction is suddenly reversed from a full throttle position. This type of reaction is intuitive for wigwag throttles, when the driver needs to stop quickly and slams the throttle into reverse instead of returning it to neutral. If this feature is not needed, Quick Stop Decel should be set the same as the fastest decel rate in Mode 1 or Mode 2.

3-**a**. Accelerate in forward to full speed, then reverse direction to full reverse. Tune Program » Speed Mode » Quick Stop Decel to provide an aggressive stop.

3-**b**. The Quick Stop Pause parameter causes the vehicle to stop at zero speed for the programmed time, before reversing direction. This is to prevent the vehicle from driving in the opposite direction while the driver recovers from the quick stop. Applications which require frequent high-speed reversals may set this to 0 seconds. Otherwise set it for an appropriate feel.

4 Set up Interlock Decel

Interlock Decel High Speed/Low Speed parameters provide the option for a more aggressive decel rate if interlock is deactivated while driving.

4-**a**. Accelerate in forward to full speed, then deactivate Interlock. Tune Program » Speed Mode » Interlock Decel High Speed to provide an aggressive stop.

4-**b**. Accelerate in forward to low speed, then deactivate Interlock. Tune Program » Speed Mode » Interlock Decel Low Speed to provide an appropriate feel.

5 Set up E Stop Decel

The E Stop Decel parameter can provide an aggressive deceleration when a vehicle fault occurs that requires the vehicle to stop, while allowing the 1229 to provide a controlled deceleration. Activating E Stop Decel requires simulating a fault on the vehicle. This is most easily done by mapping a signal to the I/O Map function 119-User Fault Estop. When the signal mapped to this input becomes non-zero, the vehicle will perform an E Stop deceleration. This parameter should be tuned from maximum vehicle speed. For the purpose of tuning this parameter, a switch can be mapped to function 119, or 40-Vehicle Speed could be mapped through a Threshold Detect function to trigger when vehicle speed exceeds a certain limit, e.g. 95%. See section 3 for more information on using I/O mapping functions.

5**-a**. Once it is determined how the E Stop fault will be simulated, perform an E Stop deceleration from maximum vehicle speed, and tune Program » Speed Mode » E Stop Decel to provide the required stopping distance.

6 Tune anti-rollback performance

The Program » Compensation » Anti-Rollback Comp parameter allows the motor control to provide a higher level of compensation to aid stopping on inclines. If the vehicle is not typically stopped on ramps, then this should be set the same as IR Comp. If the vehicle is exhibiting rollback when stopping on a ramp, Anti-Rollback Comp may be increased to provide stiffer motor control when stopping. If set too high, the vehicle may not stop smoothly.

7 Tune the BDI

Tune the Battery Discharge Indicator (BDI) if used. The 1229 provides a BDI that can be displayed on the 3100R gauge, or read as a CANopen object by other controllers on the CANopen bus, or be used in the I/O map to modify vehicle functions (for example, by lighting a warning light, limiting speed, or preventing a lift actuator from operating when BDI is low). The BDI parameters (Program » Battery menu) must be set up specifically for the battery size, the type and size of the charger, and the vehicle's expected drive cycle.

7**-a**. Set the following initial values, depending on your system's nominal voltage:

Nominal Voltage	24V	36V	48V
Full Voltage	24.5V	36.8V	49.0V
Empty Voltage	20.4V	30.6V	40.8V
Full Charge Voltage	26.3V	39.5V	52.6V
Start Charge Voltage	23.9V	35.9V	47.8V
Reset Voltage	27.5V	41.3V	55.0V
Discharge Factor	1.0	1.0	1.0
Charge Factor	3.0	3.0	3.0

7-**b**. Set the Reset and Full Charge Voltage:

i. Plug in the charger, and fully charge the batteries. With the charger still attached and running, measure the final battery voltage with a voltmeter.

ii. Set the Reset Voltage to the measured value.

iii. Turn off or disconnect the charger and let the batteries sit for an hour.

iv. Measure the battery voltage again.

v. Set the Full Charge Voltage parameter to a value between these two measurements.

