Manual

Model **1222**

Electric Steering Controller

» Software Version OS 15.0 «

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Read Instructions Carefully!

53122, OS15 2/5/13

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OVERVIEW

The Curtis Model 1222 is an AC induction motor controller for electric power steering (EPS) systems. In these "steer by wire" systems, the AC steering gearmotor functions as an actuator to change the angle of the vehicle's steered wheel(s) and thus change the direction of travel. The 1222 performs as the steering system controller, interpreting the steering command input and wheel position feedback, then driving the steering motor to move the steered wheel(s) to the desired position.

The Curtis 1222 controller is designed for use as an electric power steering controller for 300–1400W AC induction gearmotors with overall gear reductions between 50:1 and 800:1 on vehicles using Curtis VCL AC motor controllers. Intended applications are material handling vehicles such as reach trucks, order pickers, stackers, "man up" warehouse trucks, and other similar industrial vehicles.

Fig. 1 *Curtis 1222 electric steering controller.*

Advanced Motor Control

✓ Absolute Position (pedestrian stacker) or Relative Position (reach truck) control modes.

✓ Supports >360° multi-turn steering mode.

✓ Indirect Field Orientation (IFO) vector control algorithm provides maximum possible torque while ensuring maximum efficiency and accurate current control.

More Features ☞

- ✓ 16 kHz PWM switching frequency ensures silent operation across the 0–200Hz stator frequency range.
- ✓ Advanced PWM techniques produce low motor harmonics, low torque ripple, and minimized heating losses, resulting in high efficiency.
- ✓ 70A RMS 2-minute current output.
- ✓ 24–48V nominal supply voltage.

Versatile Steering Input and Feedback Options

- ✓ Steering command input via CAN, dual redundant quadrature encoder, sine/cosine sensor, sawtooth sensor, or analog voltage inputs.
- ✓ Steered angle feedback via dual redundant homing switch, quadrature encoder, sine/cosine sensor, sawtooth sensor, or analog voltage inputs.
- ✓ Fully programmable input/output ratio mapping.
- ✓ Configurable homing methods, center offset, auto-center, and end-stop protection.
- ✓ Programmable force feedback driver for command input devices featuring variable friction tactile feedback (TFD).

Maximum Safety

- ✓ Dual redundant configuration of all safety-related parts.
- ✓ Two microprocessors, each with its own EEPROM memory.
- ✓ Separate input paths to each micro for all input and feedback signals.
- ✓ 5A high-side fault output driver, consisting of two switches connected in series; each switch is controlled by one micro with independent supervision.
- ✓ Meets the requirements of the latest international functional safety standards.

Unmatched Flexibility

- ✓ CANopen system communications.
- ✓ 35-pin AMPSEAL logic connector.
- ✓ Software includes a library of pre-defined AC steering motor types from various manufacturers.
- ✓ Programmable motor temperature input prevents thermal damage to motor and supports all commonly used thermistors.

- ✓ Integrated hourmeter and diagnostic log functions.
- ✓ +5V and +10V low-power supplies for input sensors, etc.
- ✓ Curtis 1313 handheld programmer and 1314 PC Programming Station provide easy programming and powerful system diagnostic and monitoring capabilities.
- ✓ Integrated Status LED gives instant diagnostic indication.
- ✓ Field upgradeable software.

Robust Reliability

- ✓ Insulated Metal Substrate (IMS) powerbase ensures superior heat transfer.
- ✓ Intelligent thermal cutback and overvoltage/undervoltage protection functions maintain steering while reducing traction speed until severe over/under limits are reached.
- ✓ Rugged sealed housing and AMPSEAL connector meet IP65 environmental standards for use in harsh environments.
- ✓ Reverse polarity protection on battery connections and short circuit protection on all output drivers.

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 your local Curtis representative.

2

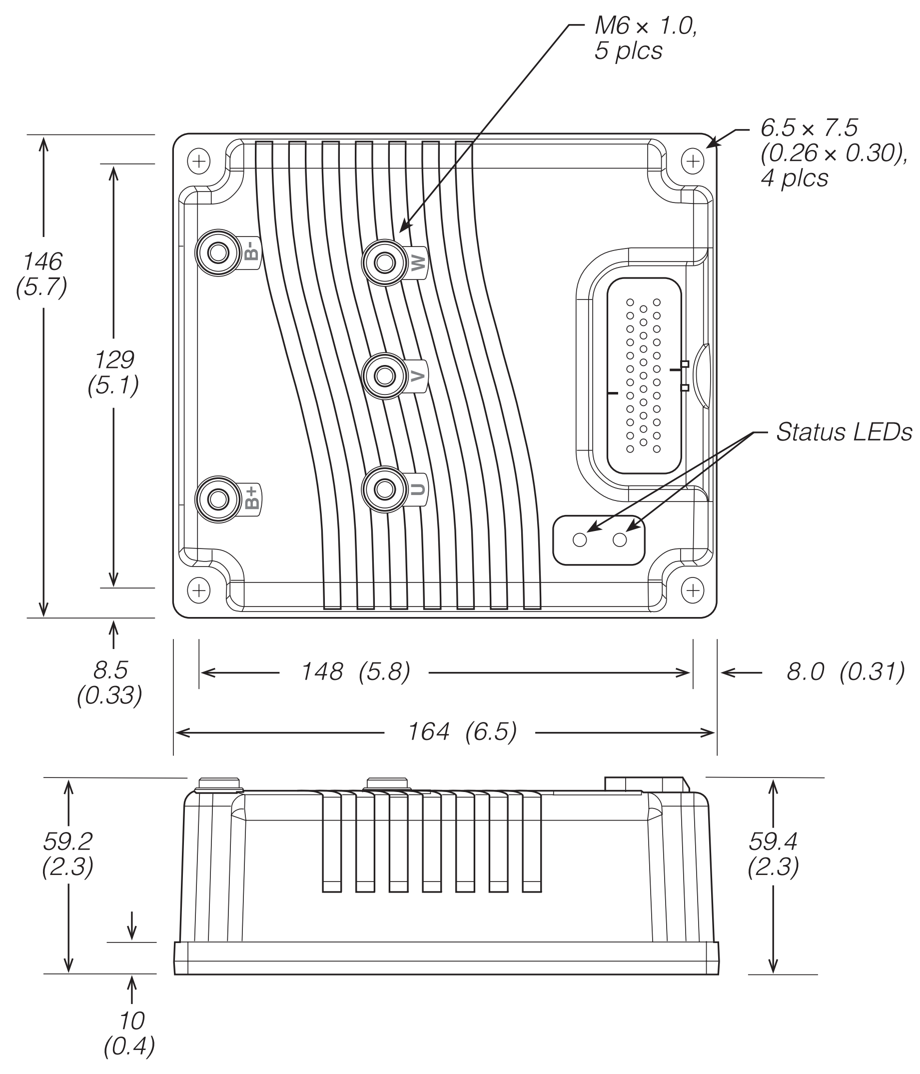
INSTALLATION AND WIRING

MOUNTING THE CONTROLLER

The outline and mounting hole dimensions for the 1222 controller are shown in Figure 2. The controller 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 four 6mm (1/4") diameter 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.

Fig. 2 *Mounting dimensions, Curtis 1222 motor controller.*



Dimensions in millimeters (and inches)

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 A.

The 1222 controller contains **ESD-sensitive components**. Use appropriate precautions in connecting, disconnecting, and handling the controller. See installation suggestions in Appendix A 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 five high-current terminals, identified on the controller housing as **B+**, **B-**, **U**, **V**, and **W**.

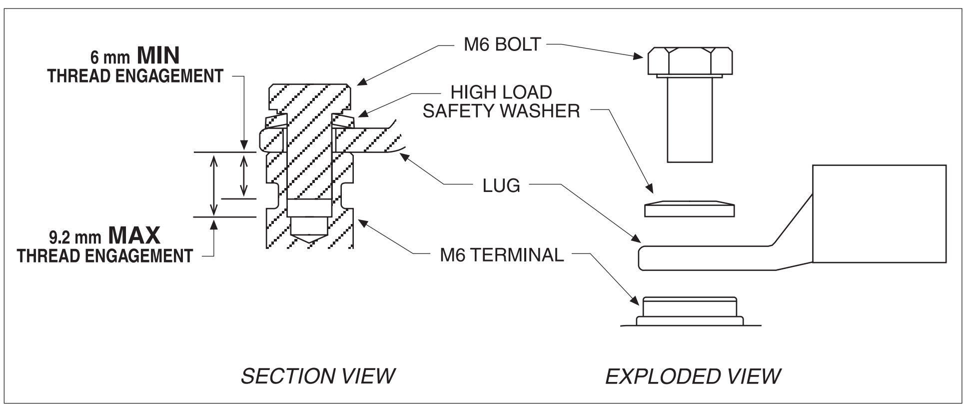
Table 1 High Current Connections

TERMINAL	FUNCTION
B+	Positive battery to controller.
B-	Negative battery to controller.
U	AC steer motor phase U.
V	AC steer motor phase V.
W	AC steer motor phase W.

Lug assembly

Five 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.

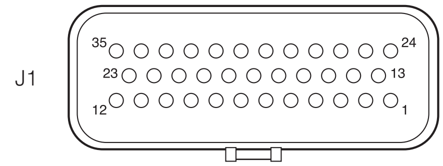
Motor wiring (**U**, **V**, **W**)

The three phase 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 next to the motor cables. When necessary they should cross the motor cables at a right angle to minimize noise coupling.

LOW CURRENT CONNECTIONS

All low power connections are made through a single 35-pin AMPSEAL connector. The mating plug housing is AMP p/n 776164-1 and the contact pins are AMP p/n 770520-3. The connector will accept 1.5 mm² (20 – 16 AWG) wire with a 1.7 – 2.7 mm diameter (thin-wall insulation).

The 35 individual pins are characterized in Table 2.



Low current wiring recommendations

Command input encoder and Steer motor encoder

The encoder wires should be bundled together as they run between the motor and controller logic connector. These can often be run with the rest of the low current wiring harness. The encoder cables should not be run near the motor cables. In applications where this is necessary, shielded cable should be used with the ground shield connected to the I/O ground (pin 18 or pin 30) at only the controller side. In extreme applications, common mode filters (e.g. ferrite beads) could be used.

CAN connection

The two CAN wires should be connected directly to the corresponding CAN pins on the traction controller: running from pin 23 (CAN High) on the steering controller to pin 23 (CAN High) on the traction controller, and from pin 35 (CAN Low) on the steering controller to pin 35 (CAN Low) on the traction controller.

Note: The 1222 controller has no internal 120Ω CAN terminating resistor. Typically the wiring of the CAN bus nodes is a daisy chain topology with 120Ω CAN terminating resistors at each end. If the vehicle wiring is done such that the 1222 is the last node in the chain, an external 120Ω terminating resistor should be provided by the OEM in the wiring harness.

CAN wiring should be kept away from the high current cables and cross it at right angles when necessary.

All other low current wiring

The remaining low current wiring should be run according to standard practices. Running low current wiring next to the high current wiring should always be avoided.

Table 2 Low Current Connections

PIN	NAME	DESCRIPTION
1	Keyswitch	Provides logic power for the controller and power for the coil drivers.
2	Contactor Driver	Driver for steer contactor.
3	[reserved]	Not used.
4	[reserved]	Not used.
5	Force Feedback Driver	Driver for force feedback coil.
6	[reserved]	Not used.
7	Ground	Ground.
8	Command Analog 1	Primary steer command pot.
9	Interlock Input 1	Primary interlock switch input.
10	Home Input 2	Primary home switch input.
11	Interlock Input 3	Supervisory interlock switch input.
12	Home Input 4	Supervisory home switch input.
13	Coil Return	This is the coil return pin for all the contactor coils.
14	Command Encoder 1A	Steer Command Encoder 1 input phase A.
15	+10V	Regulated low power +10V output.
16	Position Analog 5	Primary position feedback pot.
17	Position Analog 6	Supervisory position feedback pot.
18	Ground	Ground.
19	Command Analog 3	Supervisory steer command pot.
20	Command Encoder 2B	Steer Command Encoder 2 input phase B.
21	+5V	Regulated low power +5V output.
22	Motor Temperature Sensor	Motor temperature sensor.
23	CAN High	CAN bus high.
24	Fault Output	Steer fault output.
25	Command Encoder 1B	Steer Command Encoder 1 input phase B.

Table 2 Low Current Connections, cont'd

PIN	NAME	DESCRIPTION
26	Steer Motor Encoder 4A	Steer Motor Encoder 4 input phase A.
27	Steer Motor Encoder 4B	Steer Motor Encoder 4 input phase B.
28	TX	Serial transmit line.
29	RX	Serial receive line.
30	Ground	Ground.
31	Steer Motor Encoder 3A	Steer Motor Encoder 3 input phase A.
32	Steer Motor Encoder 3B	Steer Motor Encoder 3 input phase B.
33	Command Encoder 2A	Steer Command Encoder 2 input phase A.
34	+5V	Regulated low power +5V output.
35	CAN Low	CAN bus low.

CONTROLLER WIRING: Safety Requirements

As shown in the wiring diagram (Figure 3a), the 1222's keyswitch power must go through the traction controller so that when the keyswitch is turned off both controllers turn off. The fault output (Pin 24) should be able to shut down the traction system in the case of a serious fault; otherwise the system may not meet the international safety requirements listed in Table D-1.

As shown in the wiring diagram, two steer command devices and two position feedback devices are used. The 1222 supervises and matches each

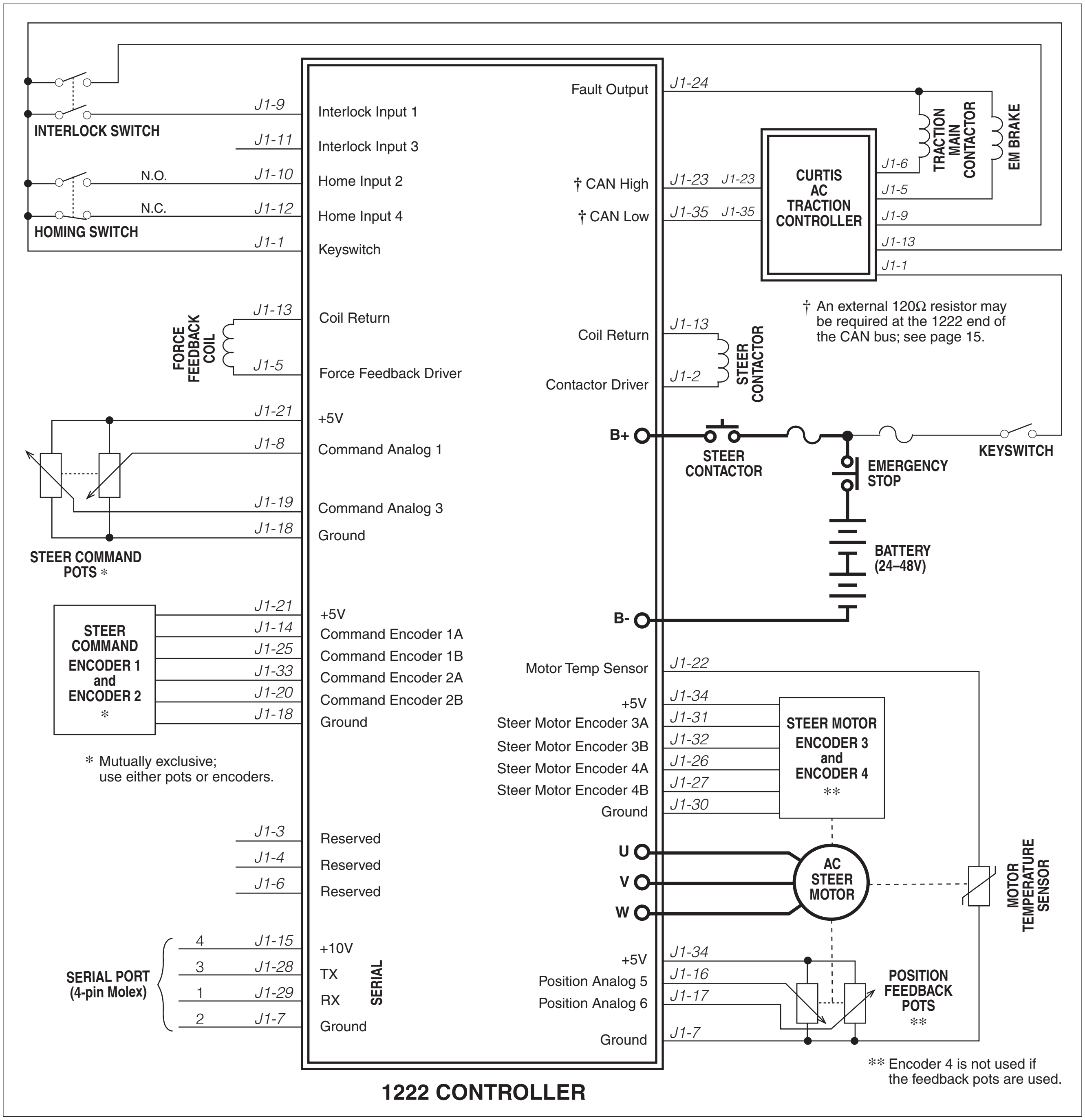


Fig. 3a *Wiring diagram, Curtis 1222 electric steering controller.*

device input to its counterpart (steering to steering, feedback to feedback). If any of these input pairs do not match, the 1222 begins its fault sequence to bring the vehicle to a stop.

As shown in the software control diagram (Figure 3b), the safety critical parts are included twice to provide redundancy:

· two microprocessors
· separate paths to each micro for the command and feedback signals
· cross checks on the normalized steer command
· cross checks on the normalized wheel position.

A following error check ensures that the wheel position tracks the steer command.

Although not shown in the wiring diagram, the analog inputs can be used for single sine/cosine sensors or sawtooth sensors instead of for redundant pairs of pots. Each single sensor has two levels of fault detection, which provide redundancy; see description of Tolerance parameter in Sin/Cos Sensor menus (pages 26 and 41) and in Sawtooth Sensor menus (pages 28 and 42).

The wiring diagram (Figure 3a) is designed for generic applications and may not fully meet the requirements of your system. You may wish to contact your local Curtis representative to discuss your particular application. In cases where the wiring deviates from the wiring shown in Figure 3a, it is up to the OEM to evaluate the overall system safety.

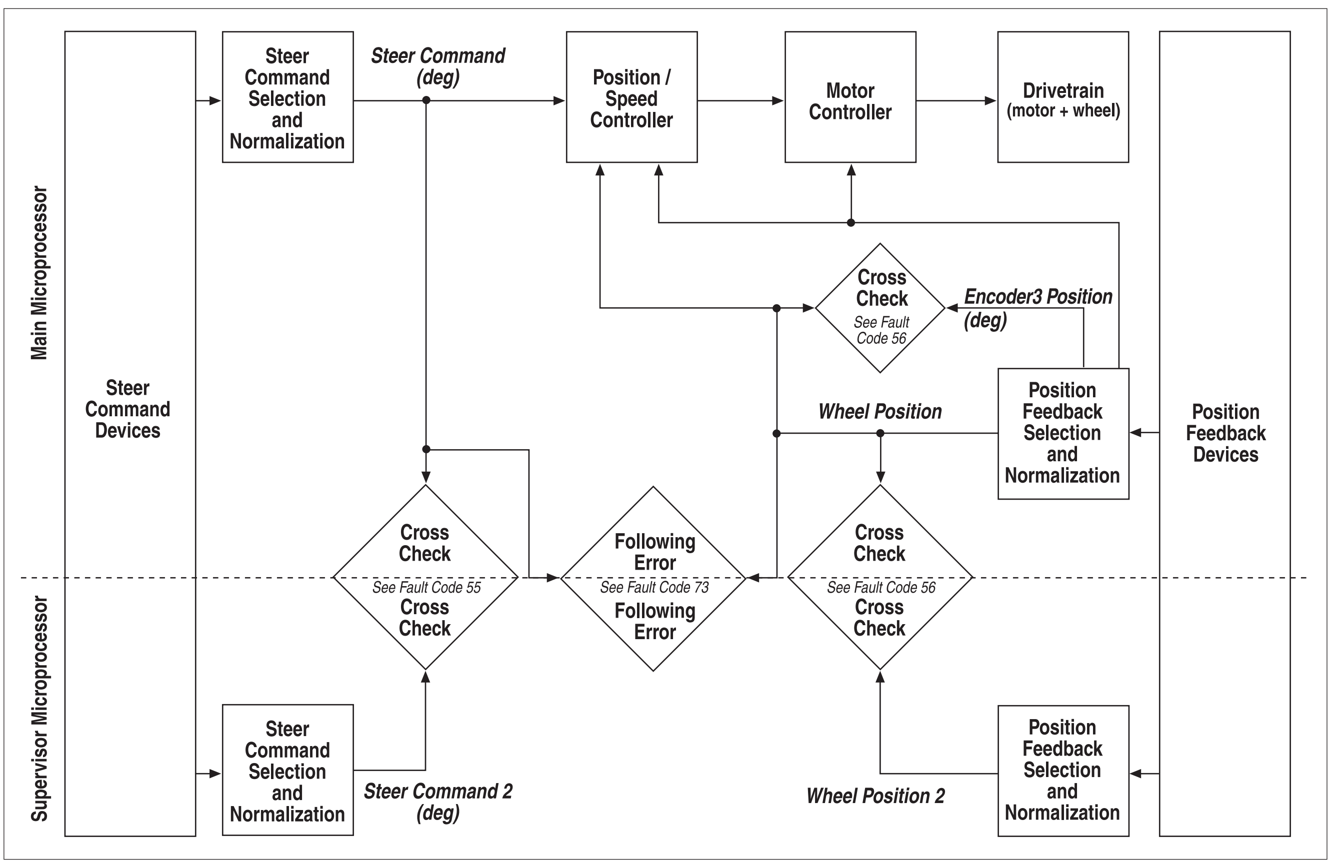


Fig. 3b *Software control diagram.*

INPUT/OUTPUT SIGNAL SPECIFICATIONS

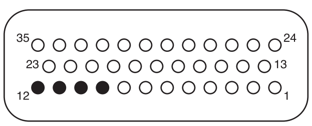
The input/output signals wired to the 35-pin connector can be grouped by type as follows; their electrical characteristics are discussed below.

— digital inputs
— driver outputs
— analog inputs
— power supply outputs
— keyswitch and coil return inputs
— communications port inputs/outputs
— encoder inputs.

Digital inputs

The digital inputs must be wired to switch to B+ (not to ground). All digital inputs are protected against shorts to B+ or B-.

A home switch is required if encoder position feedback is used (Position Feedback Device = 1).

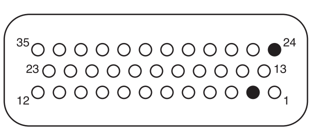


DIGITAL INPUT SPECIFICATIONS					
SIGNAL NAME	PIN	LOGIC THRESHOLDS	INPUT IMPEDANCE	VOLTAGE RANGE	ESD TOLERANCE
Interlock Input 1	9	Rising edge= 5 V max Falling edge= 1.5 V min	10.7 kΩ	10–65 V	±8 kV (air discharge)
Home Input 2	10				
Interlock Input 3	11				
Home Input 4	12				

Driver outputs

The fault output shuts down the traction system if the 1222 has a fault. This output switches B+ to the high side of the traction main contactor and EM brake; without this signal, the system shuts down.