7-**c**. Set the Full Voltage:

i. Drive the vehicle for 10 to 15 minutes on a level surface

ii. Observe Monitor » Battery » KSI.

iii. Set the Full Voltage parameter to this value.

7-**d**. Set the Empty Voltage:

i. Normally a value of 1.7 volts per cell is used as the empty point. This corresponds to a setting of 20.4V on a 24V system. For some sealed batteries, this may be too low. Consult the battery manufacturer if you are unsure.

7-**e**. Set the Discharge Factor:

i. Resume driving the vehicle in a normal cycle.

ii. Pay attention to the battery voltage, BDI, and time.

iii. Note the time when BDI reaches 0%, or when the vehicle become sluggish and you notice the battery voltage drop significantly with basic maneuvers. This is the fully discharged point of the battery. Stop driving.

iv. If the BDI does not read 0%, reduce the Discharge Factor parameter proportionately to the indicated remaining BDI. Use this formula to determine the new setting:

New Discharge Factor = Present Discharge Factor * (100% – BDI%)

v. If the BDI did go to 0%, increase the Discharge Factor parameter by the time it took to reach 0% prematurely. Use this formula to determine the new setting:

New Discharge Factor = Present Discharge Factor *
(time it took to drain the battery / time it took to get 0% BDI indication)

7-**f**. Set the Charge Factor and Start Charge Voltage. How you set the Charge Factor and Start Charge Voltage parameters depends on how you want the BDI gauge to respond to partial charging. Often the 1229 will be installed on vehicles that will never be operated after a partial charge cycle. This type of system should be configured to reset the BDI to 100% only after the battery is full. The 1229 can also be configured for the user to stop the charge in mid-cycle and display a proportional amount of charge, or "partial charge" reading.

If the partial charge feature is not required, this procedure will configure the 1229 to reset the BDI only after a full charge:

i. Set the Charge Factor to 0.1.

ii. Set the Start Charge Voltage equal to the Reset Voltage. With these settings, the BDI will not reset to 100% until the very end of the charge cycle, and the Reset Voltage—not the charge time—will reset the BDI to 100%. Skip the rest of 7-f.

If you would like to use the partial charge feature:

i. The 1229 must be powered on while charging, and an input which goes active when the charger is connected must be mapped to 91-Inhibit Input. When this signal is active (non-zero) the 1229 will prevent drive or actuators from functioning, and the partial charge detection will be active.

ii. Based on the Amp Hour rating of the batteries and the charger's average amp output, initially calculate and set the Charge Factor using this formula:

Charge Factor = Battery amp-hrs / Charger amps

iii. Starting with a dead battery, plug in the charger.

iv. After 10 minutes of charging, measure the battery voltage with a meter. Set the Start Charge Voltage parameter to this value.

v. The Charge Factor is basically a charge timer. A setting of 1.0 = 1 hour. Using the Charge Factor setting, calculate the time it should take to reach 50% charge (50% time = Charge Factor /2). After the calculated 50% time, read Monitor » Battery » BDI. Adjust the Charge Factor using this formula:

New Charge Factor = Original Charge Factor * BDI reading * 2

If the BDI reading was too low, the new Charge Factor will be reduced and thus speed up the charge calculation. If the BDI reading was too high, the charge calculation is too fast and the Charge Factor will be increased by this formula.

vi. Rerun and verify. This procedure will give good initial settings for the BDI algorithm. You should test these settings under various conditions to verify that they provide an acceptable indication of the battery state of charge. The settings can be fine-tuned by repeating the entire procedure.

8

DIAGNOSTICS AND TROUBLESHOOTING

The 1229 controller detects a wide variety of faults or error conditions. Diagnostic information can be obtained in either of two ways: (1) through a Curtis 3100R gauge or (2) through a Curtis 1313 handheld or 1314 PC programmer.

The 3100R gauge displays an error code in the format "Err ##"; the codes are listed in Table 4. Information about the faults is presented in the troubleshooting chart (Table 5).

The programmer displays the full names of all faults that are currently set as well as a history of the faults that have been set since the history log was last cleared. The troubleshooting chart (Table 5) describes the faults and their possible causes; the faults are listed in alphabetical order.

Whenever a fault is encountered and no wiring or vehicle fault can be found, shut off KSI and turn it back on to see if the fault clears. If it does not, shut off KSI and remove the 35-pin connector. Check the connector for corrosion or damage, clean it if necessary, and re-insert it.

Table 4 ERROR CODES ON 3100R GAUGE

1	HW Failsafe	42	Pot2
2	PLD Clock Fail	43	Pot3
9	Calibration Reset	50	Severe Undervoltage
10	Main Brake Driver Overcurrent	52	Controller Severe Undertemp
11	Main Driver Open Drain	53	Controller Severe Overtemp
12	EMR Redundancy	54	Precharge Failed
13	EEPROM Failure	70	Driver Shorted
15	Main Contactor Dropped	71	Driver3 Fault
16	Current Sensor	72	Driver3 Overcurrent
17	Main Contactor Welded	73	Driver4 Fault
18	Encoder	74	Driver4 Overcurrent
19	PDO Timeout	75	Driver5 Fault
20	Supervisor Comms	76	Driver5 Overcurrent
21	Supervisor Watchdog	77	Driver6 Fault
22	Supervisor Pot1 Fault	78	Driver6 Overcurrent
23	Supervisor Pot2 Fault	79	Correlation Fault
24	Supervisor Pot3 Fault	80	HPD Sequencing
25	Supervisor PotH Fault	81	Parameter Change
26	Supervisor Sw1 Fault	82	NV Memory Fault
27	Supervisor Sw2 Fault	90	Motor Temp Hot Cutback
28	Supervisor Sw3 Fault	92	Motor Open
29	Supervisor Sw4 Fault	93	Controller Overcurrent
30	Supervisor Sw5 Fault	94	VBAT Too High
31	Supervisor KSI Voltage Fault	95	Controller Undertemp Cutback
32	Supervisor Motor Speed Fault	96	Stall Detected
33	Supervisor Dir Check Fault	97	Controller Overtemp Cutback
34	External Supply Fault	98	Overvoltage Cutback
36	EMBrake Driver Open Drain	99	Undervoltage Cutback
37	EMBrake Driver On	101	User Fault Estop
41	Pot1	102	User Fault Severe

Table 5 TROUBLESHOOTING CHART

PROGRAMMER LCD DISPLAY	DESCRIPTION	POSSIBLE CAUSE
Calibration Reset		1. Controller fault.
Controller Overcurrent		1. Short circuit on motor outputs.
Controller Overtemp Cutback	controller overtemperature	1. Temperature above overtemp threshold. 2. Excessive load on vehicle. 3. Electromagnetic brake not releasing.
Controller Severe Overtemp	severe controller overtemperature	1. Temperature > severe overtemp threshold.
Controller Severe Undertemp	severe controller undertemperature	1. Temperature < severe undertemp threshold.
Controller Undertemp Cutback	controller undertemperature	1. Temperature < undertemp threshold.
Correlation Fault		1. Redundant signals mapped to Correlation Check function do not match.
Current Sensor		1. Short circuit on motor outputs. 2. Controller fault.
Driver3 Fault		1. Driver 3 output shorted. 2. Driver 3 output open.
Driver4 Fault		1. Driver 4 output shorted. 2. Driver 4 output open.
Driver5 Fault		1. Driver 5 output shorted. 2. Driver 5 output open.
Driver6 Fault		1. Driver 6 output shorted. 2. Driver 6 output open.
Driver Shorted		1. Drivers disabled due to short circuit on one or more drivers.
Driver3 Overcurrent		1. Driver 3 exceeded maximum current (10A). 2. Short circuit. 3. Improperly sized load.
Driver4 Overcurrent		1. Driver 4 exceeded maximum current (10A). 2. Short circuit. 3. Improperly sized load.
Driver5 Overcurrent		1. Driver 5 exceeded maximum current (10A). 2. Short circuit. 3. Improperly sized load.
Driver6 Overcurrent		1. Driver 6 exceeded maximum current (10A). 2. Short circuit. 3. Improperly sized load.
EEPROM Failure	controller operation system unable to write to EEPROM memory	1. Incompatible memory write initiated by the CAN bus. 2. Invalid parameter adjustment by programmer during operation. 3. Inappropriate software loaded.
EMBrake Driver On	brake On fault	1. Electromagnetic brake driver shorted. 2. Electromagnetic brake coil open.
EMBrake Driver Open Drain		
EMR Redundancy		1. Emergency reverse N/O input and N/C input are not complementary.