All driver outputs are protected against shorts to B+ or B-



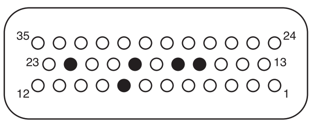
DRIVER OUTPUT SPECIFICATIONS						
SIGNAL NAME	PIN	OUTPUT TYPE	FREQUENCY	OUTPUT CURRENT	PROTECTED VOLTAGE	ESD TOLERANCE
Contactor Driver	2	Low Side	16 kHz	2 A max	65 V	±8 kV (air discharge
Force Feedback Driver	5	Low Side	16 kHz	2 A max	65 V	
Fault Output	24	High Side	n/a	5 A max	65 V	

Analog inputs

The command and position analog inputs are used when the steer command and position feedback devices are pots or sine/cosine sensors or sawtooth sensors.

The motor temperature sensor input provides a constant current appropriate for a thermistor sensor. Some standard predefined motor temperature sensors are supported in software (see Sensor Type parameter, page 49). Note: The industry standard KTY temperature sensors are silicon temperature sensors with a polarity band; **the polarity band of a KTY sensor must be the end connected to I/O Ground** (pin 7).

All analog inputs are protected against shorts to B+ or B-.

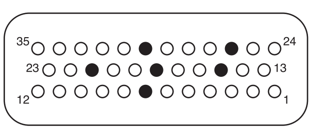


ANALOG INPUT SPECIFICATIONS

SIGNAL NAME	PIN	OPERATING VOLTAGE	INPUT IMPEDANCE	PROTECTED VOLTAGE	ESD TOLERANCE
Command Analog 1	8	0 to 10 V	100 kΩ	65 V	±8 kV (air discharge)
Command Analog 3	19				
Position Analog 5	16				
Position Analog 6	17				
Motor Temp Sensor	22				

Power supply outputs

The +5V supply is used for all steer command and position feedback devices. The +10V supply is provided for the handheld programmer; it should not be used for steer command or position feedback devices because voltage could change when the programmer is plugged in. Both power supply outputs are protected against shorts to B+ or B-.



POWER SUPPLY OUTPUT SPECIFICATIONS

SIGNAL NAME	PIN	OUTPUT VOLTAGE	OUTPUT CURRENT	PROTECTED VOLTAGE	ESD TOLERANCE
+5V	21, 34	5 V ±10%	100 mA max*	65 V	±8 kV (air discharge)
+10V	15	10 V ±10%	100 mA max*	65 V	
Ground	7, 18, 30	n/a	n/a	n/a	

*The total combined current from +5V and +10V outputs should not exceed 150 mA.

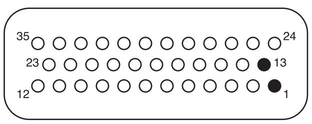
Keyswitch input and coil return

Keyswitch power to the 1222 is provided through the coil return of the traction controller. This ensures that the steer controller is not turned Off unless the traction controller is Off. Both controllers shut down in the event of a fault.

Coil suppression for the traction controller is provided when the traction main contactor and EM brake are wired to the fault output (pin 24). However, you may wish to use coil suppression diodes to reduce EMI emissions.

Coil Return should be wired to the positive battery side of the steer contactor so that switching noise associated with PWM operation of the contactor is localized to the contactor wiring only.

Reverse polarity protection is ensured only when the keyswitch input and coil return are wired as shown in Figure 3a (page 11).



KEYSWITCH AND COIL RETURN INPUT SPECIFICATIONS

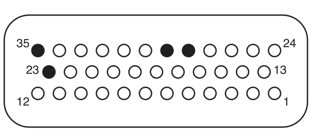
SIGNAL NAME	PIN	OPERATING VOLTAGE	MAX INPUT CURRENT	PROTECTED VOLTAGE	ESD TOLERANCE
Keyswitch	1	Between under- and overvoltage cutbacks	50–500 mA + coil return current	65 V	±8 kV (air discharge)
Coil Return	13		10 A	65 V	

Communications ports

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

Note: The 1222 controller has no internal 120Ω CAN terminating resistor. Typically the wiring of the CAN bus nodes is a daisy chain topology with 120Ω CAN terminating resistors at each end. If the vehicle wiring is done such that the 1222 is the last node in the chain, then an external 120Ω terminating resistor should be provided by the OEM in the wiring harness.

The Curtis programmer plugs into a connector wired to pins 28 and 29, along with ground (pin 7) and the +10V power supply (pin 15); see wiring diagram, Figure 3a.



COMMUNICATIONS PORT SPECIFICATIONS

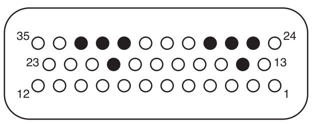
SIGNAL NAME	PIN	SUPPORTED PROTOCOL/DEVICES	DATA RATE	PROTECTED VOLTAGE	ESD TOLERANCE
CAN High	23	CANopen	up to 1 Mbps	-5 V to (MaxV + 10 V) with <30 V differentially	±8 kV (air discharge)
CAN Low	35				
Tx	28	1313 Handheld Programmer, 1314 PC Programming Station	as required, 9.6 to 56 kbps	-0.3 to 12 V	±8 kV (air discharge)
Rx	29				

Encoder inputs

These inputs are used when the steer command and position feedback devices are encoders. Command Encoders 1 and 2 are for steer commands, and Steer Motor Encoders 3 and 4 are for feedback.

Pairs (A, B) of control lines are internally configured to read quadrature type encoders. The encoders are typically powered from the 5V supply (pin 21), but can be powered from any external supply (from 5V up to B+) as long as the logic threshold requirements are met.

Note: **Steer Motor Encoder 3 is always required, even when redundant analog feedback inputs are used** (feedback pots or sine/cosine sensors or sawtooth sensors). Encoder 3 must be directly connected to the motor shaft as it is used for motor control; it must have a minimum of 32 ppr. Encoder 4, if it is used, can be connected to either the motor shaft or the steered wheel; if it is connected to the steered wheel, it should have a minimum resolution of 0.5 counts/degree (equivalent to 45 ppr).



ENCODER INPUT SPECIFICATIONS

SIGNAL NAME	PIN	LOGIC THRESHOLDS	INPUT IMPEDANCE	MAX FREQ.	PROTECTED VOLTAGE	ESD TOLERANCE
Command Encoder 1A	14	Rising edge= 4 V max Falling edge= 1 V min	1 kΩ	2 kHz	65 V	±8 kV (air discharge)
Command Encoder 1B	25					
Command Encoder 2A	33					
Command Encoder 2B	20					
Steer Motor Encoder 3A	31			10 kHz		
Steer Motor Encoder 3B	32					
Steer Motor Encoder 4A	26					
Steer Motor Encoder 4B	27					

3 PROGRAMMABLE PARAMETERS

The 1222 controller has a number of parameters that can be programmed using a Curtis 1313 handheld programmer or 1314 Programming Station. The programmable parameters allow the steering performance to be customized to fit the needs of specific applications.

PARAMETER MENU CHARTS

The programmable parameters are grouped into nested hierarchical menus, as shown in Table 3. The menu charts contain descriptions of each parameter.

PARAMETER ATTRIBUTES

Some parameters are subject to one or both of the following conditions, as noted in the menu charts.

Parameter Change Fault (PCF)

When a new value is written, a Parameter Change Fault (code 49) is issued. This is true both for writes via a CAN message and for writes via the serial bus (using the 1313/1314 programmer). For safety purposes, the Parameter Change Fault forces the vehicle operator to cycle power; cycling power clears the fault. Subject parameters are marked ◎.

Requires Idle State (RIS)

To successfully write the parameter, a Device State = 0 (Not Ready to Switch On), 2 (Switch On Disabled), 3 (Ready to Switch On) or 14 (Fault) is required. This is true both for writes via a CAN message and for writes via the serial bus (using the 1313/1314 programmer). The 1222 will reply with an Abort message to any write attempted when the Device State is not one of those listed above. The 1222 will not process the aborted write message, which means the new parameter value will not be written. Subject parameters are marked ■.

MENU CHART FORMAT

Individual parameters are presented as follows in the menu charts:

Parameter name as it appears in the programmer display ⇓	Allowable range in the programmer's units ⇓	Parameter attribute (PCF, RIS) ⇓	Description of the parameter's function and, where applicable, suggestions for setting it ⇓
Analog1 Center *0x400A 0x00*	0–10.00 V *0–1023*	◎ ■	Defines the Analog 1 wiper voltage required to produce a steer position command of center (Steer Command = 0°).
⇑ *CAN Object index and sub-index*	⇑ *Allowable range in CAN units*		

Table 3 Programmable Parameter Menus

COMMAND DEVICE

FEEDBACK DEVICE

Table 3 Programmable Parameter Menus, cont'd

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CAUTION

We strongly urge you to read Section 5, Initial Setup, before adjusting any of the parameters.

Even if you opt to leave most of the parameters at their default settings, **it is imperative that you perform the procedures outlined in Section 5, which set up the basic system characteristics for your application**.

INPUT DEVICE PARAMETER

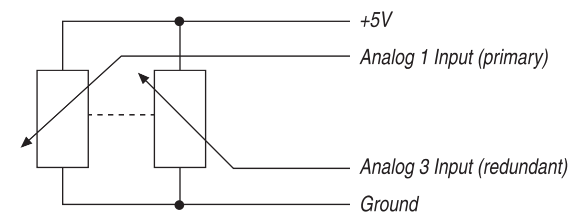
PARAMETER	ALLOWABLE RANGE	PCF	RIS	DESCRIPTION
Command Input Device *0x4003 0x00*	0–4 *0–4*	◎	■	These two parameters determine which inputs will be used as the primary and supervisory user steer commands:
Supervision Input Device *0x40E4 0x00*	0–5 *0–5*	◎	■	

0 = Pot input, where Analog 1 and Analog 3 inputs are connected to two potentiometers as redundant inputs.

When an analog steering command is used, two channels are required.

NAME	PIN	FUNCTION
Analog 1	8	Primary analog input command
Analog 3	19	Supervisory analog input command

It is best practice to wire the primary and supervisory input signals in an "X" configuration (0–5V and 5V–0). However, the 1222 has independent maps and will support redundant signals that move in the same direction.

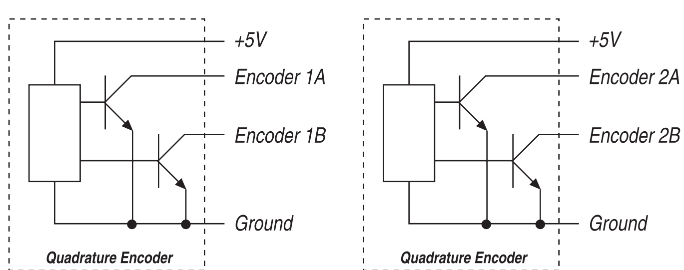


Analog Command (Command Input Device = **0**)

1 = Encoder input, where Encoder 1 and Encoder 2 inputs are connected to two quadrature encoders as redundant inputs.

When an encoder steering command is used, two quadrature encoders are required. In the table below, "+" and "-" indicate encoder phase differences ("-" being some amount of phase shift from "+"). This means that the primary and supervisory encoders do not have to have the same alignment.

NAME	PIN	FUNCTION
Encoder 1A	14	Primary quadrature encoder command A+
Encoder 1B	25	Primary quadrature encoder command A-
Encoder 2A	33	Supervisory quadrature encoder command B+
Encoder 2B	20	Supervisory quadrature encoder command B-



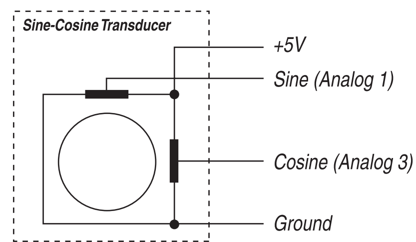
Encoder Command (Command Input Device = **1**)

INPUT DEVICE PARAMETER, cont'd

2 = Sin/Cos Sensor command, where Analog 1 and Analog 3 inputs are connected to a sine-cosine transducer. The transducer could be mounted to a steering wheel or a tiller arm. The sensor may be set up as either an absolute or relative position device, using the Absolute Mode parameter (see page 26).

When this steering command is used, sine and cosine channels are both required (and together serve as the primary and supervisory devices).

NAME	PIN	FUNCTION
Analog 1	8	Sine input (Command Analog 1)
Analog 3	19	Cosine input (Command Analog 3)

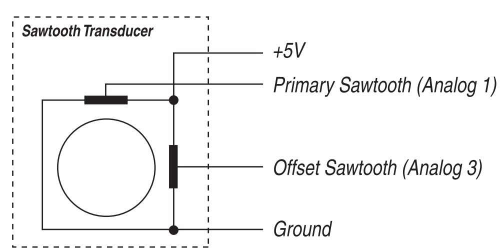


Sine-Cosine Command (Command Input Device = **2**)

3 = Sawtooth Sensor command, where Analog 1 and Analog 3 inputs are connected to a sawtooth transducer. The transducer could be mounted to a steering wheel or a tiller arm. The sensor may be set up as either an absolute or relative position device, using the Absolute Mode parameter (see page 28).

When this steering command is used, primary sawtooth and offset sawtooth channels are both required (and together serve as the primary and supervisory devices).

NAME	PIN	FUNCTION
Analog 1	8	Primary sawtooth input (Command Analog 1)
Analog 3	19	Offset sawtooth input (Command Analog 3)



Sawtooth Command (Command Input Device = **3**)

INPUT DEVICE PARAMETER, cont'd

4 = CAN Sensor command, where the input to the 1222 comes via a CAN bus message (i.e., "steer-by-wire"). The CAN sensor may be set up as either an absolute or relative position device, using the Absolute Mode parameter (see page 30).

CAN Index	*Sub-Index*	*FUNCTION*
0x4445	*0x00*	*Primary CAN Steer Command*
0x44D6	*0x00*	*Supervisory CAN Steer Command*

The CAN indexes for both steer commands should be set up with the generic CANopen PDO mapping objects. For EN 13849 it is recommended that the CAN steer commands be sent in separate PDO messages and that the supervisory CAN2 steer command be the opposite polarity and that the CAN2 Steer Swap Direction parameter be set for the supervisory command only.

5 = None. No supervisory steer command device is connected. Only a single steer command device (the primary) is used. This option is available only for the Supervision Input Device parameter. **Using this setting will make the system non-compliant with EN 13849.**

IMPORTANT

When the Supervision Input Device is set to 5, steer command supervision is disabled. This option is provided to allow systems not compliant with EN 13849 to be set up without having to supply connections to the supervisory inputs from the single primary input device.

COMMAND INPUT DEVICE 0 – ANALOG1 and 3				
PARAMETER	ALLOWABLE RANGE	PCF	RIS	DESCRIPTION
Analog1 Left *0x4008 0x00*	0–10.00 V *0–1023*	■		Defines the Analog 1 wiper voltage required to produce a steer position command of full left (Steer Command = -100% = Left Stop).
Analog1 Center *0x400A 0x00*	0–10.00 V *0–1023*	■		Defines the Analog 1 wiper voltage required to produce a steer position command of center (Steer Command = 0% = 0°).
Analog1 Right *0x4009 0x00*	0–10.00 V *0–1023*	■		Defines the Analog 1 wiper voltage required to produce a steer position command of full right (Steer Command = 100% = Right Stop).
Analog1 Fault Min *0x400E 0x00*	0–10.00 V *0–1023*			Sets the minimum threshold for the Analog 1 steer command pot input. If the Analog 1 steer command pot voltage goes below this threshhold for 60 ms, a fault is issued.
Analog1 Fault Max *0x400F 0x00*	0–10.00 V *0–1023*			Sets the maximum threshold for the Analog 1 steer command pot input. If the Analog 1 steer command pot voltage rises above this threshhold for 60 ms, a fault is issued.
Analog3 Left *0x409F 0x00*	0–10.00 V *0–1023*	■		Defines the Analog 3 wiper voltage required to produce a steer position command of full left (Steer Command = -100% = Left Stop).
Analog3 Center *0x40A1 0x00*	0–10.00 V *0–1023*	■		Defines the Analog 3 wiper voltage required to produce a steer position command of center (Steer Command = 0% = 0°).
Analog3 Right *0x40A0 0x00*	0–10.00 V *0–1023*	■		Defines the Analog 3 wiper voltage required to produce a steer position command of full right (Steer Command = 100% = Right Stop).
Analog3 Fault Min *0x400B 0x00*	0–10.00 V *0–1023*			Sets the minimum threshold for the Analog 3 steer command pot input. If the Analog 3 steer command pot voltage falls below this threshhold for 60 ms, a fault is issued.
Analog3 Fault Max *0x400C 0x00*	0–10.00 V *0–1023*			Sets the maximum threshold for the Analog 3 steer command pot input. If the Analog 3 steer command pot voltage rises above this threshhold for 60 ms, a fault is issued.

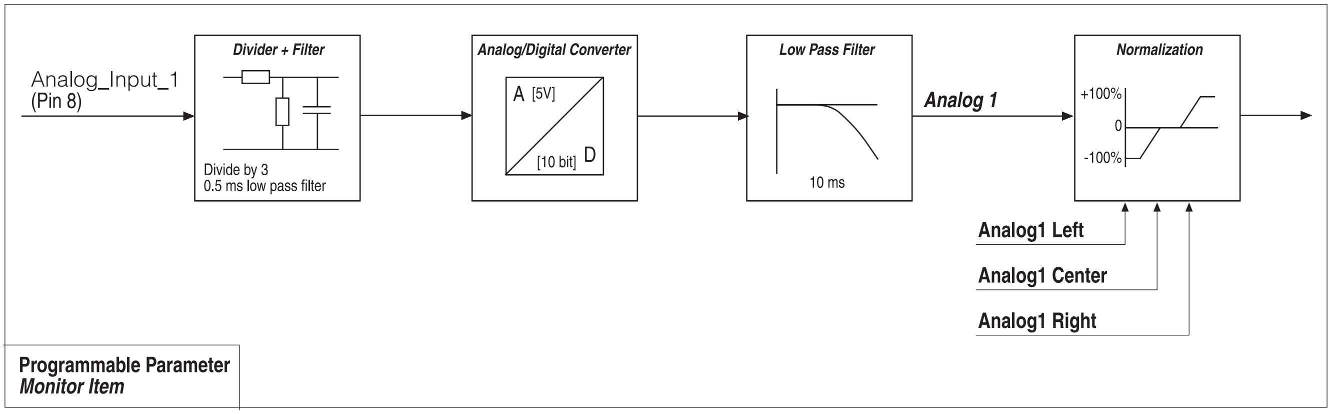


Fig. 4 *Command Input Device "0" signal flow (Analog 1 shown; Analog 3 is similar).*

COMMAND INPUT DEVICE 1 – ENCODER1 and 2				
PARAMETER	ALLOWABLE RANGE	PCF	RIS	DESCRIPTION
Left Stop to Center *0x4094 0x00*	-32768 – 0 *-32768 – 0*	■		Defines the total steer command encoder counts to produce a steer command from the center position (Steer Command = 0% = 0°) to the full left position (Steer Command = -100% = Left Stop). Left Stop to Center is always a negative number.
Right Stop to Center *0x406D 0x00*	0 – 32767 *0 – 32767*	■		Defines the total steer command encoder counts to produce a steer command from the center position (Steer Command = 0% = 0°) to the full right position (Steer Command = 100% = Right Stop). Right Stop to Center is always a positive number.
Swap Encoder1 Direction *0x406C 0x00*	On / Off *On / Off*	■		Changes the direction (left or right) of the Encoder 1 steer command input.
Swap Encoder2 Direction *0x4069 0x00*	On / Off *On / Off*	■		Changes the direction (left or right) of the Encoder 2 steer command input.

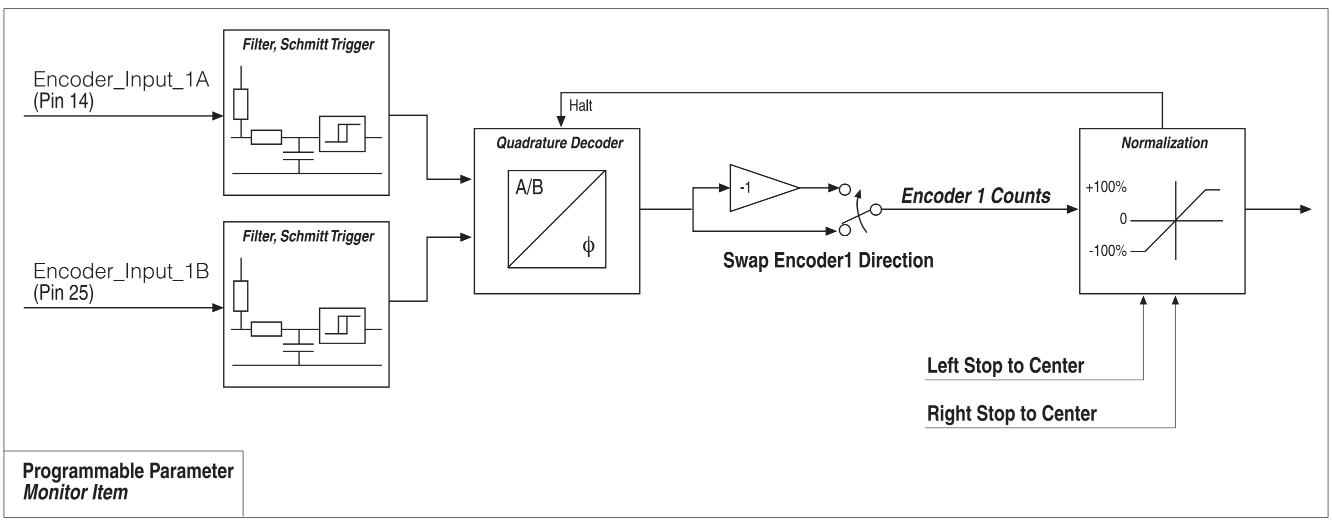


Fig. 5 *Command Input Device "1" signal flow (Encoder 1 shown; Encoder 2 is similar).*

COMMAND INPUT DEVICE 2 – SIN/COS SENSOR				
PARAMETER	ALLOWABLE RANGE	PCF	RIS	DESCRIPTION
Left Angle (deg) *0x40CC 0x00*	-1800.0° – 0.0° *-20480–0*	■		In *Absolute Position mode,* this parameter defines the position (in degrees) required to produce a steer command of full left (Steer Command = -100%). In Absolute Position mode, this parameter should be adjusted within the range -180.0° – 0.0°. In *Relative Position mode,* the parameter defines the number of turns (in degrees) required to produce a steer command from center to full left (Steer Command = -100%).
Center Angle (deg) *0x40D2 0x00*	-180.0° – 180.0° *-2048–2047*	■		In *Absolute Position mode,* this parameter defines the position (in degrees) required to produce a steer command of center position (Steer Command = 0%). In *Relative Position mode,* this parameter is not used.
Right Angle (deg) *0x40CD 0x00*	0.0° – 1800.0° *0–20479*	■		In *Absolute Position mode,* this parameter defines the position (in degrees) required to produce a steer command of full right (Steer Command = 100%). In Absolute Position mode, this parameter should be adjusted within the range 0.0° – 180.0°. In *Relative Position mode,* the parameter defines the number of turns (in degrees) required to produce a steer command from center to full right (Steer Command = 100%).
Offset *0x40CE 0x00*	0 – 10.00 V *0 – 1023*	■		Set this parameter to the midpoint voltage of the sine wave output of the sin/cos sensor. This value is usually available in the sensor specifications, and is typically half the voltage supply to the sensor.
Amplitude *0x40DE 0x00*	0 – 10.00 V *0 – 1023*	■		Set this parameter to one half of the expected peak-to-peak voltage for the sin/cos sensor input signals.
Swap Direction *0x406A 0x00*	On / Off *On / Off*	■		Use this parameter to invert the signal to avoid physically swapping the wires to pins 8 and 19.
Absolute Mode *0x40F0 0x00*	On / Off *On / Off*	■		The sensor is in absolute position mode when this parameter is set to On. The sensor is in relative position mode when this parameter is set to Off.
Fault Min *0x400B 0x00*	0 – 10.00 V *0 – 1023*			Sets the minimum threshold for the Analog 1 and Analog 3 inputs of the sin/cos sensor. If either the Analog 1 or Analog 3 voltage falls below this threshold for 60 ms, a fault is issued.
Fault Max *0x400C 0x00*	0 – 10.00 V *0 – 1023*			Sets the maximum threshold for the Analog 1 and Analog 3 inputs of the sin/cos sensor. If either the Analog 1 or Analog 3 voltage rises above this threshold for 60 ms, a fault is issued.
Tolerance *0x40DF 0x00*	0 – 10.00 V *0 – 1023*			The sine and cosine signals are used together to calculate the absolute position, i.e. arctan (Analog 1 / Analog 3). This calculated position is then used to back-calculate the expected sine and cosine inputs, based on the Amplitude parameter. If the difference between these expected inputs (Command Sin/Cos Sensor Angle 2) and the actual inputs (Command Sin/Cos Sensor Angle) is greater than the set Tolerance voltage for 60 ms, a fault is issued. This provides a second level of fault detection and triggers a separate SinCos Command fault.