Table 5 TROUBLESHOOTING CHART, cont'd

PROGRAMMER LCD DISPLAY	DESCRIPTION	POSSIBLE CAUSE
Encoder		1. Controller unable to regulate maximum speed; check encoder signals.
External Supply Fault	external load on the supplies outside the allowed current range	1. External supply current (combined current used by the +5V and +17V supplies) is greater than the upper current threshold. 2. External supply current is below the lower current threshold.
HPD Sequencing	HPD fault present >10 seconds	1. Misadjusted throttle. 2. Broken throttle pot or throttle mechanism.
HW Failsafe	motor voltage fault (hardware failsafe)	1. Motor voltage does not correspond to throttle request. 2. Short in motor or in motor wiring.
Main Brake Driver Overcurrent		1. Short circuit or improperly sized load on Driver 1 or Driver 2.
Main Contactor Dropped		1. Main contactor failed open.
Main Contactor Welded	main contactor On fault	1. Main contactor failed closed.
Main Driver Open Drain		1. Main contactor coil not connected.
Motor Open		1. Traction motor not connected.
Motor Temp Hot Cutback	motor temperature too high	1. Motor temperature above the motor hot threshold.
NV Memory Fault		1. Controller fault; cycle KSI.
Overvoltage Cutback	battery voltage too high	1. Battery voltage > overvoltage threshold. 2. Vehicle operating with charger attached. 3. Intermittent battery connection.
Parameter Change		1. Critical setting changed; cycle KSI for change to take effect.
PDO Timeout	CAN PDO message timing fault	1. Time between CAN PDO messages received exceeded the PDO Timeout period.
PLD Clock Fail		1. Controller fault.
Pot1		1. Pot 1 input out of range.
Pot2		1. Pot 2 input out of range.
Pot3		1. Pot 3 input out of range.
Precharge Failed	precharge fault	1. Low battery voltage. 2. Short circuit on traction motor outputs.
Severe Undervoltage	battery voltage extremely low	1. Battery voltage < severe undervoltage threshold. 2. Bad connection at battery or controller.
Stall Detected		1. Encoder input not reporting speed correctly; check connections.
Supervisor Comms		1. Lost communication with supervisor micro.

Table 5 TROUBLESHOOTING CHART, cont'd

<table>
<tr><th>PROGRAMMER LCD DISPLAY</th><th>DESCRIPTION</th><th>POSSIBLE CAUSE</th></tr>
<tr><td>Supervisor Dir Check Fault</td><td></td><td rowspan="13">If the fault is on an external signal, check that signal first.
If there is no problem with the external signal, the supervisor fault likely indicates an internal controller fault.
Note: If an encoder is connected to Switch 5 but Switch 5 is configured as “encoder disabled” (Program » I/O Map » Speed Sensor » 40-Vehicle Speed » Encoder Enable = Off)) it will result in a Supervisor Sw5 Fault at some speeds.</td></tr>
<tr><td>Supervisor KSI Voltage Fault</td><td></td></tr>
<tr><td>Supervisor Motor Speed Fault</td><td></td></tr>
<tr><td>Supervisor Pot1 Fault</td><td></td></tr>
<tr><td>Supervisor Pot2 Fault</td><td></td></tr>
<tr><td>Supervisor Pot3 Fault</td><td></td></tr>
<tr><td>Supervisor PotH Fault</td><td></td></tr>
<tr><td>Supervisor Sw1 Fault</td><td></td></tr>
<tr><td>Supervisor Sw2 Fault</td><td></td></tr>
<tr><td>Supervisor Sw3 Fault</td><td></td></tr>
<tr><td>Supervisor Sw4 Fault</td><td></td></tr>
<tr><td>Supervisor Sw5 Fault</td><td></td></tr>
<tr><td>Supervisor Watchdog</td><td></td></tr>
<tr><td>Undervoltage Cutback</td><td>battery voltage too low</td><td>1. Battery voltage < undervoltage threshold.
2. Bad connection at battery or controller.</td></tr>
<tr><td>User Fault Estop</td><td>User-programmed fault</td><td></td></tr>
<tr><td>User Fault Severe</td><td>User-programmed fault</td><td></td></tr>
</table>

9

MAINTENANCE

There are no user serviceable parts in Curtis 1229 controllers. **No attempt should be made to open, repair, or otherwise modify the controller.** Doing so may damage the controller and will void the warranty.

It is recommended that the controller and connections be kept clean and dry and that the controller's fault 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 6, for maximum tightening torque specifications for the battery and motor connections.

FAULT HISTORY

The 1313 handheld or 1314 PC programmer can be used to access the controller's fault history file. The programmer will read out all the faults the controller has experienced since the last time the fault 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 fault history file. This allows the controller to accumulate a new file of faults. By checking the new fault history file at a later date, you can readily determine whether the problem was indeed fixed.

APPENDIX A

EN13849 COMPLIANCE

Since January 1, 2012, conformance to the European Machinery Directive has required that the Safety Related Parts of the Control System (SRPCS) be designed and verified upon the general principles outlined in EN13849. EN13849 supersedes the EN954 standard and expands upon it by requiring the determination of the safety Performance Level (PL) as a function of Designated Architecture plus Mean Time To Dangerous Failure (MTTFd), Common Cause Faults (CCF), and Diagnostic Coverage (DC). These figures are used by the OEM to calculate the overall PL for each of the safety functions of their vehicle or machine.

The OEM must determine the hazards that are applicable to their vehicle design, operation, and environment. Standards such as EN13849-1 provide guidelines that must be followed in order to achieve compliance. Some industries have developed further standards (called type-C standards) that refer to EN13849 and specifically outline the path to regulatory compliance. EN1175-1 is a type-C standard for battery-powered industrial trucks. Following a type-C standard provides a presumption of conformity to the Machinery Directive.

Curtis 1229 motor controllers comply with these directives using advanced active supervisory techniques. The basic "watchdog" test circuits have been replaced with a Supervisor microcontroller that continuously tests the safety related parts of the control system; see the simplified block diagram in Figure A-1.

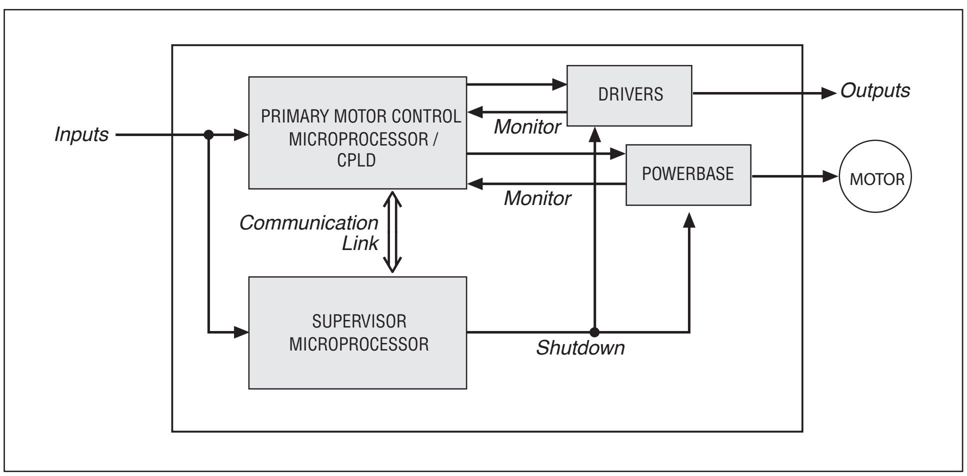


Fig. A-1 *Supervisory system in Curtis 1229 motor controller.*

The Supervisor and Primary motor control processors run diagnostic checks at startup and continuously during operation. At startup, the integrity of the code and EEPROM are ensured through CRC checksum calculations. RAM is pattern checked for proper read, write, and addressing. During operation, the arithmetic and logic processing unit of each micro is cyclically tested through dynamic stimulus and response. The operating system timing and task sequencing are continuously verified. Redundant input measurements are crosschecked over 30 times per second, and operational status information is passed between microprocessors to keep the system synchronized. Any faults in these startup tests, communication timing, crosschecks, or responses will command a safe shutdown of the controller, disabling the driver outputs and motor drive within 200 ms.