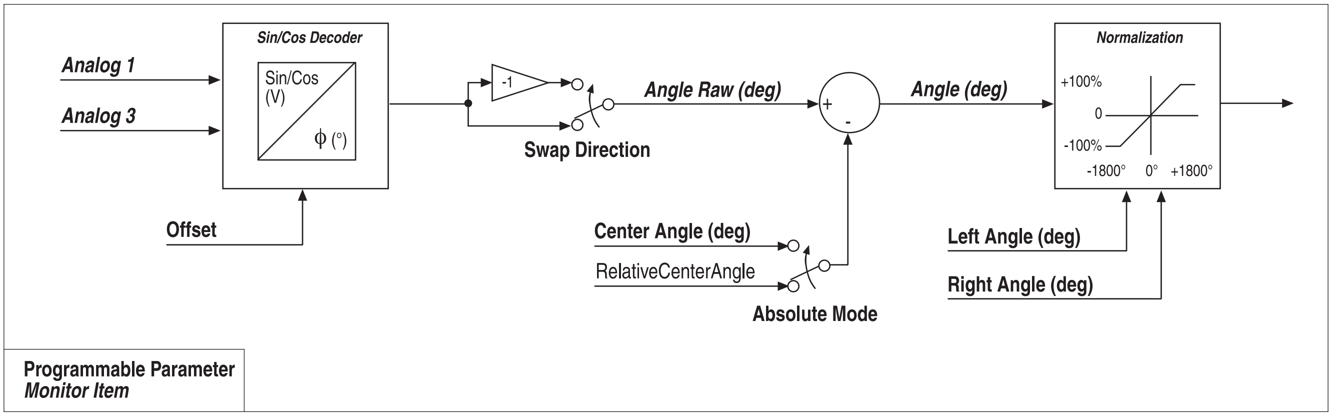


Fig. 6 *Command Input Device "2" signal flow.*

COMMAND INPUT DEVICE 3 – SAWTOOTH SENSOR				
PARAMETER	ALLOWABLE RANGE	PCF	RIS	DESCRIPTION
Left Angle (deg) *0x40CC 0x00*	-1800.0°–0.0° *-20480–0*		■	In *Absolute Position mode,* this parameter defines the position (in degrees) required to produce a steer command of full left (Steer Command = -100%). In Absolute Position mode, this parameter should be adjusted within the range -180.0° – 180.0°. In *Relative Position mode,* the parameter defines the number of turns (in degrees) required to produce a steer command from center to full left (Steer Command = -100%).
Center Angle (deg) *0x40D2 0x00*	-180.0°–180.0° *-2048–2047*		■	In *Absolute Position mode,* this parameter defines the position (in degrees) required to produce a steer command of center position (Steer Command = 0%). In Absolute Position mode, this parameter should be adjusted within the range -180.0° – 180.0°. In *Relative Position mode,* this parameter is not used.
Right Angle (deg) *0x40CD 0x00*	0.0°–1800.0° *0–20479*		■	In *Absolute Position mode,* this parameter defines the position (in degrees) required to produce a steer command of full right (Steer Command = 100%). In Absolute Position mode, this parameter should be adjusted within the range -180.0° – 180.0°. In *Relative Position mode,* the parameter defines the number of turns (in degrees) required to produce a steer command from center to full right (Steer Command = 100%).
Min Volts *0x40EC 0x00*	0–10.00 V *0–1023*		■	Set this parameter to the minimum voltage of the sawtooth waveform. Along with Max Volts and Tolerance, this parameter is used to fault-check the sawtooth signals.
Max Volts *0x40ED 0x00*	0–10.00 V *0–1023*		■	Set this parameter to the maximum voltage of the sawtooth waveform. Along with Min Volts and Tolerance, this parameter is used to fault-check the sawtooth signals.
Swap Direction *0x406A 0x00*	On/Off *On/Off*		■	Use this parameter to invert the signal to avoid physically swapping the wires to pins 8 and 19.
Absolute Mode *0x40F0 0x00*	On/Off *On/Off*		■	The sensor is in absolute position mode when this parameter is set to On. The sensor is in relative position mode when this parameter is set to Off.
Fault Min *0x400B 0x00*	0–10.00 V *0–1023*			Sets the minimum threshold for the Analog 1 and Analog 3 inputs of the sawtooth sensor. If either the Analog 1 or Analog 3 voltage falls below this threshold for 60 ms, a fault is issued.
Fault Max *0x400C 0x00*	0–10.00 V *0–1023*			Sets the maximum threshold for the Analog 1 and Analog 3 inputs of the sawtooth sensor. If either the Analog 1 or Analog 3 voltage rises above this threshold for 60 ms, a fault is issued.
Tolerance *0x40DF 0x00*	0–10.00 V *0–1023*			The Analog 1 and Analog 3 voltages of the sawtooth sensor should always be 0.5*(Max Volts - Min Volts) apart. A fault check is done by comparing the two voltages and calculating the error. If the error is greater than the Tolerance voltage for 60 ms, a fault is issued. This provides a second level of fault detection and triggers a separate Sawtooth Command Sensor fault.

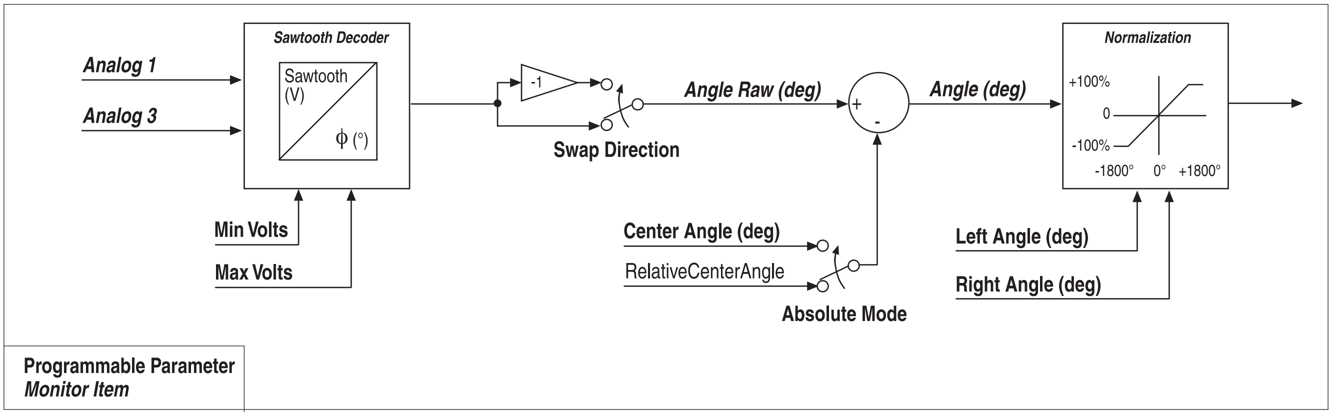


Fig. 7 *Command Input Device "3" signal flow.*

COMMAND INPUT DEVICE 4 – CAN				
PARAMETER	ALLOWABLE RANGE	PCF	RIS	DESCRIPTION
CAN Steer Center Offset *0x40E7 0x00*	-32768 – 32767 *-32768–32767*		■	Defines the position (in counts) required to produce a steer command of center position (Steer Command = 0%). This allows a service technician to recalibrate center without having to physically adjust the sensor. Note: This parameter is applicable only in absolute position mode.
CAN2 Steer Center Offset *0x40E6 0x00*	-32768 – 32767 *-32768–32767*		■	Defines the position (in counts) required to produce a steer command2 of center position (Steer Command2 = 0%). This allows a service technician to recalibrate center without having to physically adjust the sensor. Note: This parameter is applicable only in absolute position mode.
CAN Steer Left Stop to Center *0x40E8 0x00*	-32768 – 0 *-32768–0*		■	Defines the total CAN steer command sensor counts to produce a steer command from the center position (Steer Command = 0%) to the full left position (Steer Command = -100%). Left Stop to Center is always a negative number.
CAN Steer Right Stop to Center *0x40E9 0x00*	0 – 32767 *0 – 32767*		■	Defines the total CAN steer command sensor counts to produce a steer command from the center position (Steer Command = 0%) to the full right position (Steer Command = 100%). Right Stop to Center is always a positive number.
CAN Steer Swap Direction *0x40EB 0x00*	On / Off *On / Off*		■	Changes the direction (left or right) of the CAN steer command input.
CAN2 Steer Swap Direction *0x40EA 0x00*	On / Off *On / Off*		■	Changes the direction (left or right) of the CAN2 steer command input.
Absolute Mode *0x40F0 0x00*	On / Off *On / Off*		■	The sensor is in absolute position mode when this parameter is set to On.The sensor is in relative position mode when this parameter is set to Off.

☞ When setting up a steering command CAN device, for the system to be EN 13849 compliant, one PDO must be sent to the main processor and one to the supervisor. For additional security, it is recommended that the PDO sent to the supervisor be the opposite polarity and that Swap Direction be set for the supervisor only. Contact Curtis technical support for help with setting up PDOs.

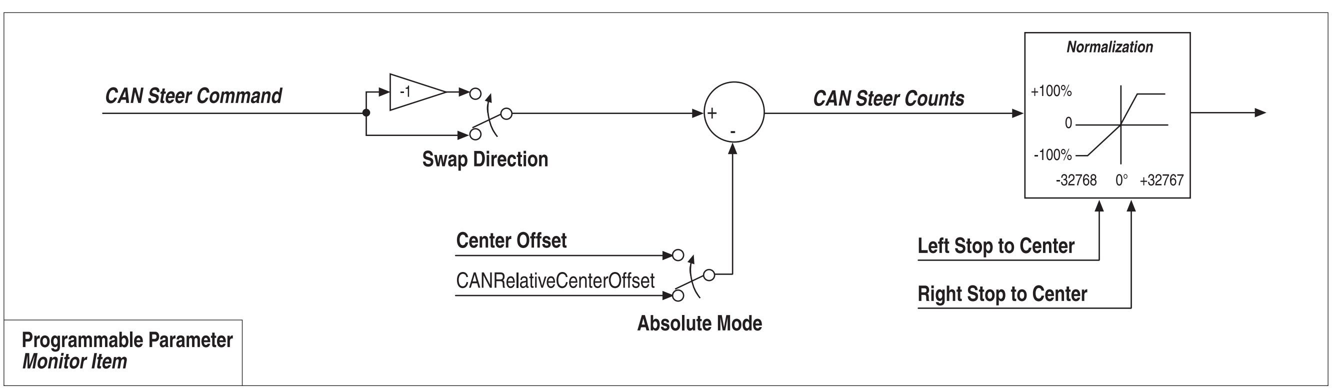


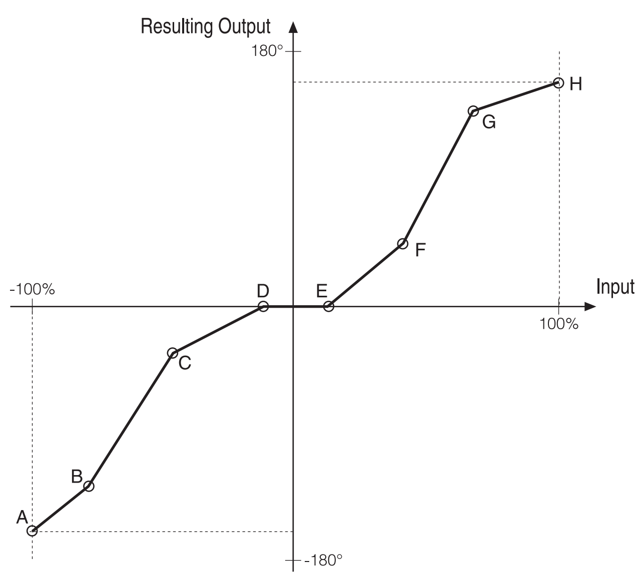
Fig. 8 *Command Input Device "4" signal flow.*

A command map is used in the input command signal flow to compensate for steering geometry differences between vehicles (steered wheel on the left side, middle, or right side).

The command map menu contains 14 parameters defining an 8-point map that modifies the steer command input. The first point (Left Stop (deg)) always defines the steer command input of -100% and the last point (Right Stop deg)) always defines the steer command input of 100%.

COMMAND MAP

PARAMETER	ALLOWABLE RANGE	PCF	RIS	DESCRIPTION
P1–P6 Input	-100.0 – 100.0 % *-32768 – 32767*			These six parameters define the steer command input (in %) to the steer command map.
			■	P1 Input = *0x401C 0x00*
			■	P2 Input = *0x401E 0x00*
			■	P3 Input = *0x4020 0x00*
			■	P4 Input = *0x4022 0x00*
			■	P5 Input = *0x4024 0x00*
			■	P6 Input = *0x4026 0x00*
Left Stop (deg),	-180.0° – 0.0° *-32768 – 0*			These eight parameters define the steer command output (in degrees) of the steer command map.
			■	Left Stop (deg) = *0x401B 0x00*
P1–P6 Output (deg),	-180.0° – 180.0° *-32768 – 32767*		■	P1 Output (deg) = *0x401D 0x00*
			■	P2 Output (deg) = *0x401F 0x00*
			■	P3 Output (deg) = *0x4021 0x00*
Right Stop (deg)	0.0° – 180.0° *0 – 32767*		■	P4 Output (deg) = *0x4023 0x00*
			■	P5 Output (deg) = *0x4025 0x00*
			■	P6 Output (deg) = *0x4027 0x00*
			■	Right Stop (deg) = *0x4028 0x00*



The steer command map is shaped by points A – H.

	X	Y
A	-100%	Left Stop (deg)
B	P1 input	P1 Output (deg)
C	P2 input	P2 Output (deg)
D	P3 input	P3 Output (deg)
E	P4 input	P4 Outpu (deg)
F	P5 input	P5 Output (deg)
G	P6 input	P6 Output (deg)
H	100%	Right Stop (deg)

The map in this example is set up to provide a deadband in the center (points D and E) and less sensitivity at the ends (between A and B, and between G and H).

Fig. 9 *Steer Command Map.*

☞ In the command map, if **Left Stop (deg) = -180°** and **Right Stop (deg) = 180°**, true 360° steering (also known as “round and round” steering) is enabled. This means the steered wheel will not have end stops and a command change from -175° to 175° will cause the steered wheel to travel 10° clockwise rather than 350° counterclockwise. 360° steering is compatible with all steering input devices except Type 0 - Analog1 and 3.

Although any map shape can be set up, **it is recommended that the map always be set so that a Steer Command of zero % equals a Steer Command (deg) of zero.** This is necessary to ensure that the auto-center functions work correctly and will aid in system troubleshooting.

FORCE FEEDBACK MENU

PARAMETER	ALLOWABLE RANGE	PCF	RIS	DESCRIPTION
Enable *0x4013 0x00*	On/Off *On/Off*		■	When set to On, enables the force feedback function via the force feedback output driver (pin 5). The force feedback function is used to make a steering input device harder to turn in proportion to the torque output of the steering motor. A force feedback coil must be connected to the force feedback output driver (pin 5).
End Stop *0x40E2 0x00*	On/Off *On/Off*			When set to On, the output will go to the Max Voltage (see below) when the steering command exceeds the end stop until the input device changes direction.
End Stop Vibe *0x40E3 0x00*	On/Off *On/Off*			When End Stop and End Stop Vibe are both set to On, the output will go to a PWM mode of Max Voltage (vibrating according to Vibe On Time and Vibe Off Time) when the steering command exceeds the end stop until the input device changes direction. Example: If Vibe On Time = 30 ms and Vibe Off Time = 70 ms, the vibration would be 10 Hz, 30% duty cycle.
Vibe On Time *0x40F2 0x00*	0–100 ms *0–100*			Sets the On time of the end stop vibration function.
Vibe Off Time *0x40F3 0x00*	0–100 ms *0–100*			Sets the Off time of the end stop vibration function.
Min Voltage *0x40BB 0x00*	0.0–80.00 V *0–800*		■	Sets the minimum voltage output of the force feedback coil at an estimated motor torque of zero. The minimum voltage corresponds to the minimum force.
Max Voltage *0x40BC 0x00*	0.0–80.00 V *0–800*		■	Sets the maximum voltage output of the force feedback coil when the absolute value of the estimated motor torque is at or above the set Max Torque. The maximum voltage corresponds to the maximum force.
Max Torque *0x40BA 0x00*	0–5000 Nm *0–5000*		■	Sets an estimated steer motor torque at with the Max Voltage is output to the force feedback coil. When setting this parameter it is useful to view the estimated steer motor torque (Monitor » Steer Motor » Motor Torque).

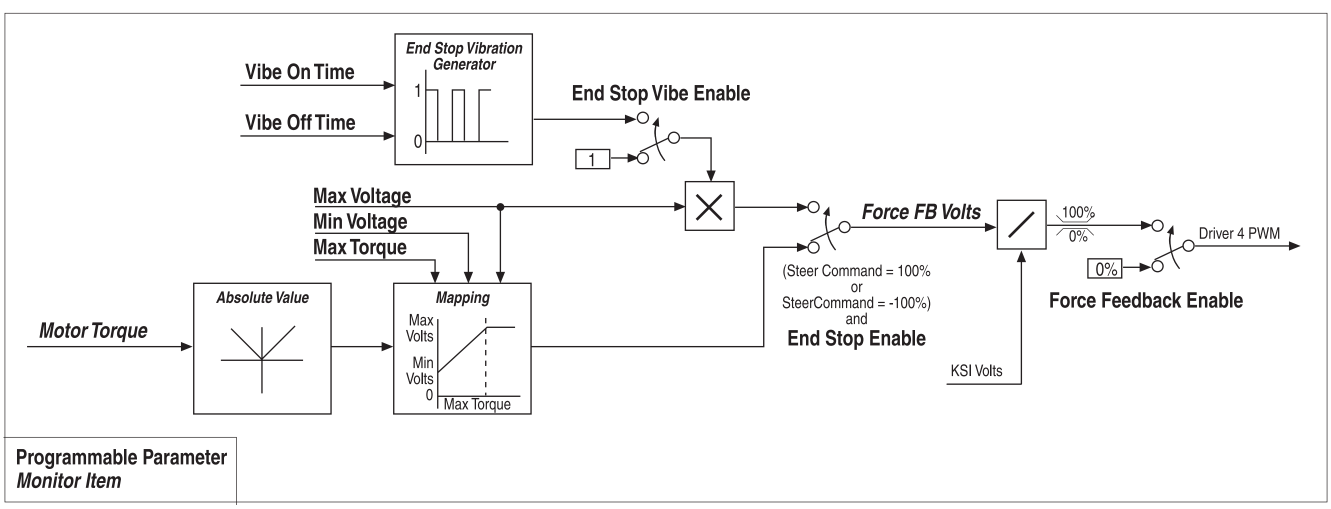


Fig. 10 *Force feedback signal flow.*

FEEDBACK DEVICE PARAMETER

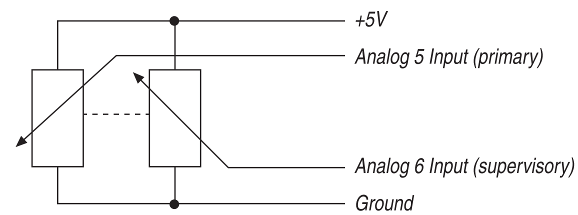
PARAMETER	ALLOWABLE RANGE	PCF	RIS	DESCRIPTION
Position Feedback Device *0x4005 0x00*	0–3 *0–3*	◎	■	These parameters define which inputs will be used to determine the primary and supervisory steer position feedback.
Supervision Feedback Device *0x40E5 0x00*	0–4 *0–4*	◎	■	

0 = Steer pot position feedback, where Analog 5 and Analog 6 inputs are connected to two potentiometers as redundant feedback pots.

When analog position feedback is used, two channels are required.

NAME	PIN	FUNCTION
Analog 5	16	Primary analog feedback
Analog 6	17	Supervisory analog feedback

It is best practice to wire the primary and supervisory input signals in an "X" configuration (0–5V and 5V–0). However, the 1222 has independent maps and will support redundant signals that move in the same direction.

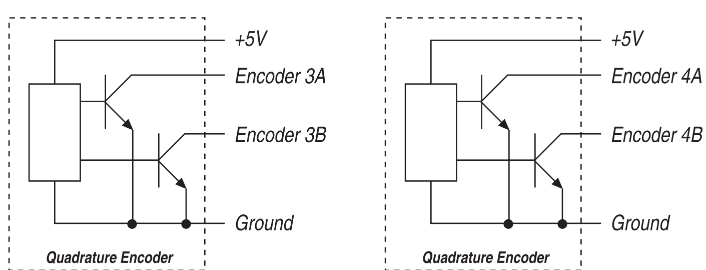


Analog Feedback (Position Feedback Device = **0**)

1 = Encoder position feedback, where Encoder 3 and Encoder 4 are connected to two quadrature encoders as redundant inputs.

When encoder position feedback is used, two quadrature encoders are required. In the table below, "+" and "-" indicate encoder phase differences ("-" being some amount of phase shift from "+"). This means that the primary and supervisory encoders do not have to have the same alignment.

NAME	PIN	FUNCTION
Encoder 3A	31	Primary quadrature encoder feedback A
Encoder 3B	32	Primary quadrature encoder feedback B
Encoder 4A	26	Supervisory quadrature encoder feedback A
Encoder 4B	27	Supervisory quadrature encoder feedback B



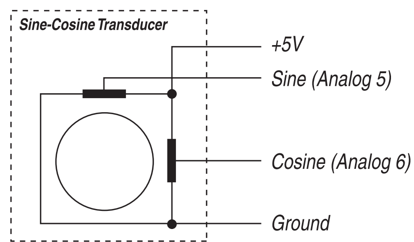
Encoder Feedback (Position Feedback Device = **1**)

FEEDBACK DEVICE PARAMETER, cont'd

2 = Sin/Cos Sensor feedback, where Analog 5 and Analog 6 inputs are connected to a sine-cosine transducer. This transducer is mounted in a location where it can sense the actual wheel position.

When this position feedback is used, sine and cosine channels are both required (and together serve as the primary and supervisory feedback devices).

NAME	PIN	FUNCTION
Analog 5	6	Sine input (Feedback Analog 5)
Analog 6	17	Cosine input (Feedback Analog 6)

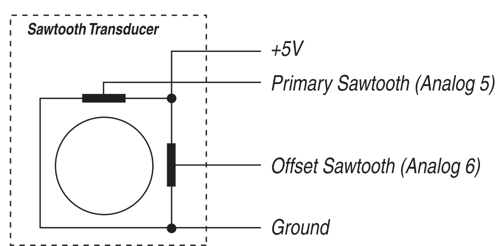


Sine-Cosine Feedback (Position Feedback Device = **2**)

3 = Sawtooth Sensor feedback, where Analog 5 and Analog 6 inputs are connected to a sawtooth transducer. This transducer is mounted in a location where it can sense the actual wheel position.

When this position feedback is used, primary sawtooth and offset sawtooth channels are both required (and together serve as the primary and supervisory feedback devices).

NAME	PIN	FUNCTION
Analog 5	6	Primary Sawtooth input (Position Analog 5)
Analog 6	17	Offset Sawtooth input (Position Analog 6)



Sawtooth Feedback (Position Feedback Device = **3**)

FEEDBACK DEVICE PARAMETER, cont'd

4 = None. No supervisory position feedback device is connected. Only a single position feedback device (the primary) is used. This option is available only for the Supervision Feedback Device parameter. **Using this setting may make the system non-compliant with EN 13849, and must be evaluated by the OEM.**

IMPORTANT

When the Supervision Feedback Device is set to 4, wheel position supervision is disabled. This option is provided to allow systems not compliant with EN 13849 to be set up without having to supply connections to the supervisory inputs from the single primary feedback device.

POSITION FEEDBACK DEVICE 0 – ANALOG5 and 6

PARAMETER	ALLOWABLE RANGE	PCF	RIS	DESCRIPTION
Analog5 Left Stop *0x407F 0x00*	0–10.00 V *0–1023*		■	Defines the Analog 5 wiper voltage when the steer position feedback is at the Left Stop (Wheel Position = Left Stop).
Analog5 Center *0x4081 0x00*	0–10.00 V *0–1023*		■	Defines the Analog 5 wiper voltage when the steer position feedback is at the center position (Wheel Position = 0°).
Analog5 Right Stop *0x4080 0x00*	0–10.00 V *0–1023*		■	Defines the Analog 5 wiper voltage when the steer position feedback is at the Right Stop (Wheel Position = Right Stop).
Analog5 Fault Min *0x40AE 0x00*	0–10.00 V *0–1023*			Sets the minimum threshold for the Analog 5 steer position feedback pot. If the Analog 5 steer position feedback pot voltage falls below this threshold for 60 ms, a fault is issued.
Analog5 Fault Max *0x40AF 0x00*	0–10.00 V *0–1023*			Sets the maximum threshold for the Analog 5 steer position feedback pot. If the Analog 5 steer position feedback pot voltage rises above this threshold for 60 ms, a fault is issued
Analog6 Left Stop *0x40A3 0x00*	0–10.00 V *0–1023*		■	Defines the Analog 6 wiper voltage when the steer position feedback is at the Left Stop (Wheel Position = Left Stop).
Analog6 Center *0x4082 0x00*	0–10.00 V *0–1023*		■	Defines the Analog 6 wiper voltage when the steer position feedback is at the center position (Wheel Position = 0°).
Analog6 Right Stop *0x40A4 0x00*	0–10.00 V *0–1023*		■	Defines the Analog 6 wiper voltage when the steer position feedback is at the Right Stop (Wheel Position = Right Stop).
Analog6 Fault Min *0x4011 0x00*	0–10.00 V *0–1023*			Sets the minimum threshold for the Analog 6 steer position feedback pot. If the Analog 6 steer position feedback pot voltage falls below this threshold for 60 ms, a fault is issued.
Analog6 Fault Max *0x4012 0x00*	0–10.00 V *0–1023*			Sets the maximum threshold for the Analog 6 steer position feedback pot. If the Analog 6 steer position feedback pot voltage rises above this threshold for 60 ms, a fault is issued.

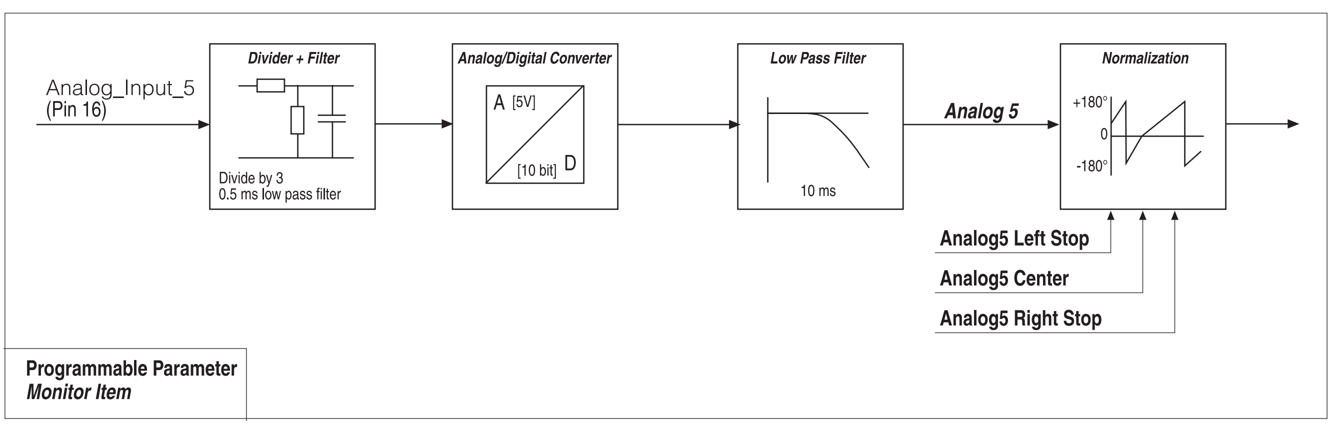
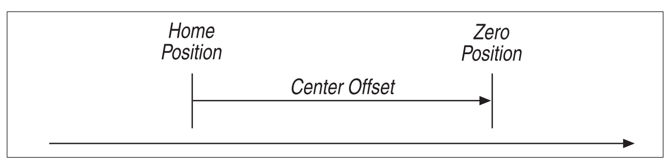


Fig. 10 *Position Feedback Device "0" signal flow (Analog 5 shown; Analog 6 is similar).*

POSITION FEEDBACK DEVICE 1 – ENCODER3 and 4

PARAMETER	ALLOWABLE RANGE	PCF	RIS	DESCRIPTION
Encoder3 Counts/Degree *0x40C7 0x00*	10.0–1000.0 *100–10000*		■	Defines the number of Encoder 3 counts (pulses × 4) per degree of wheel position. Encoder3 Counts/Degree is always a positive number.
Encoder4 Counts/Degree *0x40C8 0x00*	0.5–1000.0 *5–10000*		■	Defines the number of Encoder 4 counts (pulses × 4) per degree of wheel position. Encoder4 Counts/Degree is always a positive number. Note that a lower range is provided for Encoder4 Counts/Degree than for Encoder3 Counts/Degree. This allows the Encoder 4 sensor to use the steering gear rather than being a sensor pickup on the motor.
Swap Encoder3 Direction *0x4014 0x00*	On/Off *On/Off*		■	Changes the direction of the Encoder 3 steer position feedback.
Swap Encoder4 Direction *0x4068 0x00*	On/Off *On/Off*		■	Changes the direction of the Encoder 4 steer position feedback.
Auto Center Type *0x407D 0x00*	0–1 *0–1*			Defines which event will trigger the controller to center the steered wheel. 0 = Auto Center after homing. 1 = Auto Center after homing and every interlock.
Center Offset (deg) *0x4018 0x00*	-180.0°–180.0° *-32768–32767*			The Center Offset is the difference between the zero position (center) for the application and the home reference position (found during homing). During homing, the home position is found and once the homing is completed the zero position is offset from the home position by adding the Center Offset to the home position. All subsequent absolute moves shall be taken relative to this new zero position, including Auto Center. If the home switch is at the same position as center, set Center Offset to zero.



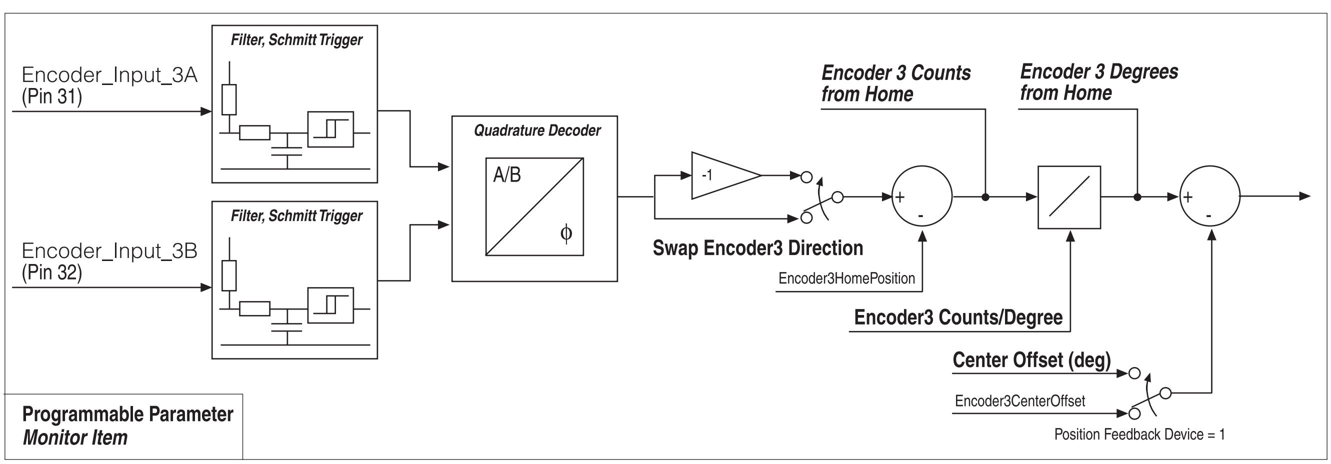
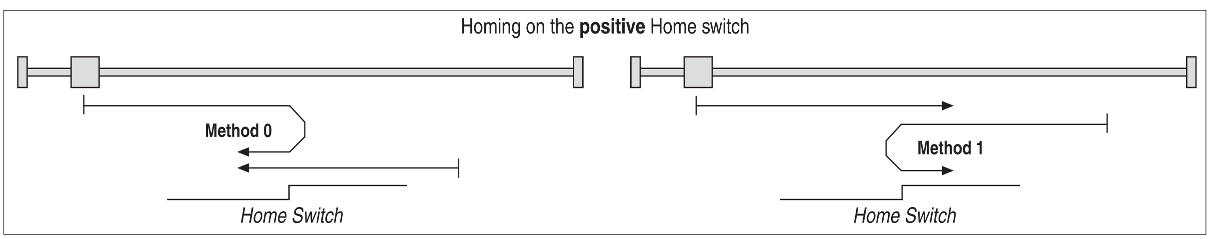


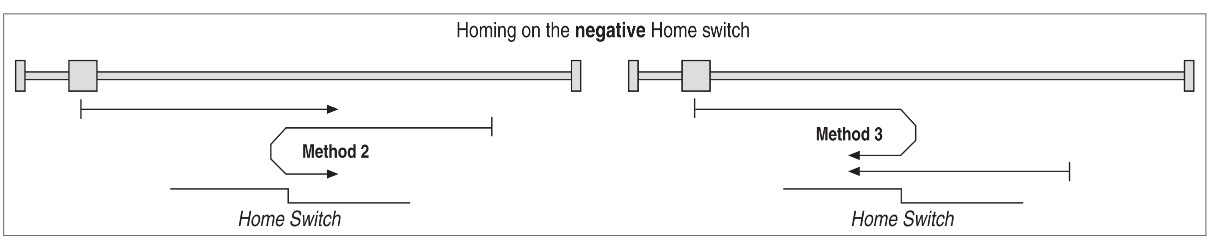
Fig. 11 *Position Feedback Device "1" signal flow (Encoder 3 shown; Encoder 4 is similar).*

POSITION FEEDBACK DEVICE 1 – ENCODER3 and 4: HOMING

PARAMETER	ALLOWABLE RANGE	PCF	RIS	DESCRIPTION
Input Type *0x407E 0x00*	0–2 *0–2*			Defines which inputs will be used to determine Home position. 0 = Single NO switch (switch 2 input). 1 = Single switch with NO and NC contacts (same as two switches with crossed polarity: switch 2 is NO and switch 4 is NC). 2 = Two switches with the same NO polarity (switch 2 is NO and switch 4 is NO).
Home on Interlock *0x4075 0x00*	0–1 *0–1*			Defines when the homing function is activated. 0 = Home when keyswitch is turned On. 1 = Homing on first Interlock = On. If the interlock signal is turned off during the homing, the homing procedure is paused (PWM off) and will resume when the interlock becomes active again.
Homing Direction Method *0x407C 0x00*	0–3 *0–3*			Defines which method is used to find Home position. The method determines the initial direction the homing function takes and on which edge the homing function is complete. 0 = Left of positive Home switch. 1 = Right of positive Home switch. 2 = Right of negative Home switch. 3 = Left of negative Home switch. Methods 0 and 1 use a Home switch that is On if the wheel is to the right of it and Off if the wheel is to the left of it. At the start of homing the wheel will move to the left if the Home switch is On and to the right if it is Off. The home position is just to the left of the switch transition in method 0 and just to the right of the switch transition in method 1.



Methods 2 and 3 use a Home switch that is On if the wheel is to the left of it and Off if the wheel is to the right of it. At the start of homing the wheel will move to the right if the Home switch is On and to the left if it is Off. The home position is just to the right of the switch transition in method 2 and just to the left of the switch transition in method 3.



POSITION FEEDBACK DEVICE 1 – ENCODER3 and 4: HOMING, cont'd				
PARAMETER	ALLOWABLE RANGE	PCF	RIS	DESCRIPTION
Homing Cam Angle (deg) *0x40F5 0x00*	5.0° – 180.0° *910 – 32767*			For 360° steering this parameter should be set to the angle of the homing cam. This setting is necessary because the 360° function has the homing switch triggered in two different wheel positions.
Homing Speed *0x407B 0x00*	0 – 100.0 % *0 – 32767*			Defines the speed of the steering motor during the homing function, as a percentage of the steer motor Max Speed. The lower the set value of Homing Speed, the more accurate the homing will be; it is therefore recommended that Homing Speed be set as low as tolerable. Although higher values will allow the homing function to be completed more quickly, the results will be less consistent than with lower values.
Homing Timeout *0x40F4 0x00*	0.1 – 5.0 s *1 – 50*			Defines the allowable time for homing to find home. A Home Position Not Found fault is issued if the homing goes longer than the set Homing Timeout without finding home.

POSITION FEEDBACK DEVICE 2 – SIN/COS SENSOR

PARAMETER	ALLOWABLE RANGE	PCF	RIS	DESCRIPTION
Offset *0x40D1 0x00*	0–10.00 V *0–1023*		■	Set this parameter to the midpoint voltage of the sine wave output of the sin/cos sensor. This value is usually available in the sensor specifications, and is typically half the voltage supply to the sensor.
Amplitude *0x40E0 0x00*	0–10.00 V *0–1023*		■	Set this parameter to one half of the expected peak-to-peak voltage for the sin/cos sensor input signals.
Swap Direction *0x4015 0x00*	On/Off *On/Off*		■	Use this parameter to invert the signal to avoid physically swapping the wires to pins 16 and 17.
Center Position (deg) *0x40D3 0x0*	-180.0°–180.0° *-32768–32767*		■	Defines the sin/cos position (in degrees) that corresponds to a steer position feedback at the center (straight) position (Wheel Position = 0%). This setting allows the service technician to re-calibrate the center (straight) without having to physically adjust the sin/cos sensor.
Fault Min *0x4011 0x00*	0–10.00 V *0–1023*			Sets the minimum threshold for the Analog 5 and Analog 6 inputs of the sin/cos sensor. If either the Analog 5 or Analog 6 voltage falls below this threshold for 60 ms, a fault is issued.
Fault Max *0x4012 0x00*	0–10.00 V *0–1023*			Sets the maximum threshold for the Analog 5 and Analog 6 inputs of the sin/cos sensor. If either the Analog 5 or Analog 6 voltage rises above this threshold for 60 ms, a fault is issued.
Tolerance *0x40E1 0x00*	0–10.00 V *0–1023*			The sine and cosine signals are used together to calculate the absolute position, i.e. arctan (Analog 5 / Analog 6). This calculated position is then used to back-calculate the expected sine and cosine inputs, based on the Amplitude parameter. If the difference between these expected inputs and the actual inputs is greater than the set Tolerance voltage for 60 ms, a fault is issued. This provides a second level of fault detection and triggers a separate SinCos feedback fault.

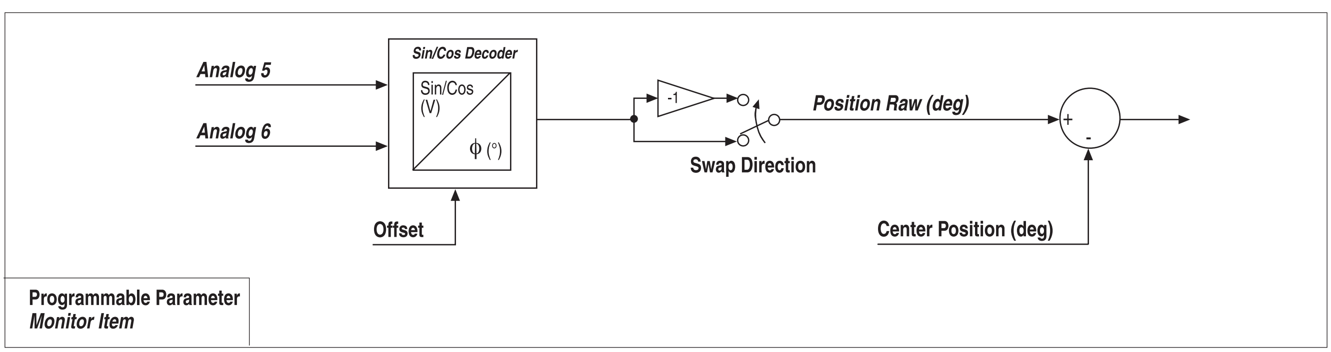


Fig. 12 *Position Feedback Input Device "2" signal flow.*

POSITION FEEDBACK DEVICE 3 – SAWTOOTH SENSOR				
PARAMETER	ALLOWABLE RANGE	PCF	RIS	DESCRIPTION
Center Position (deg) *0x40D3 0x00*	-180.0°–180.0° *-32768–32767*		■	Defines the position (in degrees) that corresponds to a steer position feedback at the center (straight) position (Wheel Position = 0%). This setting allows the service technician to re-calibrate the center (straight) without having to physically adjust the sawtooth sensor.
Min Volts	0–10.00 V		■	Along with Max Volts and Tolerance, this parameter is used to fault-check the sawtooth signals.
Max Volts *0x40EF 0x00*	0–10.00 V *0–1023*		■	Set this parameter to the maximum voltage of the sawtooth waveform. Along with Min Volts and Tolerance, this parameter is used to fault-check the sawtooth signals.
Swap Direction *0x4015 0x00*	On/Off *On/Off*		■	Inverts the signal to prevent having to physically swap the wires to pins 16 and 17.
Fault Min *0x4011 0x00*	0–10.00 V *0–1023*			Sets the minimum threshold for the Analog 5 and Analog 6 inputs of the sawtooth sensor. If either the Analog 5 or Analog 6 voltage falls below this threshold for 60 ms, a fault is issued.
Fault Max *0x4012 0x00*	0–10.00 V *0–1023*			Sets the maximum threshold for the Analog 5 and Analog 6 inputs of the sawtooth sensor. If either the Analog 5 or Analog 6 voltage rises above this threshold for 60 ms, a fault is issued.
Tolerance *0x40E1 0x00*	0–10.00 V *0–1023*			The Analog 5 and Analog 6 voltages of the sawtooth sensor should always be 0.5*(Max Volts - Min Volts) apart. A fault check is done by comparing the two voltages and calculating the error. If the error is greater than the Tolerance voltage for 60 ms, a fault is issued. This provides a second level of fault detection and triggers a separate Sawtooth Command fault.

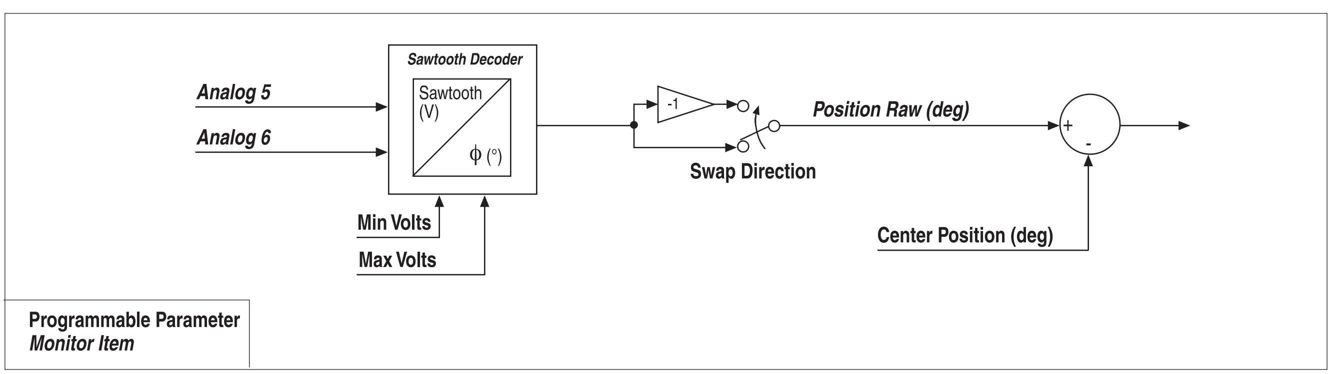


Fig. 13 *Position Feedback Input Device "3" signal flow.*

VEHICLE CONFIGURATION MENU

PARAMETER	ALLOWABLE RANGE	PCF	RIS	DESCRIPTION
Nominal Voltage *0x405E 0x00*	24.0–48.0 V *307–614*		■	This parameter must be set to the vehicle's nominal battery pack voltage.
Interlock Type *0x4001 0x00*	0–3 *0–3*	◎		Defines which inputs will be used to determine an interlock: 0 = KSI (interlock turns on with keyswitch). 1 = Single NO switch (Switch 1 Input). 2 = Single switch with NO and NC contacts (same as two switches with crossed polarity, such as Switch 1 is NO and Switch 3 is NC). 3 = CAN bus PDO message from the traction controller.
Fault Steering Timeout *0x40DD 0x00*	0.0–8.0 s *0–80*			This parameter applies only when a steer fault action of either "Warning then Shutdown" or "Hold then Shutdown" is triggered (see Table 6, troubleshooting chart). When one of these faults is detected, the Fault Steering Timeout sets the maximum time allowed for the traction controller to bring the vehicle to a stop. Typically this parameter is set to zero. When set to zero, there is no "warning" and there is no "hold" before the shutdown. Setting this parameter to a value greater than zero can allow time for the traction system to start interlock braking to come to a smoother, gentler stop before the fault output forces the traction contactor to open and EM brake to release. If the vehicle does not stop within the set timeout, at the end of the timeout the fault output will force the traction contactor to open and the EM brake to release, thus causing the vehicle to stop. If the vehicle does stop within the set timeout, the fault output will open the traction contactor and release the EM brake immediately when the vehicle stops, without waiting for the expiration of the timeout. Note: Setting this parameter to a value greater than zero requires the traction controller's software (VCL and parameters) to permit interlock braking. Please review your traction software before setting this parameter to a non-zero value.