To mitigate the hazards typically found in machine operations, EN13849 requires that safety functions be defined; these must include all the input, logic, outputs, and power circuits that are involved in any potentially hazardous operation. Two safety functions are defined for Curtis 1229 motor controllers: Uncommanded Powered Motion and Motor Torque.

The Uncommanded Powered Motion safety function provides detection and safe shutdown in the following circumstances: faulted throttle; improper sequence of forward/reverse switches, throttle, and interlock; incorrect direction of travel; loss of speed control or limiting; uncommanded movement; or movement at startup. The Motor Torque safety function provides detection and safe shutdown in the event of an emergency reverse event.

Curtis has analyzed each safety function and calculated its Mean Time To Dangerous Failure (MTTFd) and Diagnostic Coverage (DC), and designed them against Common Cause Faults (CCF). The safety-related performance of the Curtis 1229 is summarized as follows:

Safety Function	Designated Architecture	MTTFd	DC	CCF	PL
Uncommanded Powered Motion	2	49	93	Pass	d
Motor Torque	2	22	92	Pass	c

EN1175 specifies that traction and hydraulic electronic control systems must use Designated Architecture 2 or greater. This design employs input, logic, and output circuits that are monitored and tested by independent circuits and software to ensure a high level of safety performance.

Mean Time To Dangerous Failure (MTTFd) is related to the expected reliability of the safety related parts used in the controller. Only failures that can result in a dangerous situation are included in the calculation.

Diagnostic Coverage (DC) is a measure of the effectiveness of the control system's self-test and monitoring measures to detect failures and provide a safe shutdown.

Common Cause Faults (CCF) are so named because some faults within a controller can affect several systems. EN13849 provides a checklist of design techniques that should be followed to achieve sufficient mitigation of CCFs. The CCF value is a pass/fail criterion.

Performance Level (PL) categorizes the quality or effectiveness of a safety channel to reduce the potential risk caused by dangerous faults within the system with "a" being the lowest and "e" being the highest achievable performance.

Contact Curtis technical support for more details.

APPENDIX B

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 motor controllers.

Emissions

Signals with high frequency content can produce significant emissions if connected to a large enough radiating area (created by long wires spaced far apart). Contactor drivers and the motor drive output from Curtis controllers can contribute to RF emissions. Both types of output are pulse width modulated square waves with fast rise and fall times that are rich in harmonics. (Note: contactor drivers that are not modulated will not contribute to emissions.) The impact of these switching waveforms can be minimized by making the wires from the controller to the contactor or motor as short as possible and by placing the wires near each other (bundle contactor wires with Coil Return; bundle motor wires separately).

For applications requiring very low emissions, the solution may involve enclosing the controller, interconnect wires, contactors, and motor together in one shielded box. Emissions can also couple to battery supply leads and throttle circuit wires outside the box, so ferrite beads near the controller may also be required on these unshielded wires in some applications. It is best to keep the noisy signals as far as possible from sensitive wires.

Immunity

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

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

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

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

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

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

The shielding effectiveness of an enclosure is further reduced when a wire passes through a hole in the enclosure; RF energy on the wire from an external field is re-radiated into the interior of the enclosure. This coupling mechanism can be reduced by filtering the wire where it passes through the shield boundary.

Given the safety considerations involved in connecting electrical components to the chassis or frame in battery powered vehicles, such filtering will usually consist of a series inductor (or ferrite bead) rather than a shunt capacitor. If a capacitor is used, it must have a voltage rating and leakage characteristics that will allow the end product to meet applicable safety regulations.

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

Keep all low power I/O separate from the motor and battery leads. When this is not possible, cross them at right angles.