VEHICLE CONFIGURATION: STEER CONTACTOR				
PARAMETER	ALLOWABLE RANGE	PCF	RIS	DESCRIPTION
Contactor Control Type *0x4095 0x00*	0–2 *0–2*		■	This parameter determines how the steer contactor is controlled. 0 = No steer contactor (Contactor Driver = Off). This setting is used when the 1222 B+ stud is wired to a battery with no steer contactor. This setting is not recommended and may not meet the required vehicle safety standards. 1 = Steer contactor controlled by contactor driver. This is the recommended setting, and is used when the 1222 B+ stud is wired to a steer contactor. Type 1 requires programming the Pull-in Voltage, Holding Voltage, Open Delay, and Checks Enable parameters. 2 = Steer contactor controlled by traction controller (Cont. Driver = Off). This setting is used in systems that have only one main contactor to supply both the traction controller and the 1222. In these systems, the traction controller must tell the 1222 that the contactor is open or closed in the CAN PD01 message.
Pull-in Voltage *0x4061 0x00*	0–80.0 V *0–800*			The contactor pull-in voltage parameter allows a high initial voltage when the contactor driver first turns on, to ensure contactor closure. After 1 second, the pull-in voltage drops to the steer contactor holding voltage. Note: The pull-in voltage is always battery voltage compensated.
Holding Voltage *0x4062 0x00*	0–80.0 V *0–800*		■	The 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 holding voltage is always battery voltage compensated.
Open Delay *0x4060 0x00*	0–40 s *0–40*			The open delay can be set to allow the steer contactor to remain closed for a period of time (the open delay) after the interlock is turned off. The delay is useful for preventing unnecessary cycling of the contactor and for maintaining power to auxiliary functions that may still be used for a short time after the interlock has turned off.
Checks Enable *0x4067 0x00*	On/Off *On/Off*			When programmed On, the controller performs ongoing checks to ensure that the steer contactor has closed properly each time it was commanded to do so, and that it has not welded closed. These checks (Contactor Welded and Contactor Did Not Close) are not performed if the parameter is programmed Off. The contactor driver, however, is always protected from short circuits.
Sequencing Delay *0x4063 0x00*	0–5.0 s *0–50*			The sequencing delay feature allows the interlock switch to be cycled within a set time (the sequencing delay), thus preventing inadvertent deactivation of the steering control. This feature is useful in applications where the interlock switch may bounce or be momentarily cycled during operation.

VEHICLE CONFIGURATION: TRACTION SPEED INPUT

PARAMETER	ALLOWABLE RANGE	PCF	RIS	DESCRIPTION
Input Type *0x40B5 0x00*	0–2 *0–2*			This parameter defines how the traction speed is determined by the 1222. 0 = Traction speed input disabled. 1 = Encoder1 input (not allowed if Command Input Device = 1) 2 = CAN bus PDO message from the traction controller.
Encoder1 Steps *0x4007 0x00*	32–1024 *32–1024*	■		Sets the number of traction motor encoder pulses per revolution. This must be set to match the traction motor encoder; see info on the traction motor nameplate. This parameter is valid only for Traction Speed Input Type 1.
Swap Encoder1 Direction *0x406C 0x00*	On/Off *On/Off*	■		Changes the traction motor encoder's effective direction of rotation. The traction encoder provides data used to determine traction speed. This parameter must be set such that when the traction motor is turning forward, the traction speed is positive. This parameter is valid only for Traction Speed Input Type 1.
Interlock Enabled Speed *0x40B7 0x00*	0–500 rpm *0–500*			This parameter sets the traction speed above which interlock will automatically be enabled, thus enabling steering. A setting of zero disables this function.

SUPERVISION MENU

PARAMETER	ALLOWABLE RANGE	PCF	RIS	DESCRIPTION
5V Current Min *0x4096 0x00*	0–100 mA *0–1000*			Defines the lower threshold of the output current of the +5V supply (pins 21 and 34). At or below this threshold, a fault is issued.
5V Current Max *0x4097 0x00*	0–100 mA *0–1000*			Defines the upper threshold of the output current of the +5V supply (pins 21 and 34). At or above this threshold, a fault is issued.
Steer Command Tolerance (deg) *0x40AA 0x00*	2.0°–90.0° *364–16380*			Defines the maximum difference allowed between the two steer command inputs (Steer Command and Steer Command 2). If the programmed tolerance is exceeded, a fault is issued. The difference between the two steer command inputs can be seen in the monitor variable Steer Command Error. A setting of 90.0° turns off this fault check.
Wheel Position Tolerance (deg) *0x40AB 0x00*	2.0°–90.0° *364–16380*			Defines the maximum difference allowed between the two position feedback outputs (Wheel Position and Wheel Position 2). If the programmed tolerance is exceeded, a fault is issued. The difference between the two wheel position outputs can be seen in the monitor variable Wheel Position Error. A setting of 90.0° turns off this fault check.
Encoder Position Tolerance (deg) *0x40DC 0x00*	2.0°–90.0° *364–16380*			Defines the maximum difference allowed between the Wheel Position and the Encoder 3 Position. This parameter should be used only for configurations where the programmed Position Feedback Device = 0 (Analog 5 and 6) or = 2 (Sin/Cos Sensor) or = 3 (Sawtooth Sensor). If Position Feedback Device = 1 (Encoders 3 and 4) the Wheel Position and Encoder 3 Position are the same. Therefore this check should not be used when Position Feedback Device = 1. If the programmed tolerance is exceeded, a fault is issued. The difference between the Wheel Position and the Encoder 3 Position can be seen in the monitor variable Encoder Position Error. A setting of 90.0° turns off this fault check. For 360° steering, disable the fault check (set Encoder Position Tolerance (deg) = 90.0°). This is necessary because if the wheel were turned in the same direction multiple rotations, Wheel Position would eventually drift away from the Encoder 3 Position due to the small inaccuracy in the Encoder Counts Per Degree which would build over multiple rotations.
Home Reference Tolerance (deg) *0x40B6 0x00*	2.0°–90.0° *364–16380*			Defines the maximum difference allowed between the two home reference inputs (Home Reference and Home Reference 2). If the programmed tolerance is exceeded, a fault is issued. The difference between the two home reference inputs can be seen in the monitor variable Home Reference Error. A setting of 90.0° turns off this fault check. .
Stall Steering Speed *0x40DB 0x00*	0–65535 rpm *0–65535*			Defines the speed below which the steer motor will be considered stalled if it remains below this speed for the length of time defined by the Stall Timeout parameter. When this condition is detected, a fault is issued (code 36, Motor Stalled). A setting of Stall Speed = 0 turns off this fault check.

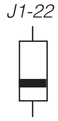
SUPERVISION MENU, cont'd				
PARAMETER	ALLOWABLE RANGE	PCF	RIS	DESCRIPTION
Stall Timeout *0x40DA 0x00*	0–2000 ms *0–2000*			Defines the timeout time for the motor stalled fault check.

SUPERVISION: FOLLOWING ERROR				
PARAMETER	ALLOWABLE RANGE	PCF	RIS	DESCRIPTION
Error Tolerance (deg) *0x40BE 0x00*	1.0°–90.0° *182–16380*			Defines the maximum difference allowed between Steering Command (deg) and Wheel Position (deg). The difference can be seen in the monitor variable Following Error (deg). If the programmed Error Tolerance (deg) is exceeded for the programmed Error Time while the wheel speed is less than the programmed Speed Tolerance (deg/s), a Following Error fault is issued. A setting of Error Tolerance (deg) = 90.0° turns off this fault check.
Speed Tolerance (deg/s) *0x40C0 0x00*	0.0–180.0 *0–32767*			This parameter defines the minimum allowed speed for the steered wheel. This is a second condition for the Following Error check. By checking the velocity of the steered wheel (first derivative of Wheel Position) this check ensures that the steered wheel is moving in the correct direction at or above the minimum allowed speed. The wheel speed can be seen in the monitor variable Wheel Speed (deg/s). A setting of Speed Tolerance (deg/s) = 0.0 removes the influence of steered wheel speed from the Following Error check. Setting Speed Tolerance (deg/s) to a value greater than zero (thus enabling the influence of wheel speed in the Following Error check) should allow the Error Tolerance (deg) and Error Time parameters to be set lower without false fault trips. Setting Error Time lower allows the Following Error fault to be detected more quickly.
Error Time *0x40BF 0x00*	0.1–10.0 s *1–100*			Defines how long Error Tolerance (deg) can be exceeded if the steered wheel is not moving in the right direction with a Wheel Speed (deg/s) equal to or greater than the Speed Tolerance (deg/s). Since the first derivative (Wheel Speed (deg/s)) is inherently noisy, the timer is implemented as a count-up/count-down timer (Following Error Time Accumulated) where the fault time is set by the parameter Error Time. Example: If Error Tolerance (deg) = 5 and Speed Tolerance (deg/s) = 10, the Following Error Time Accumulated will count *up* when the Error Tolerance is >5 **and** the Wheel Speed (deg/s) <10. Following Error Time Accumulated will count *down* if either the Error Tolerance ≤5 **or** the Wheel Speed (deg/s) ≥10. Error Time must be set long enough for the steered wheel to reverse direction and reach the minimum speed (Speed Tolerance (deg/s)) under the worst case conditions.

MOTOR MENU

PARAMETER	ALLOWABLE RANGE	PCF	RIS	DESCRIPTION
Max Speed *0x401A 0x00*	0–8000 rpm *0–8000*		■	Defines the maximum allowed steer motor rpm.
Max Current *0x4126 0x00*	5–100 % *1638–32767*		■	Defines the maximum rms current the controller will supply to the steer motor during steering operation, as a percentage of the controller's full rated current. Reducing this value will reduce the maximum steer torque.
Encoder3 Steps *0x40D6 0x00*	32–1024 *32–1024*		■	Sets the number of of steer motor encoder pulses per revolution. This must be set to match the steer motor encoder; see specifications on the steer motor nameplate. Adjusting this parameter can be hazardous; setting it improperly may cause vehicle malfunction, including uncommanded steer motor drive.
Swap Encoder3 Direction *0x4014 0x00*	On/Off *On/Off*		■	Changes the steer motor encoder's effective direction of rotation. The steer encoder provides data used to determine steer speed.

MOTOR: TEMPERATURE CONTROL

PARAMETER	ALLOWABLE RANGE	PCF	RIS	DESCRIPTION
Sensor Enable *0x403C 0x00*	On/Off *On/Off*			The Sensor Enable parameter can be used only if a temperature sensor has been properly configured in the steering motor. When Sensor Enable is programmed On, the motor temperature cutback feature and the motor temperature compensation feature are enabled. The motor temperature cutback feature will reduce traction speed between the Temperature Hot and Temperature Max setpoints, but it will not inhibit the 1222 steering. The motor temperature compensation feature will adapt the motor control algorithms to varying motor temperatures, for improved efficiency and more consistent performance.
Sensor Type *0x4085 0x00*	0–5 *0–5*			The following sensor types are predefined in the software. Type 0 User-defined sensor Type 1 KTY83–122 Type 2 2 × Type 1 in series Type 3 KTY84-130 or KTY84-150 Type 4 2 × Type 3 in series Type 5 PT1000 Custom sensor types can be set up if none of the predefined types is appropriate for your application. Sensor Type 0 is for a user-defined motor temperature sensor; see menu on the next page for the user-defined parameters that must be configured for Type 0 sensors. CAUTION Note: The industry standard KTY temperature sensors are silicon temperature sensors with a polarity band; **the polarity band of a KTY sensor must be connected to I/O ground** (pin 7). 
Sensor Temp Offset *0x4064 0x00*	-20.0–20.0 °C *-200–200*			Often the sensor is placed in the motor at a location with a known offset to the critical temperature; the offset can be corrected with this parameter. The parameter can also be used to correct a known offset in the sensor itself.
Temperature Hot *0x40AC 0x00*	0–250.0 °C *0–2500*			Defines the temperature at which traction speed cutback begins. The cutback is linear between the Temperature Hot and Temperature Max setpoints.
Temperature Max *0x40AD 0x00*	0–250.0 °C *0–2500*			Defines the temperature at which traction speed is cut back to the speed defined by the Sensor Fault Traction Cutback parameter.
Sensor Fault Traction Cutback *0x40BD 0x00*	0–100 % *0–100*			In the event of a sensor fault, traction speed is cut back. This parameter defines the traction speed after a sensor fault. A value of 100% would result in no cutback of traction speed. A value of 0% would result in a complete cutback of traction speed to 0 rpm.

MOTOR: USER-DEFINED TEMPERATURE SENSOR

This menu contains 14 parameters (7 sensor-temperature pairs) which define a 7-point map that is used to map the voltage input to a sensor temperature profile.

This menu is used only when Motor Temperature Sensor Type = 0 (User-defined).

It is best to select one point near the Temperature Hot value so the controller will accurately regulate motor temperature.

PARAMETER	ALLOWABLE RANGE	PCF	RIS	DESCRIPTION
Sensor 1–7 *see list*	0.0–10.0 V *0–1023*			The seven Sensor parameters define inputs to the user-defined temperature sensor map. The units are in volts. Sensor 1 = *0x4086 0x00* Sensor 2 = *0x4088 0x00* Sensor 3 = *0x408A 0x00* Sensor 4 = *0x408C 0x00* Sensor 5 = *0x408E 0x00* Sensor 6 = *0x4090 0x00* Sensor 7 = *0x4092 0x00*
Temp 1–7 *see list*	-60.0–250.0 °C *-600–2500*			The seven Temp parameters define outputs to the user-defined temperature sensor map. The units are in °C. Temp 1 = *0x4087 0x00* Temp 2 = *0x4089 0x00* Temp 3 = *0x408B 0x00* Temp 4 = *0x408D 0x00* Temp 5 = *0x408F 0x00* Temp 6 = *0x4091 0x00* Temp 7 = *0x4093 0x00*

CANopen MENU

PARAMETER	ALLOWABLE RANGE	PCF	RIS	DESCRIPTION
CAN Required *0x40F6 0x00*	On/Off *On/Off*	◎	■	Set CAN Required = On for systems where the 1222 steering controller is connected to the CAN bus. Set CAN Required = Off for systems where the 1222 steering controller is stand-along (not connected to the CAN bus). When programmed On, a fault check is made to verify that the steering controller is set (via the CAN bus) to CAN NMT State = Operational within 80 ms of the interlock being applied.
Node ID *0x5001 0x01*	1–127 *1–127*	◎	■	Sets the Node ID of the CANopen Slave system. This is the first of the two node IDs that need to be set up for the 1222 controller.
Node ID Supervisor *0x40B2 0x00*	1–127 *1–127*	◎	■	Sets the supervisor Node ID of the CANopen Slave system. This is the second of the two node IDs that need to be set up for the 1222 controller. The Node ID Supervisor should always be different from the Node ID.
Baud Rate *0x5001 0x02*	0–4 *0–4*	◎	■	Sets the CAN baud rate for the CANopen Slave system: 0 = 125 Kbps 1 = 250 Kbps 2 = 500 Kbps 3 = 800 Kbps 4 = 1 Mbps
Producer Heartbeat Rate *0x1017 0x00*	16–200 ms *16–200*		■	Sets the rate at which the CAN heartbeat messages are sent from the 1222 controller.
PDO1 Timeout Time *0x40CB 0x00*	40–120 ms *40–120*		■	Sets the PDO1 timeout period for receiving the PDO1 CAN message. The steering controller will set a fault if this timer expires between receiving PDO1 messages.

MOTOR CONTROL TUNING MENU

PARAMETER	ALLOWABLE RANGE	PCF	RIS	DESCRIPTION
Position Kp *0x4047 0x00*	0.1–100.0 % *1–32767*			Determines how aggressively the steer controller attempts to match the steer position to the commanded steer position. Larger values provide tighter control. If the gain is set too high, you may experience oscillations as the controller tries to control position. If it is set too low, the motor may behave sluggishly and be difficult to control. See Figure 14. Position Kp can be fine-tuned using the Steering Sensitivity parameters (page 54).
Velocity Kp *0x4065 0x00*	0–100.0 % *0–32767*			Determines how aggressively the steer controller attempts to match the steer velocity to the determined velocity to reach the desired position. Larger values provide tighter control. If the gain is set too high, you may experience oscillations as the controller tries to control velocity. If it is set too low, the motor may behave sluggishly and be difficult to control. See Figure 15.
Velocity Ki *0x4066 0x00*	0–100.0 % *0–32767*			The integral term (Ki) forces zero steady state error in the determined velocity, so the motor will run at exactly the determined velocity. Larger values provide tighter control. If the gain is set too high, you may experience oscillations as the controller tries to control velocity. If it is set too low, the motor may take a long time to approach the exact commanded velocity. See Figure 15.

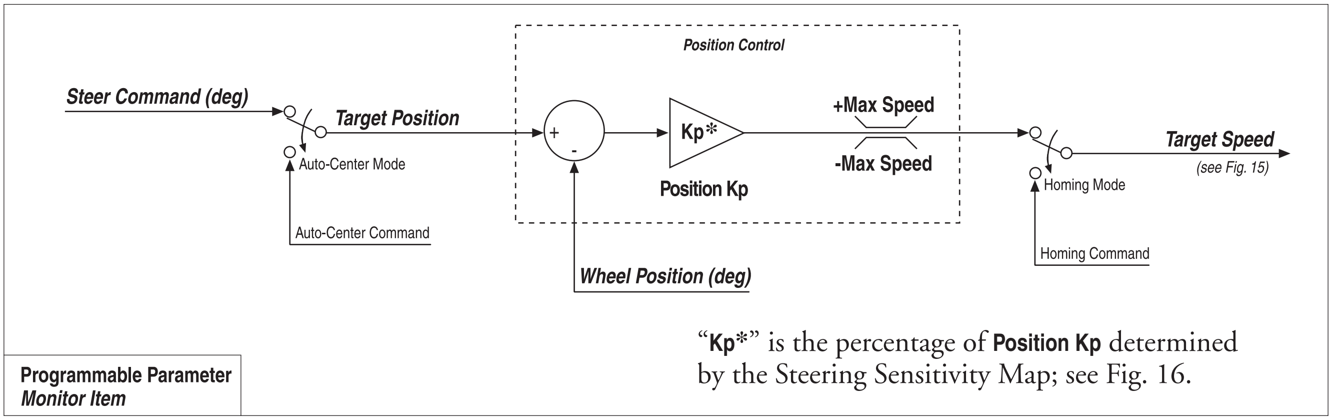


Fig. 14 *Position Control signal flow.*

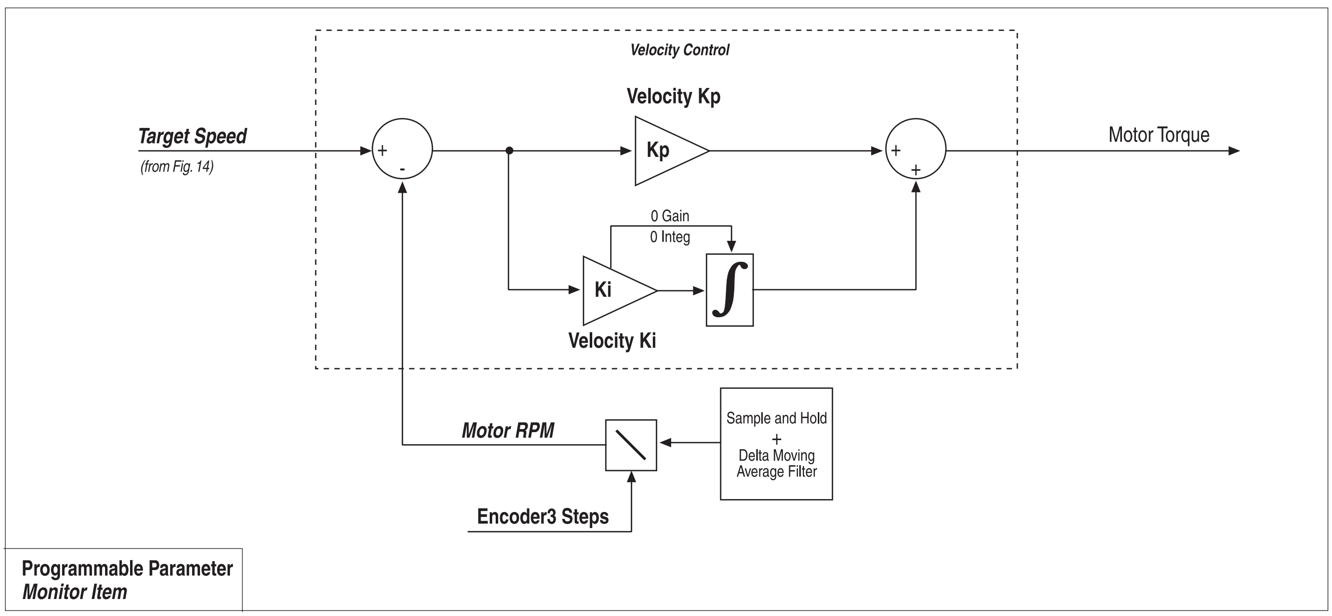
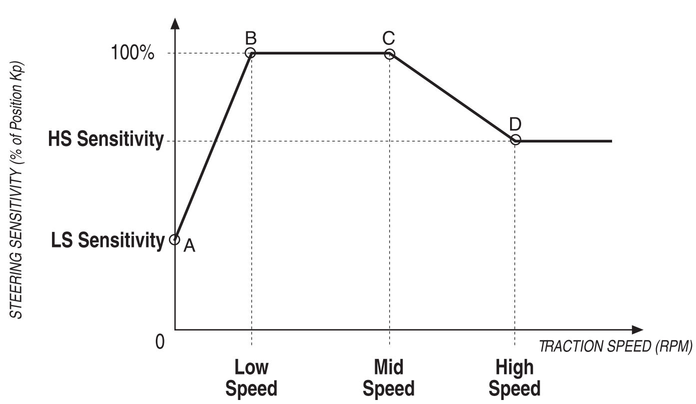


Fig. 15 *Velocity Control signal flow.*

MOTOR CONTROL TUNING: STEERING SENSITIVITY				
PARAMETER	ALLOWABLE RANGE	PCF	RIS	DESCRIPTION
LS Sensitivity *0x4132 0x00*	20–100 % *6553–32767*			Defines the steering sensitivity at very low speeds (i.e., at near zero traction rpm), as a percentage of the programmed Position Kp. Sensitivity is typically reduced at low speeds to prevent excessive hunting for the commanded position.
HS Sensitivity *0x4133 0x00*	20–100 % *6553–32767*			Defines the steering sensitivity at high speeds, as a percentage of the programmed Position Kp. Sensitivity is typically reduced at high speeds to make the vehicle easier to drive.
Low Speed *0x4134 0x00*	0–32767 rpm *0–32767*		■	Defines the speed at which 100% sensitivity will be applied, as the vehicle accelerates.
Mid Speed *0x4135 0x00*	0–32767 rpm *0–32767*		■	Defines the speed at which 100% sensitivity will start to decrease to the programmed HS Sensitivity value as the vehicle accelerates.
High Speed *0x4136 0x00*	0–32767 rpm *0–32767*		■	Sets the speed at and above which the programmed HS Sensitivity value will be applied.



The steering sensitivity map is shaped by the settings of the five parameters in the Steering Sensitivity menu, with the two sensitivity parameters along the Y axis and the three speed parameters along the X axis.

	X (RPM)	Y (%)
A	0	**LS Sensitivity**
B	**Low Speed**	100%
C	**Mid Speed**	100%
D	**High Speed**	**HS Sensitivity**

The map adjusts the proportional gain (Position Kp) as a function of traction speed.

Fig. 16 *Steering Sensitivity Map.*

MOTOR CONTROL TUNING: FIELD WEAKENING CONTROL				
PARAMETER	ALLOWABLE RANGE	PCF	RIS	DESCRIPTION
FW Base Speed *0x410A 0x00*	200–6000 rpm *200–6000*			This parameter needs to be reset each time the Motor Type is changed. See Motor Type table on page 56.
Field Weakening *0x4108 0x00*	0–100 % *0–1024*			Determines the amount of high speed power the controller will allow, while still maintaining maximum effficiency at the allowed power. Reducing this parameter effectively reduces controller current at high speeds, which can reduce energy consumption and motor heating, but at the expense of reduced available torque from the motor.
Weakening Rate *0x412B 0x00*	0–100 % *0–500*			Determines the control loop gains for field weakening. Setting the rate too low may create surging in the vehicle as it accelerates at mid to high speeds. Setting the rate too high may create high frequency oscillations (usually audible) when the vehicle accelerates at mid to high speeds.
Min Field Current *0x4112 0x00*	0–800 A *0–8000*			Min Field Current sets the amount of current used to pre-flux the steer motor field. This current will run in the steer motor whenever the bridge is enabled (Interlock = On). Pre-fluxing the steer motor improves steering response, but because it also reduces efficiency and causes controller and steer motor heating, this parameter is typically set to zero.

MOTOR TYPE PARAMETER

PARAMETER	ALLOWABLE RANGE	PCF	RIS	DESCRIPTION
Motor Type *0x40B0 0x00*	0–22 *0–22*	◎	■	This parameter references a predefined set of motor parameters for many AC motors. The table also provides appropriate settings for the FW Base Speed parameter. If your motor is not included here, consult your local Curtis customer support engineer for information on how to set these three parameters based on your application and motor.

Motor Type	STEER MOTOR	VOLTAGE (V)	WATTAGE (W)	**FW Base Speed (rpm)**
0	[User defined]	n/a	n/a	n/a
1	ABM 4DG63D_4	24	670	2600
2	CFR AM106.0026	24	1000	2500
3	Kordel KM A 63/4-80/3	24	700	450
4	Iskra ASG 7101	24	300	1525
5	[Reserved]	n/a	n/a	n/a
6	Metalrota ARD114	24	700	2020
7	CFR AM106.0124	36	600	2200
8	CFR AM106.0059.01	48	600	1250
9	Schabmuller 50060170	24	580	500
10	Superec SY09-0.6Q	24	600	2300
11	Kordel KM A 80/4-60/3	24	400	2300
12	Iskra ASG 7102	24	300	2900
13	Metalrota ARD111A or ARD 117	48	700	790
14	Schabmueller 10066174	48	500	600
15	CFR AM090.0019	48	400	960
16	CFR AM090.0021	24	400	1500
17	Yuchen XQY-0.6	24	600	3000
18	Tongda OR743001	48	700	1200
19	ABM SDH14576/DG63D-4	48	900	2000
20	Superec B493112	48	600	2200
21	CFR AG106.0060	24	800	2850
22	KDS YDZ0.6-4-6740	48	600	1620

4a

MONITOR MENU

Through its Monitor menu, the handheld programmer provides access to real-time data during vehicle operation. This information is helpful during diagnostics and troubleshooting, and also while adjusting programmable parameters.

Table 3 Monitor Menu

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  - Target Position (deg)
  - Steer Command (deg)
  - Steer Command 2 (deg)
  - Steer Command
  - Steer Command 2
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    - Analog 3
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    - Angle 2 (deg)
    - Angle Raw (deg)
    - Angle Raw 2 (deg)
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    - Encoder 2 Counts
    - Encoder 1A
    - Encoder 1B
    - Encoder 2A
    - Encoder 2B
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    - CAN2 Steer Command
    - CAN Steer Counts
    - CAN2 Steer Counts
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  - Wheel Position 2 (deg)
  - Left Stop Reached
  - Right Stop Reached
  - **Analog Input** .... p. 62
    - Analog 5
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    - Position Raw (deg)
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    - Encoder 4 Degrees from Home
    - Encoder 3 Counts from Home
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    - Encoder 3A
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  - Following Error (deg)
  - Wheel Speed (deg/s)
  - Steer Command Error (deg)
  - Wheel Position Error (deg)
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- **INTERLOCK** .... p. 65
  - Interlock
  - Switch1
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  - Temperature
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    - CAN Interlock
  - **To Traction Controller** .... p. 69
    - Enable Traction
    - Traction Cutback
    - Traction Fault Action

Monitor Menu: COMMAND INPUT

VARIABLE	DISPLAY RANGE	DESCRIPTION
Target Speed *0x442E 0x00*	-32768 – 32767 rpm *-32768 – 32767*	Steer motor speed target for the velocity control loop.
Target Position (deg) *0x4427 0x00*	-180.0° – 180.0° *-32768 – 32767*	Wheel position target for the position control loop.
Steer Command (deg) *0x44BA 0x00*	-180.0° – 180.0° *-32768 – 32767*	The operator's final Steer Command (in degrees).
Steer Command 2 (deg) *0x44BB 0x00*	-180.0° – 180.0° *-32768 – 32767*	The operator's redundant final Steer Command (in degrees).
Steer Command *0x4423 0x00*	-100.0 – 100.0 % *-32768 – 32767*	The operator's Steer Command (in percent) that is the input into the command map. The output of the command map is the Steer Command (in degrees).
Steer Command 2 *0x446A 0x00*	-100.0 – 100.0 % *-32768 – 32767*	The operator's redundant Steer Command (in percent) that is the input into the command map. The output of the command map is the Steer Command 2 (in degrees).

Monitor Menu: COMMAND INPUT → Analog Input

VARIABLE	DISPLAY RANGE	DESCRIPTION
Analog 1 *0x4413 0x00*	0 – 10.00 V *0 – 1023*	The voltage measured at the Command Analog 1 input (pin 8).
Analog 3 *0x4414 0x00*	0 – 10.00 V *0 – 1023*	The voltage measured at the Command Analog 3 input (pin 19).
Angle (deg) *0x44BC 0x00*	-2880.0 – 2880.0 *-32768 – 32767*	This variable is used by both the Sin/Cos and Sawtooth sensor inputs. In *Absolute Position mode,* Angle (deg) = Angle Raw (deg) minus the Center Angle (deg) parameter. In *Relative Position mode*, Angle (deg) = Angle Raw (deg) minus the relative center angle (which is recalculated each time the interlock is enabled).
Angle 2 (deg) *0x44BD 0x00*	-2880.0 – 2880.0 *-32768 – 32767*	This variable is used by both the Sin/Cos and Sawtooth sensor inputs. In *Absolute Position mode,* Angle 2 (deg) = Angle Raw 2 (deg) minus the Center Angle (deg) parameter. In *Relative Position mode*, Angle 2 (deg) = Angle Raw 2 (deg) minus the relative center angle (which is recalculated each time the interlock is enabled).
Angle Raw (deg) *0x44BE 0x00*	-2880.0 – 2880.0 *-32768 – 32767*	This variable is used by both the Sin/Cos and Sawtooth sensor inputs. It is calculated from the sensor input voltages (pins 8 and 19).
Angle Raw 2 (deg) *0x44BF 0x00*	-2880.0 – 2880.0 *-32768 – 32767*	This variable is used by both the Sin/Cos and Sawtooth sensor inputs. It is calculated from the sensor input voltages (pins 8 and 19).

Monitor Menu: COMMAND INPUT → Encoder Input		
VARIABLE	DISPLAY RANGE	DESCRIPTION
Encoder 1 Counts *0x4420 0x00*	-2147483648 – 2147483647 *-2147483648 – 2147483647*	Encoder 1 counts from a command to the center position. Moving the command encoder should increase the counts (positive or negative, depending on the direction moved). A command left of center will be negative counts. A command right of center will be positive counts.
Encoder 2 Counts *0x4474 0x00*	-2147483648 – 2147483647 *-2147483648 – 2147483647*	Encoder 2 counts from a command to the center position. Moving the command encoder should increase the counts (positive or negative, depending on the direction moved). A command left of center will be negative counts. A command right of center will be positive counts.
Encoder 1A *0x4478 0x00*	On / Off *On / Off*	Command Encoder 1A switch input On or Off (pin 14). This can be used to verify that phase A of Command Encoder 1 is operating correctly.
Encoder 1B *0x4479 0x00*	On / Off *On / Off*	Command Encoder 1B switch input On or Off (pin 25). This can be used to verify that phase B of Command Encoder 1 is operating correctly.
Encoder 2A *0x447A 0x00*	On / Off *On / Off*	Command Encoder 2A switch input On or Off (pin 33). This can be used to verify that phase A of Command Encoder 2 is operating correctly.
Encoder 2B *0x447B 0x00*	On / Off *On / Off*	Command Encoder 2B switch input On or Off (pin 20). This can be used to verify that phase B of Command Encoder 2 is operating correctly.

Monitor Menu: COMMAND INPUT → CAN Input		
VARIABLE	DISPLAY RANGE	DESCRIPTION
CAN Steer Command *0x4445 0x00*	-32768 – 32767 *-32768 – 32767*	The incoming primary CAN steering command communicated on the CAN bus. Typically the CAN object is mapped into a PDO message. The system arrangement determines which PDO message is used.
CAN 2 Steer Command *0x44D6 0x00*	-32768 – 32767 *-32768 – 32767*	The incoming supervisory CAN steering command communicated on the CAN bus. Typically the CAN object is mapped into a PDO message. The system arrangement determines which PDO message is used.
CAN Steer Counts *0x44D5 0x00*	-32768 – 32767 *-32768 – 32767*	The primary CAN steering sensor counts from the center position command. A command left of center will be negative counts; a command right of center will be positive counts. In *Absolute Position mode,* CAN Steer Counts = CAN Steer Command minus the Center Offset parameter. In *Relative Position mode,* CAN Steer Counts = CAN Steer Command minus the relative center angle (which is recalculated each time the interlock is enabled).
CAN 2 Steer Counts *0x44D4 0x00*	-32768 – 32767 *-32768 – 32767*	The supervisory CAN steering sensor counts from the center position command. A command left of center will be negative counts; a command right of center will be positive counts. In *Absolute Position mode,* CAN 2 Steer Counts = CAN 2 Steer Command minus the Center Offset parameter. In *Relative Position mode,* CAN 2 Steer Counts = CAN 2 Steer Command minus the relative center angle (which is recalculated each time the interlock is enabled).

Monitor Menu: POSITION FEEDBACK		
VARIABLE	DISPLAY RANGE	DESCRIPTION
Wheel Position (deg) *0x2000 0x00*	-180.0° – 180.0° *-32768 – 32767*	The final wheel position.
Wheel Position 2 (deg) *0x4458 0x00*	-180.0° – 180.0° *-32768 – 32767*	The operator's redundant final wheel position. Wheel Position 2 is compared to Wheel Position, and if the difference exceeds the programmed Wheel Position Tolerance, a fault is issued (code 56: Wheel Position Supervision).
Left Stop Reached *0x4421 0x00*	On / Off *On / Off*	Flag indicating the left stop has been reached.
Right Stop Reached *0x4422 0x00*	On / Off *On / Off*	Flag indicating the right stop has been reached.

Monitor Menu: POSITION FEEDBACK → Analog Input		
VARIABLE	DISPLAY RANGE	DESCRIPTION
Analog 5 *0x4411 0x00*	0 – 10.00 V *0 – 1023*	The voltage measured at the Position Analog 5 input (pin 16).
Analog 6 *0x4480 0x00*	0 – 10.00 V *0 – 1023*	The voltage measured at the Position Analog 6 input (pin 17).
Position Raw (deg) *0x44C0 0x00*	-180.0° – 180.0° *-32768 – 32767*	The angle calculated by the primary microprocessor from the input voltages (pins 16 and 17) for the Sin/Cos or Sawtooth sensors.
Position 2 Raw (deg) *0x44C1 0x00*	-180.0° – 180.0° *-32768 – 32767*	The angle calculated by the supervisory microprocessor from the input voltages (pins 16 and 17) for the Sin/Cos or Sawtooth sensors.

Monitor Menu: POSITION FEEDBACK → Encoder Input

VARIABLE	DISPLAY RANGE	DESCRIPTION
Encoder 3 Degrees from Home *0x44C3 0x00*	-180.0° – 180.0° *-32768 – 32767*	Encoder 3 degrees from home position. The steer motor rotating should change the degrees; a move left of home position will be in negative degrees and a move right of home will be in positive degrees.
Encoder 4 Degrees from Home *0x44C4 0x00*	-180.0° – 180.0° *-32768 – 32767*	Encoder 4 degrees from home position. The steer motor rotating should change the degrees; a move left of home position will be in negative degrees and a move right of home will be in positive degrees.
Encoder 3 Counts from Home *0x441F 0x00*	-2147483648 – 2147483647 *-2147483648 – 2147483647*	Encoder 3 counts from the home position. The steer motor rotating should change the counts; a move left of home position will be negative counts, and a move right of home will be positive counts.
Encoder 4 Counts from Home *0x4473 0x00*	-2147483648 – 2147483647 *-2147483648 – 2147483647*	Encoder 4 counts from the home position. The steer motor rotating should change the counts; a move left of home position will be negative counts, and a move right of home will be positive counts.
Encoder 3 Position (deg) *0x44D0 0x00*	-180.0° – 180.0° *-32768 – 32767*	Wheel position based on Encoder 3 counts. Accuracy depends on the parameters Encoder 3 Counts from Home and Center Offset being configured correctly. This variable is used in a supervision check (see code 56: Wheel Position Supervision).
Encoder 3A *0x4434 0x00*	On / Off *On / Off*	Steer Motor Encoder 3A switch input On or Off (pin 31). This can be used to verify that phase A of Steer Motor Encoder 3 is operating correctly.
Encoder 3B *0x4435 0x00*	On / Off *On / Off*	Steer Motor Encoder 3B switch input On or Off (pin 32). This can be used to verify that phase B of Steer Motor Encoder 3 is operating correctly.
Encoder 4A *0x447C 0x00*	On / Off *On / Off*	Steer Motor Encoder 4A switch input On or Off (pin 26). This can be used to verify that phase A of Steer Motor Encoder 4 is operating correctly.
Encoder 4B *0x447D 0x00*	On / Off *On / Off*	Steer Motor Encoder 4B switch input On or Off (pin 27). This can be used to verify that phase B of Steer Motor Encoder 4 is operating correctly.

Monitor Menu: SUPERVISION

VARIABLE	DISPLAY RANGE	DESCRIPTION
Following Error (deg) *0x44C9 0x00*	-180.0° – 180.0° *-32768 – 32767*	Following Error = Steer Command 2 minus Wheel Position 2. If the difference exceeds the programmed Following Tolerance, a fault is issued (code 73: Following Error).
Wheel Speed (deg/s) *0x44D8 0x00*	-180.0° – 180.0° *-32768 – 32767*	Rotational velocity of the steered wheel. This variable can be useful when setting up the Following Error check parameters, particularly Speed Tolerance (deg/s).
Steer Command Error (deg) *0x44CA 0x00*	-180.0° – 180.0° *-32768 – 32767*	Steer Command Error = Steer Command minus Steer Command 2. If the difference exceeds the programmed Steer Command Tolerance, a fault is issued (code 55: Steer Command Supervision).
Wheel Position Error (deg) *0x44CB 0x00*	-180.0° – 180.0° *-32768 – 32767*	Wheel Position Error = Wheel Position minus Wheel Position 2. If the difference exceeds the programmed Wheel Position Tolerance, a fault is issued (code 56: Wheel Position Supervision).
Encoder Position Error (deg) *0x44D2 0x00*	-180.0° – 180.0° *-32768 – 32767*	Encoder Position Error = Wheel Position minus Encoder 3 Position. If the difference exceeds the programmed Encoder Position Tolerance, a fault is issued (code 56: Wheel Position Supervision).
Home Reference Error (deg) *0x44CC 0x00*	-180.0° – 180.0° *-32768 – 32767*	Home Reference Error = Home Reference minus Home Reference 2. If the difference exceeds the programmed Home Reference Tolerance, a fault is issued (code 54: Home Reference Tolerance Fault).

Monitor Menu: INTERLOCK		
VARIABLE	DISPLAY RANGE	DESCRIPTION
Interlock *0x440C 0x00*	On / Off *On / Off*	The interlock is used to enable/disable the the electric steering. The source of the interlock state is determined by the Interlock Type parameter.
Switch1 *0x440A 0x00*	On / Off *On / Off*	Switch 1 input On or Off (pin 9). This input is used as an input for the NO contact of the Interlock switch.
Switch3 *0x444F 0x00*	On / Off *On / Off*	Switch 3 input On or Off (pin 11). This input is used as an input for the NC contact of the Interlock switch.

Monitor Menu: HOME REFERENCE		
VARIABLE	DISPLAY RANGE	DESCRIPTION
Home *0x440D 0x00*	On / Off *On / Off*	Home is used to recalibrate the position, when the position feedback devices are encoders (Position Feedback Device = 1).
Switch2 *0x440B 0x00*	On / Off *On / Off*	Switch 2 input On or Off (pin 10). This input is used as an input for the NO contact of the Home switch.
Switch4 *0x4450 0x00*	On / Off *On / Off*	Switch 4 input On or Off (pin 12). This input is used as an input for the NC contact of the Home switch.

Monitor Menu: OUTPUTS		
VARIABLE	DISPLAY RANGE	DESCRIPTION
Fault Output Voltage *0x440F 0x00*	0.0 – 80.0 V *0 – 1023*	Voltage measured at the Fault Output (pin 24).
Contactor Driver PWM *0x44A4 0x00*	0 – 100 % *0 – 32767*	Steer contactor driver PWM output (pin 2).
Force Feedback Driver PWM *0x44A7 0x00*	0 – 100 % *0 – 32767*	Force feedback driver PWM output (pin 5).

Monitor Menu: BATTERY AND SUPPLY

VARIABLE	DISPLAY RANGE	DESCRIPTION
Capacitor Voltage *0x4417 0x00*	0.0–80.0 V *0–1023*	Voltage of steer controller's internal capacitor bank at the B+ terminal.
Keyswitch Voltage *0x4416 0x00*	0.0–80.0 V *0–1023*	Voltage measured at the keyswitch input (pin 1).
10v Out *0x445E 0x00*	0.0–20.0 V *0–1023*	Voltage measured at the +10V output (pin 15).
5v Out *0x44A9 0x00*	0.00–10.00 V *0–1023*	Voltage measured at the +5V output (pins 21 and 34).
5v Out Current *0x4415 0x00*	0–100.0 mA *0–1000*	Measured current of the +5V output supply (pins 21 and 34).

Monitor Menu: STEER MOTOR

VARIABLE	DISPLAY RANGE	DESCRIPTION
Motor RPM *0x4433 0x00*	-32768–32767 rpm *-32768–32767*	Steer motor speed in revolutions per minute.
Motor Torque *0x44D7 0x00*	-5000–5000 Nm *-5000–5000*	The estimated torque in the steer motor. This variable can be useful when setting up the force feedback parameters, particularly Max Torque.
Temperature *0x441B 0x00*	-3276.8–3276.7 °C *-32768–32767*	Steer motor temperature as measured by the motor temperature sensor input (pin 22).
Temperature Sensor Voltage *0x4410 0x00*	0.00–10.00 V *0–1023*	Voltage measured at the motor temperature sensor input (pin 22).

Monitor Menu: CONTROLLER

VARIABLE	DISPLAY RANGE	DESCRIPTION
Current (RMS) *0x44B1 0x00*	0–6553.5 A *0–65535*	RMS current of the steer controller, taking all three phases into account.
Modulation Depth *0x4520 0x00*	0.0–100.0 % *0–1024*	Percentage of available voltage being used.
Frequency *0x452F 0x00*	-300–300 Hz *-18000–18000*	Steer controller electrical frequency.
Temperature *0x441A 0x00*	-3276.8–3276.7 °C *-32768–32767*	Steer controller internal temperature.
Contactor State *0x44AA 0x00*	0–4 *0–4*	Steer contactor state: 0= open 1= closing 2= closed 3= opening 4= fault.
Steer Command State *0x4432 0x00*	0–255 *0–255*	Steer command state: 0= init 1= open phase check 2= homing 3= auto center 4= steering 5= idle 6= steering faulted.
Device State *0x444C 0x00*	0–255 *0–255*	Device state: 0= “Not Ready To Switch On”: controller initialization state 2= “Switch On Disabled”: software upload state 3= “Ready To Switch On”: controller enabled, motor bridge disabled, Interlock = Off 4= “Switched On”: controller enabled, processing the Interlock = On command 5= “Operation Enabled”: controller enabled, motor bridge enabled, Interlock = On 13= “Fault Reaction State”: controller processing a shutdown fault action 14= “Fault”: controller shut down by shutdown fault action, Fault Output = Off.

Monitor Menu: CONTROLLER, cont'd

VARIABLE	DISPLAY RANGE	DESCRIPTION
Keyswitch Hour Meter *0x4499 0x00*	0–429496729.5 hour *0–4294967295*	Displays the total time the steer controller has been powered On.
Interlock Hour Meter *0x4498 0x00*	0–429496729.5 hour *0–4294967295*	Displays the total time the steer controller has had the interlock On.

Monitor Menu: CAN STATUS

VARIABLE	DISPLAY RANGE	DESCRIPTION
CAN NMT State *0x1C00 0x00*	0–255 *0–255*	Controller CAN NMT state: 0= initialization 4= stopped 5= operational 127= pre-operational.

Monitor Menu: CAN STATUS → FROM TRACTION CONTROLLER

VARIABLE	DISPLAY RANGE	DESCRIPTION
Traction Motor RPM *0x441E 0x00*	-32768 – 32767 rpm *-32768 – 32767*	Traction motor speed in revolutions per minute. This variable is based on the input selected with the Traction Speed Input Type parameter.
Traction Is Ready *0x2081 0x00*	On / Off *On / Off*	Flag sent by the traction controller over the CAN bus (PDO1_MOSI Byte 3) to indicate whether the traction motor is ready. Typically implemented in the traction controller VCL to indicate that the traction main contactor is closed.
CAN Interlock *0x4447 0x00*	On / Off *On / Off*	Flag sent by the traction controller over the CAN bus (PDO1_MOSI Byte 4) to indicate whether the interlock is enabled. This flag is used by the 1222 only when Interlock Type = 3.

Monitor Menu: CAN STATUS → TO TRACTION CONTROLLER

VARIABLE	DISPLAY RANGE	DESCRIPTION
Enable Traction *0x2001 0x00*	On / Off *On / Off*	Flag sent from the steer controller to enable the traction controller.
Traction Cutback *0x2003 0x00*	0 – 100 % *0 – 100*	Variable sent from the steer controller to cut back the speed of the traction motor.
Traction Fault Action *0x2005 0x00*	0 – 10 *0 – 10*	Variable sent from the steer controller to trigger a fault action in the traction controller. 0= no fault 1= stop traction 2= reduce traction speed 3= no action.

4b

CONTROLLER INFORMATION MENU

This menu provides ID and version numbers for your controller hardware and software.

CONTROLLER INFORMATION MENU

VARIABLE	DISPLAY RANGE	DESCRIPTION
Model Number *0x5000 0x08*	0 – 4294967295 *0 – 4294967295*	Model number. For example, if you have a 1222 controller with the model number 1222-5101, the Model Number variable will have a value of 12225101.
Serial Number *0x1018 0x04*	0 – 4294967295 *0 – 4294967295*	Serial number. For example, if the serial number printed on your controller is 13125L.11493, the Serial Number variable will have the value of 11493.
Protocol Version	0 – 32767 *0 – 32767*	Version of the serial communications protocol.
Param Block Version	0 – 32767 *0 – 32767*	Version of the parameter block.
Mfg Date Code *0x4801 0x00*	0 – 65535 *0 – 65535*	Controller date of manufacture, with the first two digits indicating the year and the last three indicating the day. For example, if the serial number printed on your controller is 13125L.11493, the Mfg Date Code variable will have the value of 13125 (125th day of 2013).
Hardware Version *0x4802 0x00*	0 – 65.535 *0 – 65535*	The hardware version number uniquely describes the combination of power base assembly and the logic, cap, and IMS board assemblies used in the controller.
OS Version *0x4804 0x00*	0 – 65535 *0 – 65535*	Version number of the operating system software that is loaded into the controller. This variable specifies the major version number of the controller's operating system.
Build Number *0x4803 0x00*	0 – 65535 *0 – 65535*	Build number of the operating system software that is loaded into the controller. This variable specifies the minor version number of the controller's operating system.
SM Version *0x4800 0x00*	0 – 655.35 *0 – 65535*	Version number of the Start Manager software that is loaded into the controller.