ELECTROSTATIC DISCHARGE (ESD)

Curtis motor controllers contain ESD-sensitive components, and it is therefore necessary to protect them from ESD (electrostatic discharge) damage. Most of these control lines have protection for moderate ESD events, but must be protected from damage if higher levels exist in a particular application.

ESD immunity is achieved either by providing sufficient distance between conductors and the ESD source 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 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 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.

MOV, transorbs, or other devices can be placed between B- and offending wires, plates, and touch points if ESD shock cannot be otherwise avoided.

APPENDIX C
PROGRAMMING DEVICES

Curtis programmers provide programming, diagnostic, and test capabilities for the 1229 controller. The power for operating the programmer is supplied by the host controller via a 4-pin connector. When the programmer powers up, it gathers information from the controller.

Two types of programming devices are available: the 1314 PC Programming Station and the 1313 handheld programmer. The Programming Station has the advantage of a large, easily read screen; on the other hand, the handheld programmer (with its 45×60mm screen) has the advantage of being more portable and hence convenient for making adjustments in the field.

Both programmers are available in User, Service, Dealer, and OEM versions. Each programmer can perform the actions available at its own level and the levels below that—a User-access programmer can operate at only the User level, whereas an OEM programmer has full access.

PC PROGRAMMING STATION (1314)

The Programming Station is an MS-Windows 32-bit application that runs on a standard Windows PC. Instructions for using the Programming Station are included with the software.

HANDHELD PROGRAMMER (1313)

The 1313 handheld programmer is functionally equivalent to the PC Programming Station; operating instructions are provided in the 1313 manual. This programmer replaces the 1311, an earlier model with fewer functions.

PROGRAMMER FUNCTIONS

Programmer functions include:

Parameter adjustment — provides access to the individual programmable parameters.

Monitoring — presents real-time values during vehicle operation; these include all inputs and outputs.

Diagnostics and troubleshooting — presents diagnostic information, and also a means to clear the fault history file.

Programming — allows you to save/restore custom parameter settings.

Favorites — allows you to create shortcuts to your frequently-used adjustable parameters and monitor variables.

APPENDIX D

SPECIFICATIONS

Table D-1 SPECIFICATIONS: 1229 CONTROLLERS

Nominal input voltage: 24–36 V, 48 V

NOMINAL VOLTAGE	MINIMUM VOLTAGE	MAXIMUM VOLTAGE	BROWNOUT VOLTAGE)
24 V	16.5 V	45 V	15 V
36 V	24.8 V	45 V	15 V
48 V	33.0 V	60 V	20 V

PWM operating frequency	15 kHz
Maximum speed sensor frequency	30 kHz
Maximum controller output frequency	1 kHz
Electrical isolation to heatsink	500 V ac (minimum)
Storage ambient temperature range	-40°C to 95°C (-40°F to 203°F)
Operating ambient temp. range	-40°C to 50°C (-40°F to 122°F)
Thermal cutback	Controller linearly reduces maximum current limit with an internal heatsink temperature from 85°C (185°F) to 95°C (203°F); complete cutoff occurs above 95°C (203°F) and below -40°C (-40°F)
Design life	9,000 hours
Operating duration at maximum current	2 minutes minimum (unless otherwise noted), with initial temperature of 25°C and no additional external heatsink
Package environmental rating	IP65 per IEC529; compliance requires AMPSEAL 23-pin connector header
Weight	1.13 kg (2.5 lbs)
Dimensions, W×L×H	122 × 150 × 59 mm (4.8" × 5.9" × 2.3")
EMC	Designed to the requirements of EN 12895:2000
Safety	Designed to the requirements of EN 1175-1:1998 + A1:2010 and EN 13849-1:2008 Category 2
UL	UL recognized component per UL583

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

MODEL NUMBER	NOMINAL BATTERY VOLTAGE (V)	2-MINUTE CURRENT (A)	10 SECOND BOOST CURRENT (A)	S2-60 MINUTE CONTINUOUS CURRENT (A)
1229-31XX	24–36	200	220	100
1229-32XX	24–36	250	275	125
1229-41XX	48	200	220	100