4c

CONTROLLER FUNCTIONS MENU

This menu allows you to reset parameters to their default values and reset the interlock hour meter to zero.

CONTROLLER INFORMATION MENU

FUNCTION	DISPLAY RANGE	DESCRIPTION
Restore to Factory Defaults	Yes / No *Yes / No*	Set to "Yes" to reset all programmable parameters to their factory default settings.
Clear Interlock Hour Meter	Yes / No *Yes / No*	Set to "Yes" to set the interlock hour meter to zero hours.

5

COMMISSIONING

The 1222 steer controller can be used in a variety of vehicles, which differ widely in characteristics and in their input and feedback devices. Before driving the vehicle, it is imperative that the commissioning procedures be carefully followed to ensure that the controller is set up to be compatible with your application.

The 1222 controller must be used in conjunction with a Curtis AC traction controller with VCL. The Curtis traction controller must implement special software (VCL) to communicate with the 1222 controller, via the CAN bus, and to support safe vehicle operation.

A single main contactor can be used to support both traction and steer controllers. **All vehicles must use the Fault Output connection** (J1-24) to allow the 1222 to disable the traction main contactor during certain fault conditions.

*** * * BEFORE YOU START * * ***

The correct value for the Motor Type and FW Base Speed parameters must be determined individually for each AC motor. You can determine these values in one of the following ways:

➡ Check the motor types that are already supported by comparing your motor model number to the list of characterized motors listed in the parameter description for Motor Type (page 56). If there is a match, consult the table for the correct FW Base Speed based on the Motor Type and Nominal Voltage.

➡ Contact Curtis with the manufacturer's part number for your motor. We have a database of many AC motors for which we have already determined the correct motor parameter settings. If no testing has been done, it may be possible for Curtis to dyno test your motor. Contact Curtis before shipping your motor.

After obtaining this information, set the **Motor Type** and **FW Base Speed** parameters to their correct values.

CAUTION ☞

Before starting the commissioning procedures, **jack the vehicle drive wheels up off the ground** so that they spin freely and steer freely from stop to stop. **Manually disable the Interlock** (traction and steer) so that the 1222 will not begin steering and the traction wheel will not turn. Double-check all wiring to ensure it is consistent with the wiring guidelines presented in Section 2. Make sure all connections are tight. Turn on the controller and plug in the handheld programmer.

The commissioning procedures are grouped into four sections, as follows.

The first section covers the initial setting of various parameters, before the actual commissioning begins.

① Preparation for commissioning

The procedures in the second section set up the steer command. The 1222 interlock and the traction interlock both remain Off.

② Command Map setup

③ Command Input Device setup
"0" — Setup for Pot input
"1" — Setup for Encoder input
"2" — Setup for Sin/Cos Sensor input
"3" — Setup for Sawtooth Sensor input
"4" — Setup for CAN Sensor input
"5" — None (applies only to Supervision parameter)

④ Force Feedback setup

⑤ Verify the Command Input setup

⑥ Verify the Steer Motor Encoder 3 setup

The procedures in the third section require the steer motor to turn, so the 1222 interlock (the steer interlock) must be set to On. The vehicle drive wheels continue to be jacked up off the ground to they can spin freely and steer freely from stop to stop.

⑦ Position Feedback Device setup
"0" — Setup for Pot feedback
"1" — Setup for Encoder feedback
"2" — Setup for Sin/Cos Sensor feedback
"3" — Setup for Sawtooth Sensor feedback
"4" — None (applies only to Supervision parameter)

⑧ Set the remaining Performance and Supervision parameters

⑨ Verify the Position Feedback Setup

⑩ Resolve any existing faults

Last, the vehicle drive wheels are lowered to the ground and the final procedures are conducted. For these procedures, the traction interlock must also be set to On.

⑪ Set the Following Error parameters

⑫ Set the remaining Supervision parameters.

① Preparation for commissioning

CAUTION ☞

Lower these five parameter values to force low steering performance and stable response (with the wheel off the ground) while the setup procedures are performed:

Motor
- **Max Speed** = 1000 rpm or lower
- **Max Current** = 20%

Motor Control Tuning
- **Position Kp** = 5%
- **Velocity Kp** = 5%
- **Velocity Ki** = 5%.

Verify that the 1222 interlock = Off (Monitor » Interlock » *Interlock*) and the traction controller interlock = Off. If either interlock is On, either change the interlock input to the controllers or adjust the **Interlock Type** parameter until the interlock variables are both Off. If the interlock is accidentally set to On during commissioning, the steered wheel may turn without warning.

Set these parameters based on the vehicle configuration:

Motor Control Tuning
- **Motor Type** (see above)
- Field Weakening Control
  - **FW Base Speed** (see above)

Vehicle Configuration
- **Interlock Type** (see above)
- **Nominal Voltage**
- Contactor Driver
  - **Contactor Control Type**
  - **Pull-In Voltage**
  - **Holding Voltage**
  - **Open Delay**
  - **Checks Enable**
  - **Sequencing Delay**

Motor
- **Encoder3 Steps**
- Temperature Control
  - **Sensor Enable**
  - **Sensor Type**
  - **Temperature Hot**
  - **Temperature Max**
  - **Sensor Fault Traction Cutback**

CANopen
- **Baud Rate**

Temporarily set these six parameters to disable the supervision; this will allow for easier setup of the primary and redundant signals:

Supervision
- Steer Command Tolerance = 90°
- Wheel Position Tolerance = 90°
- Encoder Position Tolerance = 90°
- Home Reference Tolerance = 90°
- Stall Steering Speed = 0
- Following Error » Error Tolerance = 90°

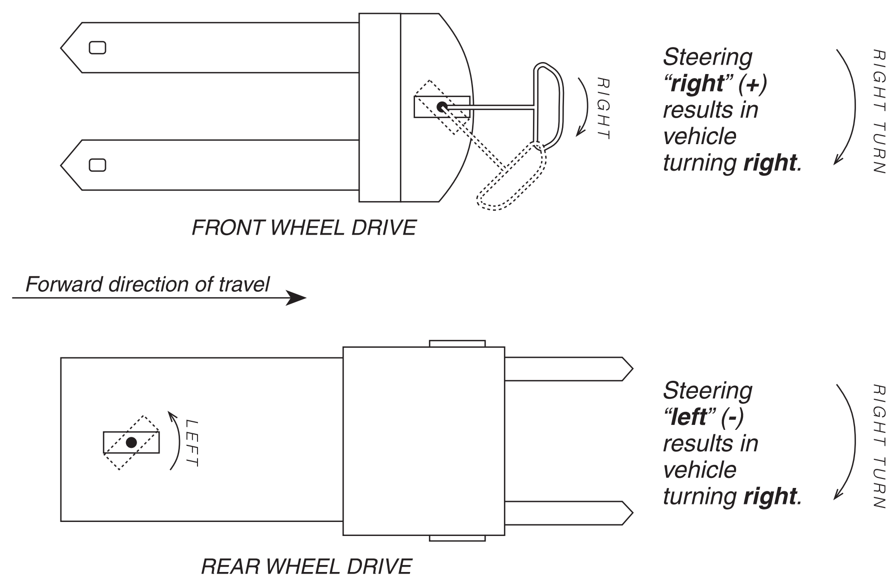
Steer Direction

Parameter and monitor values for wheel position and steer motor speed are signed (i.e., they are positive and negative values).

Right wheel positions (positive values) are such that when traveling in the forward vehicle direction in a vehicle with the steered wheel in the front the steer direction is to the driver's right.

Left wheel positions (negative values) are such that when traveling in the forward vehicle direction in a vehicle with the steered wheel in the front the steer direction is to the driver's left.

In vehicles where the steered wheel is in the back, these directions are reversed.



If your application has a motor temperature sensor, check the temperature (Monitor » Steer Motor » *Temperature*) and verify that the reading is correct or resolve the problem.

Verify that the correct VCL software is loaded into the Curtis AC traction controller to support the 1222. Verify that the CAN communications between the AC traction controller and the 1222 are operating correctly. Resolve any problems with the traction software or CAN communications before continuing on to the commissioning procedures.

② Command Map setup *(see page 31)*

The fourteen parameters in the Command Map menu define an 8-point map, as described on page 31. The *input* to the Command Map (in units of %) can be observed in Monitor» Command Input» *Steer Command*. The *output* to the Command Map (in units of degrees) can be observed in Monitor» Command Input» *Steer Command (deg)*.

The **Left Stop (deg)** parameter is paired with a value of -100%, and the **Right Stop (deg)** parameter is paired with a value of 100%. The **P1-P6 Output** values fill in the continuum between the two stops; these values should get positive when center is crossed. Similarly, the **P1-P6 Input** parameters should start with negative percent values and increase to positive percent values. The settings of the point pairs can be customized to shape the map according to the needs of the application. In general, starting with a linear command map without any deadband is recommended for vehicles that have the steered wheel in the center.

IMPORTANT

Setting the **Left Stop (deg)** and **Right Stop (deg)** to the correct angle is critical to the setup of the vehicle as these two parameters set the maximum steering angle. They must be set before continuing on to set up the position feedback.

Although any map shape can be set up, it is recommended that the map always be set so that a *Steer Command* of zero equals a *Steer Command (deg)* of zero. This is necessary to ensure that the auto-center functions work correctly, and will aid in system troubleshooting.

IMPORTANT

Setting the parameters **Left Stop (deg)** to -180° and **Right Stop (deg)** to 180° results in true 360° steering (also known as "round and round" steering). This means the steered wheel will not have end stops and a command change from -175° to 175° will cause the steered wheel to travel 10° clockwise rather than 350° counterclockwise. True 360° steering is compatible with all command input devices except Type 0 - Analog1 and 3.

③ Command Input Device setup *(see pages 20–22)*

Your steering command input device will be a dual potentiometer or a sine/cosine sensor or sawtooth sensor (using pins J1-8 and J1-19) or a dual encoder (using pins J1-14, J1-25, J1-33, and J1-20). Most applications will have a primary command input device and a supervisory command input device.

Set the **Command Input Device** parameter and the **Supervision Input Device** parameter to the type of input you will be using:

Command Input Device Types	**Supervision Input Device** Types
0 = Pot input	**0** = Pot input
1 = Encoder input	**1** = Encoder input
2 = Sin/Cos Sensor input	**2** = Sin/Cos Sensor input
3 = Sawtooth Sensor input	**3** = Sawtooth Sensor input
4 = CAN Sensor input	**4** = CAN Sensor input
	5 = None

Use the appropriate setup procedure for the devices, for the input you have chosen for each. For applications with only a primary command input device, you will need to set the **Supervision Input Device** parameter to 5.

"0" — Setup for Pot input *(see page 23)*

Note: The steer motor should not respond to this command input because the Interlock is Off. If the steer motor shows any movement (or if the Interlock is On), stop and resolve the issue; see Preparation for commissioning, page 74.

a. Move the steer command pots to the Left position (not to the actual physical stop, but a small amount away, to allow for pot tolerance variation) and observe the two voltages shown in the Monitor»Command Input»Analog Input»*Analog1* and *Analog3* variables. Set the parameters **Analog1 Left** and **Analog3 Left** to the observed voltages.

b. Move the steer command pots to the Center position and observe the two voltages shown in the *Analog1* and *Analog3* variables. Set the parameters **Analog1 Center** and **Analog3 Center** to the observed voltages.

c. Move the steer command pots to the Right position (not to the actual physical stop, but a small amount away, to allow for pot tolerance variation) and observe the two voltages shown in the *Analog1* and *Analog3* variables. Set the parameters **Analog1 Right** and **Analog3 Right** to the observed voltages.

d. Set the four fault parameters (**Analog1 Fault Min**, **Analog1 Fault Max**, **Analog3 Fault Min**, and **Analog3 Fault Max**). Set these to voltages that will not be reached during normal operation, but will be reached when the steer command inputs become faulty (e.g., should there be an open or short circuit).

The Fault Min settings must be below the minimum voltage seen on *Analog1* or *Analog3* when steered to the maximum left and right positions.

The Fault Max settings must be above the maximum voltage seen on *Analog1* or *Analog3* when steered to the maximum left and right positions.

"1" — Setup for Encoder input *(see page 25)*

Note: The steer motor should not respond to this command input because the Interlock is Off. If the steer motor shows any movement (or if the Interlock is On), stop and resolve the issue; see Preparation for commissioning, page 74.

a. Both command encoders must move in the same direction and the values must be positive for the Right direction and negative for the Left direction, as defined on page 75. Observe the Monitor»Command Input»Encoder Input»*Encoder1 Counts* and *Encoder2 Counts* variables. While moving the command encoders, verify that these values are both positive (for movements to command Right steer direction) or negative (for movements to command Left steer direction). If so, go on to Step "b".

If one or both of the Encoder Counts is incorrect, use the parameters **Swap Encoder1 Direction** and/or **Swap Encoder2 Direction**. Recheck the *Encoder1 Counts* and *Encoder2 Counts* variables and verify that they both move in the same direction with the correct sign. If problems persist, contact your Curtis customer support engineer before continuing.

b. Set the parameters **Left Stop to Center** and **Right Stop to Center**. These parameters determine how many revolutions of the command encoders are required to steer between the Left and Right stops. These values can be calculated based on the encoders' pulses per revolution (ppr) and the desired number of revolutions of the steering wheel (counts = 4 × encoder ppr × number of revolutions). Both encoders must have the same ppr.

   Another way to set up these parameters is by observing the *Encoder1 Counts* and *Encoder2 Counts* values and steering while observing the change in the encoder counts during one complete revolution of the steering wheel.

"2" — Setup for Sin/Cos Sensor input *(see page 26)*

Note: The steer motor should not respond to this command input because the Interlock is Off. If the steer motor shows any movement (or if the Interlock is On), stop and resolve the issue; see Preparation for commissioning, page 74.

a. Set the parameters **Amplitude** and **Offset** according to the sensor manufacturer's specifications. Amplitude is usually referred to as Gain in the specs. Amplitude is half the peak-to-peak voltage, and Offset is the center of the peak-to-peak from ground.

   If sensor specs are not available, use the voltages shown in the Monitor » Command Input » Analog Input » *Analog1* and *Analog3* variables as follows. To calculate the Offset, find the highest and lowest values of *Analog1* and *Analog3* while slowly sweeping the command device. Add these two values together and divide by two. Input this number in the **Offset** parameter. Next, subtract the lowest value of *Analog1* and *Analog3* from the Offset parameter value. Input this number in the **Amplitude** parameter. Example: While the command device is moved slowly, *Analog1* and *Analog3* are shown to have a maximum voltage of 4.1 V and a minimum voltage of 1.9 V; therefore, Offset = 3.0 V and Amplitude = 1.1 V.

b. Decide if the sensor input will be in absolute position mode or relative position mode, and then follow Step "c" or "d" as appropriate.

   Absolute Mode = On is for absolute position mode. The sensor input typically has a range of motion that matches the range of motion of the steered wheel (not multi-turn) and the center, right, and left positions are all defined. Absolute position mode is typically used for walkie and walkie rider material handling applications.

   Absolute Mode = Off is for relative position mode. The sensor input is typically a multi-turn device with the center position being wherever the sensor is positioned when the interlock is turned on. Relative position mode is typically used for reach trucks and man-up material handling applications.

c. For Absolute Position Mode (Absolute Mode = On):
   1. Move the Sin/Cos Sensor to the center position and observe the angle shown in the Monitor » Command Input » Analog Input » *Angle Raw* variable. Set the **Center Angle** to the observed angle. This parameter

must be set before the Left and Right angle parameters are set, because the center angle is based on the raw reading and normalizes the angle for setting up the Left and Right angles.

2. Move the Sin/Cos Sensor to the Left position (not to the actual physical stop, but a small amount away, to allow for sensor tolerance variation) and observe the angle shown in the Monitor » Command Input » Analog Input » *Angle* variable. If the observed angle was negative, set the **Left Angle** parameter to the observed angle.

   If the observed angle was positive, change the parameter **Swap Direction**. Verify that the steer direction sign is correct (-), and then return to step b to reset the **Center Angle** parameter. Finally, set the **Left Angle** parameter to the observed angle.
3. Move the Sin/Cos Sensor to the Right position (not to the actual physical stop, but a small amount away, to allow for sensor tolerance variation) and observe the angle shown in the *Angle* variable. Set the **Right Angle** parameter to the observed angle.

d. For Relative Position Mode (Absolute Mode = Off):

1. Set the **Center Angle** to zero, as this parameter is not used in relative position mode.
2. Set the **Left Angle** parameter to the number of turns (in negative degrees) required to produce a steer command from center to full left.
3. Set the **Right Angle** parameter to the number of turns (in degrees) required to produce a steer command from center to full right.

e. Set the two fault parameters (**Fault Min** and **Fault Max**) to voltages that will not be reached during normal operation, but will be reached when the steer command inputs become faulty (e.g., should there be an open or short circuit).

The Fault Min settings must be below the minimum voltage seen on *Analog1* or *Analog3* when steered to the maximum left and right positions.

The Fault Max settings must be above the maximum voltage seen on *Analog1* or *Analog3* when steered to the maximum left and right positions.

f. The **Tolerance** parameter can be set in either of two ways.

1. Obtain the tolerance of **Min Volts** and **Max Volts** from the manufacturer's specs, and then calculate the worst case difference in voltage between the calculated voltages and the measured *Analog1* and *Analog3* voltages over the range of the sensor. Set the **Tolerance** to a comfortable margin above the maximum calculated difference.
2. Manually lower the **Tolerance** value while adjusting the Sin/Cos Sensor over the entire output range until the fault Sin/Cos Command Sensor (Fault Code 47) is generated. Repeat this until you find the minimum **Tolerance** value that will not cause the fault (over the entire sensor range). Set the **Tolerance** to a comfortable margin above the minimum tolerance found.

"3" — Setup for Sawtooth Sensor input *(see page 28)*

Note: The steer motor should not respond to this command input because the Interlock is Off. If the steer motor shows any movement (or if the Interlock is On), stop and resolve the issue; see Preparation for commissioning, page 74.

a. Set the parameters **Min Volts** and **Max Volts** according to the sensor manufacturer's specifications. If sensor specs are not available, use the voltages shown in the Monitor » Command Input » Analog Input » *Analog1* and *Analog3* variables as follows. To get the correct values for **Min Volts** and **Max Volts**, find the highest and lowest values of *Analog1* and *Analog3* while slowly sweeping the command device. Input the lowest value as **Min Volts** and the highest value as **Max Volts**. Example: While the command device is moved slowly, *Analog1* and *Analog3* are shown to have a minimum voltage of 1.9 V and a maximum voltage of 4.1 V; therefore, **Min Volts** = 1.9 V and **Max Volts** = 4.1 V.

b. Decide if the sensor input will be in absolute position mode or relative position mode, and then follow Step "c" or "d" as appropriate.

Absolute Mode = On is for absolute position mode. The sensor input typically has a range of motion that matches the range of motion of the steered wheel (not multi-turn) and the center, right, and left positions are all defined. Absolute position mode is typically used for walkie and walkie rider material handling applications.

Absolute Mode = Off is for relative position mode. The sensor input is typically a multi-turn device with the center position being wherever the sensor is positioned when the interlock is turned on. Relative position mode is typically used for reach trucks and man-up material handling applications.

c. For Absolute Position Mode (Absolute Mode = On):

1. Move the Sawtooth Sensor to the center position and observe the angle shown in the Monitor » Command Input » Analog Input » *Angle Raw* variable. Set the **Center Angle** to the observed angle. This parameter must be set before the Left and Right angle parameters are set, because the center angle is based on the raw reading and normalizes the angle for setting up the Left and Right angles.
2. Move the Sawtooth Sensor to the Left position (not to the actual physical stop, but a small amount away, to allow for sensor tolerance variation) and observe the angle shown in the Monitor » Command Input » Analog Input » *Angle* variable. If the observed angle was negative, set the **Left Angle** parameter to the observed angle.

   If the observed angle was positive, change the parameter **Swap Direction**. Verify that the steer direction sign is correct (-), and then return to Step "b" to reset the **Center Angle** parameter. Finally, set the **Left Angle** parameter to the observed angle.
3. Move the Sawtooth Sensor to the Right position (not to the actual physical stop, but a small amount away, to allow for sensor tolerance variation) and observe the angle shown in the *Angle* variable. Set the **Right Angle** parameter to the observed angle.

d. For Relative Position Mode (Absolute Mode = Off):
   1. Set the **Center Angle** to zero, as this parameter is not used in relative position mode.
   2. Set the **Left Angle** parameter to the number of turns (in negative degrees) required to produce a steer command from center to full left.
   3. Set the **Right Angle** parameter to the number of turns (in degrees) required to produce a steer command from center to full right.

e. Set the two fault parameters (**Fault Min** and **Fault Max**) to voltages that will not be reached during normal operation, but will be reached when the steer command inputs become faulty (e.g., should there be an open or short circuit).

   The Fault Min settings must be below the minimum voltage seen on *Analog1* or *Analog3* when steered to the maximum left and right positions.

   The Fault Max settings must be above the maximum voltage seen on *Analog1* or *Analog3* when steered to the maximum left and right positions.

f. The *Analog1* and *Analog3* voltages of the Sawtooth Sensor should always be 0.5*(**Max Volts** - **Min Volts**) apart. A fault check is done by comparing the two voltages and calculating the error. If the error is greater than the **Tolerance** voltage for 60 ms, a fault is issued.

   The **Tolerance** parameter can be set in either of two ways.
   1. Obtain the tolerance of the sensor from the manufacturer's specs, and then calculate the worst case difference between the two channels. Next determine the difference between the worst case and the ideal, ABS (WorstCase - 0.5*(**Max Volts** - **Min Volts**)). This is the minimum **Tolerance** value. Set the **Tolerance** to a comfortable margin above the minimum Tolerance found.
   2. Manually lower the **Tolerance** value while adjusting the Sawtooth Sensor over the entire output range until the Sawtooth Command Sensor (Fault Code 47) is generated. Repeat this until you find the minimum **Tolerance** value that will not cause the fault (over the entire sensor range). Set the **Tolerance** to a comfortable margin above the minimum tolerance found.

"4" — Setup for CAN Sensor input *(see page 30)*

Note: The steer motor should not respond to this command input because the Interlock is Off. If the steer motor shows any movement (or if the Interlock is On), stop and resolve the issue; see Preparation for commissioning, page 74.

a. Decide if the sensor input will be in absolute position mode or relative position mode, and then follow Step "b" or "c" as appropriate.

   Absolute Mode = On is for absolute position mode. The sensor input typically has a range of motion that matches the range of motion of the steered wheel (not multi-turn) and the center, right, and left positions are all defined. Absolute position mode is typically used for walkie and walkie rider material handling applications.

Absolute Mode = Off is for relative position mode. The sensor input is typically a multi-turn device with the center position being wherever the sensor is positioned when the interlock is turned on. Relative position mode is typically used for reach trucks and man-up material handling applications.

b. For Absolute Position Mode (Absolute Mode = On):
   1. Move the CAN Sensor to the center position and observe the counts shown in the Monitor » Command Input » CAN Input » *CAN Steer Command* variable. Set the **CAN Steer Center Offset** to the observed counts.
   2. With the CAN Sensor still in the center position, observe the counts shown in the Monitor » Command Input » CAN Input » *CAN2 Steer Command* variable. Set the **CAN2 Steer Center Offset** to the observed counts.
   3. Move the CAN Sensor to the Left position (not to the actual physical stop, but a small amount away, to allow for sensor tolerance variation) and observe the counts shown in the Monitor » Command Input » CAN Input » *CAN Steer Counts* and *CAN2 Steer Counts* variables. The observed *CAN Steer Counts* and *CAN2 Steer Counts* must both be negative. Change the **CAN Steer Swap Direction** and **CAN2 Steer Swap Direction** as necessary to achieve negative count values for the *CAN Steer Counts* and *CAN2 Steer Counts* variables. If changes were made to either of the swap parameters, return to the beginning of Step "b" to reset the **CAN Steer Center Offset** and **CAN2 Steer Center Offset** parameters. Set the **CAN Steer Left Stop** parameter to the observed count.
   4. Move the CAN Sensor to the Right position (not to the actual physical stop, but a small amount away, to allow for sensor tolerance variation) and observe the counts shown in the Monitor » Command Input » CAN Input » *CAN Steer Counts* and *CAN2 Steer Counts* variables. Set the **CAN Steer Right to Center** parameter to the observed count.

c. For Relative Position Mode (Absolute Mode = Off):
   1. Set the **CAN Steer Center Offset** and **CAN2 Steer Center Offset** to zero, as these parameters are not used in relative position mode.
   2. Set the **CAN Steer Left Stop to Center** parameter to the number of negative counts required to produce a steer command from center to full left.
   3. Set the **CAN Steer Right Stop to Center** parameter to the number of counts required to produce a steer command from center to full right.
   4. Verify that turning the CAN sensor to the left results in negative counts for both the *CAN Steer Counts* and the *CAN2 Steer Counts* variables. Change the **CAN Steer Swap Direction** and **CAN2 Steer Swap Direction** as necessary to achieve negative count values for both the *CAN Steer Counts* and the *CAN2 Steer Counts* variables.

"5" — None. No Supervisory Steer Command Input Device *(see page 22)*

This option is available only for the Supervision Input Device parameter, and allows systems with a single steer command device to be set up without having to supply connections from the single primary input device to the supervisory inputs. **Using a single steer command device will make the system non-compliant with EN 13849.**

IMPORTANT

④ **Force Feedback Setup** *(see page 33)*

If the command input device has a force feedback option, turn this function on by setting the parameter Command Device » Force Feedback Device » **Enable** = On.

Set up the force using the **Min Voltage**, **Max Voltage**, and **Max Torque** parameters. If end stop force desired, set the parameter **End Stop** = On. If end stop force vibration is desired, set the parameter **End Stop Vibe** = On and set the vibration frequency and duty cycle using the parameters **Vibe On Time** and **Vibe Off Time**.

⑤ **Verification of the Command Input Setup**

To verify the setup thus far, observe Monitor » Command Input » *Steer Command (deg)* and *Steer Command 2 (deg)*. If either signal gives an undesired output, you must go back and resolve this problem before continuing.

Observe the variable Monitor » Supervision » *Steer Command Error* while changing the steer command input; this will show the difference between *Steer Command (deg)* and *Steer Command 2 (deg)*. Find the maximum Steer Command Error, and set the Supervision » **Steer Command Tolerance** to a comfortable margin above the maximum Steer Command Error found. In most vehicles the sensors should be designed to allow using a **Steer Command Tolerance** of 10° or less.

⑥ **Verification of Steer Motor Encoder 3 Direction**

Note: The steer motor should move freely as there should be no power applied to the steer motor. If the steered wheel cannot move freely and be safely moved (or if the Interlock is On), please stop and resolve the issue.

Use the Monitor » Steer Motor » *Motor RPM* menu to check the Encoder 3 direction. Rotate the steer motor by hand and observe the sign of *Motor RPM*. Positive is Right and negative is Left. If you get a positive *Motor RPM* when you rotate the motor in the Right direction and a negative *Motor RPM* when you rotate the motor in the Left direction, the Motor » **Swap Encoder3 Direction** parameter is set correctly and should not be changed.

If you get negative *Motor RPM* when you rotate the motor in the Right direction, **Swap Encoder3 Direction** must be changed. Cycle KSI power and repeat until you are satisfied that **Swap Encoder3 Direction** is correctly set. Contact your Curtis customer support engineer to resolve any issues about encoder direction before continuing.

CAUTION

> Continuing with the commissioning procedures will require the steer motor to turn, so you will have to enable the steer interlock (interlock = On). The vehicle drive wheels should continue to be jacked up off the ground so they can spin freely and steer freely from stop to stop. **Enabling the steer interlock can result in erratic movement of the steer motor.**

⑦ Position Feedback Device Setup *(see pages 34–36)*

Manually enable the steer interlock, so that the 1222 will begin steering; the traction interlock can remain Off. Verify that the 1222 interlock is now On (Monitor » Interlock » *Interlock*). If *Interlock* = Off, resolve the fault condition that is causing this, change the interlock input to the steer controller, or adjust the Interlock Type parameter (Vehicle Configuration » **Interlock Type**) until the *Interlock* variable = On.

Your position feedback device will be a dual potentiometer or a sine/cosine sensor or sawtooth sensor (using pins J1-16 and J1-17) or a dual encoder motor encoder with a Home switch (using pins J1-31, J1-32, J1-26, and J1-27 for the motor encoders and J1-12 for the Home switch). Most applications will have a primary feedback device and a supervisory feedback device.

Set the **Position Feedback Device** parameter and the **Supervision Feedback Device** parameter to the type of input you will be using:

Position Feedback Device Types	**Supervision Feedback Device** Types
0 = Pot feedback	**0** = Pot feedback
1 = Encoder feedback	**1** = Encoder feedback
2 = Sin/Cos Sensor feedback	**2** = Sin/Cos Sensor feedback
3 = Sawtooth Sensor feedback	**3** = Sawtooth Sensor feedback
	4 = None

Use the appropriate setup procedure for the devices, for the type of device you have chosen for each. For applications with only a primary position feedback device, you will need to set the **Supervision Feedback Device** parameter to 4.

"0" — Setup for Pot feedback *(see page 37)*

a. Use the steer command input to move the steered wheel to the Left stop. If the steer motor turns to the Right when the command is to turn to the Left, shut down the vehicle and disconnect the battery. Swap any two of the steer motor phase cables (U, V, or W) at the 1222; this will reverse the direction of the steer motor. Reconnect the battery and retest to confirm that the steer motor now turns to the Left when commanded to turn Left.

   Once the steered wheel has moved to the Left stop, observe the two voltages shown in the Monitor » Position Feedback » Analog Input » *Analog5* and *Analog6* variables. Set the parameters **Analog5 Left Stop** and **Analog6 Left Stop** to the observed voltages.

   If the steered wheel fails to reach the Left stop because it reaches the **Analog5 Left Stop** voltage before it reaches the stop, adjust the **Analog5 Left Stop** to a value that will allow the Left stop to be reached. Adjust **Analog6 Left Stop** similarly, if necessary.

b. Similarly, move the steered wheel to the Center and observe the two voltages shown in the *Analog5* and *Analog6* variables. Set the parameters **Analog5 Center** and **Analog6 Center** to the observed voltages.

c. Finally, move the steered wheel to the Right stop and observe the two voltages shown in the *Analog5* and *Analog6* variables. Set the parameters **Analog5 Right Stop** and **Analog6 Right Stop** to the observed voltages.

d. Set the four fault parameters (**Analog5 Fault Min**, **Analog5 Fault Max**, **Analog6 Fault Min**, and **Analog6 Fault Max**). Set these to voltages that will not be reached during normal operation, but will be reached if the steer position feedback becomes faulty (e.g., should there be an open or short circuit).

The Fault Min settings must be below the minimum voltage seen on *Analog5* or *Analog6* when steered to the maximum left and right positions.

The Fault Max settings must be above the maximum voltage seen on *Analog5* or *Analog6* when steered to the maximum left and right positions.

"1" — Setup for Encoder feedback and Home Switch *(see pages 38–40)*

a. If you have set up a 360° steering function with the command map (see page 76), you must set up the parameter Feedback Device » 1-Encoder3 and 4 » Homing » **Homing Cam Angle (deg)**. For 360° steering this parameter should be set to the angle of the homing cam. This setting is necessary because the 360° steering function has the homing switch triggered in two different wheel positions.

b. Set the **Input Type**, **Home on Interlock**, and **Homing Speed** parameters. **Homing Speed** can be set to a lower speed than required as the final setting will be performed in Step ⑧-a.

c. Review the diagrams in the **Homing Direction Method** parameter description on page 39. Then determine the correct **Homing Direction Method** by observing the Monitor » Home Reference » *Home* variable while also observing the position of the steered wheel and the Home switch.

If *Home* = On and the steered wheel is to the right of the Home switch (or *Home* = Off and steered wheel is to the leftt), setting **Homing Direction Method** to either 0 or 1 will result in the correct direction toward the Home switch during homing. Choose 0 or 1 depending on which side of the Home switch you prefer the steered wheel to be when homing is complete.

If *Home* = On and the steered wheel is to the left of the Home switch (or *Home* = Off and steered wheel is to the right), setting **Homing Direction Method** to either 2 or 3 will result in the correct direction toward the Home switch during homing. Choose 2 or 3 depending on which side of the Home switch you prefer the steered wheel to be when homing is complete.

After setting the **Homing Direction Method**, verify that the homing function works correctly starting from either side of the Home switch.

d. The correct settings for **Encoder3 Counts/Degree** and **Encoder4 Counts/Degree** can be either calculated or determined by testing.

Calculation method:

Encoder Counts/Degree = Gear Ratio * Encoder PPR * 4/360

Note: The factor of 4 in the equation accounts for the number of edges in one encoder pulse (rising phase A, falling phase A, rising phase B, falling phase B).

Example: Steer motor gearbox ratio = 45:1
Big gear around steer motor = 80 teeth
Small gear around steer motor shaft = 20 teeth
Encoder 3 steps (pulses per revolution) = 32.

The overall Gear Ratio = 45 * 80/20 = 180:1.

Encoder3 Counts/Degree = Gear Ratio * Encoder PPR * 4/360
= 180 * 32 * 4/360 = 64.

Testing method:

Use the steer command input to move the wheel position to a known angle. For best accuracy, choose a known angle as far as possible from the Home switch; this will usually be either the Left stop or the Right stop. If you cannot reach the "known angle," most likely the present setting of **Encoder# Counts/Degree** is too high; you can check whether Monitor » Position Feedback » *Left Stop Reached* or *Right Stop Reached* = On. Decreasing the **Encoder# Counts/Degree** values will move the Left and Right stops out, allowing more movement of the steered wheel.

When the wheel position reaches the "known angle" (usually either the Left or Right stop), observe the two variables Monitor » Position Feedback » Encoder Input » *Encoder3 Counts from Home* and *Encoder4 Counts from Home*. Divide these values by the number of degrees between the known angle and the Home switch to get the Encoder Counts/Degree for both encoders.

Example: Home Switch is at -4°
Left Stop (deg) set to 90°
Right Stop (deg) set to 90°.

Use the steer command input to steer the wheel to a 90° position. (This is the confirmed physical steer angle and may not agree with the monitored wheel position variable.) Observe the variables Monitor » Position Feedback » Encoder Input » *Encoder3 Counts from Home* and *Encoder4 Counts from Home*.

Encoder3 Counts from Home = 6016
Encoder4 Counts from Home = 3008.

6016/90 - (-4) = 6016/94 = 64

So set **Encoder3 Counts/Degree** = 64.

3008/90 - (-4) = 3008/94 = 32

So set **Encoder4 Counts/Degree** = 32.

Note: Encoders 3 and 4 can have different counts/degree, either because they have different PPRs or because Encoder 4 is not a steer motor encoder (e.g., it may be counting teeth of the steering gear).

"2" — Setup for Sin/Cos Sensor feedback *(see page 41)*

a. Set the parameters **Amplitude** and **Offset** according to the sensor manufacturer's specifications. Amplitude is usually referred to as Gain in the specs. Amplitude is half the peak-to-peak voltage, and Offset is the center of the peak-to-peak from ground.

If sensor specs are not available, use the voltages shown in the Monitor » Position Feedback » Analog Input » *Analog5* and *Analog6* variables as follows. To calculate the Offset, find the highest and lowest values of *Analog5* and *Analog6* while slowly sweeping the position feedback device. Add these two values together and divide by two. Input this number in the **Offset** parameter. Next, subtract the lowest value of *Analog5* and *Analog6* from the Offset parameter value. Input this number in the **Amplitude** parameter. Example: While the position feedback device is moved slowly, *Analog5* and *Analog6* are shown to have a maximum voltage of 4.1 V and a minimum voltage of 1.9 V; therefore, Offset = 3.0 V and Amplitude = 1.1 V.

b. Use the steer command input to move the steered wheel (and the position feedback Sin/Cos Sensor) to the center position and observe the angle shown in the Monitor » Position Feedback » Analog Input » *Position Raw* variable. Set the **Center Position** to the observed angle.

c. Use the steer command input to move the steered wheel (and the position feedback Sin/Cos Sensor) to the Left position and observe the angle shown in the Monitor » Position Feedback » *Wheel Position* variable. The Left steer direction must be set up as negative. If the observed angle is positive, change the **Swap Direction** parameter and verify that the wheel position sign is now correct.

d. Set the two fault parameters (**Fault Min** and **Fault Max**) to voltages that will not be reached during normal operation, but will be reached if the position feedback inputs become faulty (e.g., should there be an open or short circuit).

The Fault Min settings must be below the minimum voltage seen on *Analog5* or *Analog6* when steering between the maximum left and right positions.

The Fault Max settings must be above the maximum voltage seen on *Analog5* or *Analog6* when steering between the maximum left and right positions.

e The **Tolerance** parameter can be set in either of two ways.

1. Obtain the tolerance of **Min Volts** and **Max Volts** from the manufacturer's specs, and then calculate the worst case difference in voltage between the calculated voltages and the measured *Analog5* and *Analog6* voltages over the range of the sensor. Set the **Tolerance** to a comfortable margin above the maximum calculated difference.
2. Manually lower the **Tolerance** value while adjusting the Sin/Cos Sensor over the entire output range until the fault Sin/Cos Feedback

Sensor (Fault Code 48) is generated. Repeat this until you find the minimum **Tolerance** value that will not cause the fault (over the entire sensor range). Set the **Tolerance** to a comfortable margin above the minimum tolerance found.

"3" — Setup for Sawtooth Sensor feedback *(see page 42)*

a. Set the parameters **Min Volts** and **Max Volts** according to the sensor manufacturer's specifications.

If sensor specs are not available, use the voltages shown in the Monitor » Position Feedback » Analog Input » *Analog5* and *Analog6* variables as follows. Find the highest and lowest values of *Analog5* and *Analog6* while slowly sweeping the position feedback device. Input the lowest value as **Min Volts** and the highest value as **Max Volts**. Example: While the position feedback device is moved slowly, *Analog5* and *Analog6* are shown to have a maximum voltage of 4.1 V and a minimum voltage of 1.9 V; therefore, Max Volts = 4.1 V and Min Volts = 1.9 V.

b. Use the steer command input to move the steered wheel (and the position feedback Sin/Cos Sensor) to the center position and observe the angle shown in the Monitor » Position Feedback » Analog Input » *Position Raw* variable. Set the **Center Position** to the observed angle.

c. Use the steer command input to move the steered wheel (and the position feedback Sawtooth Sensor) to the Left position and observe the angle shown in the Monitor » Position Feedback » *Wheel Position* variable. The Left steer direction must be set up as negative. If the observed angle is positive, change the **Swap Direction** parameter and verify that the wheel position sign is now correct.

d. Set the two fault parameters (**Fault Min** and **Fault Max**) to voltages that will not be reached during normal operation, but will be reached if the position feedback inputs become faulty (e.g., should there be an open or short circuit).

The Fault Min settings must be below the minimum voltage seen on *Analog5* or *Analog6* when steering between the maximum left and right positions.

The Fault Max settings must be above the maximum voltage seen on *Analog5* or *Analog6* when steering between the maximum left and right positions.

e. The *Analog5* and *Analog6* voltages of the Sawtooth Sensor should always be 0.5*(**Max Volts** - **Min Volts**) apart. A fault check is done by comparing the two voltages and calculating the error. If the error is greater than the **Tolerance** voltage for 60 ms, a fault is issued.

The **Tolerance** parameter can be set in either of two ways.

1. Obtain the tolerance of the sensor from the manufacturer's specs, and then calculate the worst case difference between the two channels. Next determine the difference between the worst case and the ideal, ABS (WorstCase - 0.5*(**Max Volts** - **Min Volts**)). This is the minimum **Tolerance** value. Set the **Tolerance** to a comfortable margin above the minimum Tolerance found.

2. Manually lower the **Tolerance** value while adjusting the Sawtooth Sensor over the entire output range until the fault Sawtooth Feedback Sensor (Fault Code 48) is generated. Repeat this until you find the minimum **Tolerance** value that will not cause the fault (over the entire sensor range). Set the **Tolerance** to a comfortable margin above the minimum tolerance found.

"4" — None. No Supervisory Position Feedback Device *(see page 36)*

This option is available only for the Supervision Feedback Device parameter, and allows systems with a single position feedback device to be set up without having to supply connections from the single primary feedback device to the supervisory inputs. **Using a single position feedback device may make the system non-compliant with EN 13849, and must be evaluated by the OEM.**

IMPORTANT

⑧ Set the remaining Performance and Supervision parameters

a. Restore these two parameter values to their desired performance settings:

   Motor » **Max Speed**
   Motor » **Max Current**.

   If **Position Feedback Device** = 1, set **Homing Speed** (which is a percentage of **Max Speed**) to the desired setting.

b. Observe Monitor » Battery and Supply » *5v Out* and set the following parameter values to a comfortable margin above and below the observed value:

   Supervision » **5V Current Max**
   Supervision » **5V Current Min**.

   The **5V Current Min** setting should be such that it will detect a disconnected sensor (pot, encoder, or sine/cosine sensor) in either the steer command or position feedback circuit. Check the settings by disconnecting a steer command sensor and verify that a 5V Current Out of Range fault (code 69) is triggered. Similarly, disconnect a position feedback sensor and verify that a code 69 fault is triggered.

c. If a Home switch is present, steer across the Home switch while observing Monitor » Supervision » *Home Reference Error*. Set Supervision » **Home Reference Tolerance** to a comfortable margin above the maximum Home Reference Error found.

d. Temporarily set Steering Sensitivity » **LS Sensitivity** and **HS Sensitivity** = 100%.
   With this setting, and the drive wheels still jacked up off the ground, set the three parameters in the Motor Control Tuning menu (see page 52) to get correct responsiveness to the steer command input.

Note: Setting these values too high will result in unstable responsiveness. Increase these values as high as possible without becoming unstable.

Motor Control Tuning » **Position Kp**
Motor Control Tuning » **Velocity Kp**
Motor Control Tuning » **Velocity Ki**.

After setting these three parameters, return **LS Sensitivity** and **HS Sensitivity** to their proper values.

⑨ Verify the Position Feedback Setup

To verify the setup thus far, observe Monitor » Position Feedback » *Wheel Position (deg)* and *Wheel Position 2 (deg)* while exercising the steer command input device over the entire operational steer range. If either signal gives an undesired output, go back and resolve this problem before continuing.

Next, observe the variable Monitor » Supervision » *Wheel Position Error* while changing the position; this will show the difference between *Wheel Position (deg)* and *Wheel Position 2 (deg)*. Find the maximum Wheel Position Error, and set the Supervision » **Wheel Position Tolerance** to a comfortable margin above the maximum Wheel Position Error found.

⑩ Resolve any existing faults

Cycle the Keyswitch input to reset the vehicle controllers. Check the active faults in the controller and resolve any faults until all have been cleared. All faults must be cleared before lowering the vehicle drive wheels to the ground. Use Section 6 for help in troubleshooting. Contact your Curtis customer support engineer to resolve any remaining issues about faults before continuing.

CAUTION

Do not take the vehicle down off the blocks until both the steer and traction motors are responding properly. Once the motors are responding properly, lower the vehicle to put the drive wheels on the ground.

⑪ Set the Following Error parameters *(see page 47)*

Setting up the following-error function involves setting three parameters: Supervision » Following Error » **Error Tolerance (deg)**, **Speed Tolerance (deg/s)**, and **Error Time**.

The parameters **Error Tolerance (deg)** and **Speed Tolerance (deg/s)** are related through the equation:

$$\text{Speed Tolerance (deg/s)} \leq \text{Error Tolerance (deg)} * \text{Min}(\text{LS Sensitivity}, \text{HS Sensitivity}) * \text{Position Kp}$$

$$* \frac{360 \text{ RPM}}{1 \text{ deg}} * \frac{360 \text{ deg}}{1} * \frac{1 \text{ Min}}{\text{Rev } 60 \text{ s}} * \frac{1}{\text{Gear Ratio}} ,$$

$$\text{where Gear Ratio} = \frac{\text{Motor Revs}}{\text{Wheel Revs}} .$$

Note that **Error Tolerance (deg)** is in degrees and **Speed Tolerance (deg/s)** is in degrees/second. **LS Sensitivity**, **HS Sensitivity**, and **Position Kp** are all in percent, and should be entered in decimal form in this equation (e.g., 50% = 0.5). It is recommended that **Speed Tolerance (deg/s)** be set to about half the value given by the above equation, to allow some safety factor.

If the gear ratio is not known, it may be determined experimentally by adjusting the **Encoder3 Counts/Degree** until the *Encoder 3 Position (deg)* looks close after multiple revolutions. The gear ratio can then be calculated as:

$$\text{Gear Ratio} = \frac{\text{Encoder3 Counts/Degree}}{\text{Encoder3 Steps} * 4} * \frac{360 \text{ deg}}{1 \text{ Rev}} .$$

Likewise, if the gear ratio is known, **Encoder3 Counts/Degree** may be determined by the above equation. If we then combine these two equations and include the suggested safety factor of 1/2, we get:

$$\text{Speed Tolerance (deg/s)} = 0.5 * \text{Error Tolerance (deg)} * \text{Min}(\text{LS Sensitivity}, \text{HS Sensitivity})$$

$$* \text{Position Kp} * \frac{\text{Encoder3 Steps}}{\text{Encoder3 Counts/Degree}} .$$

The **Error Tolerance (deg)** value should be not too large to accept the steady state error, and not too small to accept the resulting **Speed Tolerance (deg/s)**. For example, an **Error Tolerance (deg)** of 20° means that no fault will be detected as long as the **Wheel Position (deg)** is within ±20° of **Steer Command (deg)**. Thus a steady state error of 20° is allowed, which is probably too high for most applications. If we choose instead an **Error Tolerance (deg)** of only 2° and calculate the resulting **Speed Tolerance (deg/s)** for some typical settings of **Position Kp** = 35%, **LS Sensitivity** = 70%, **HS Sensitivity** = 50%, and a gear ratio of 132, we get a **Speed Tolerance (deg/s)** of 2.9 deg/s. For most applications this is probably too slow for the wheel to be moving in the right direction without a fault being issued. For most applications, an **Error Tolerance (deg)** between 5° and 10° works well. Likewise, a **Speed Tolerance (deg/s)** of at least 10 deg/s is often needed to be acceptable.

The **Error Time** must be set long enough for the steered wheel to reverse direction and get to the minimum speed under the worst case conditions. This may be measured in the field by moving the steer input command rapidly one direction and then the other. This should achieve the maximum speed in one direction followed by a reversal and acceleration past the **Speed Tolerance (deg/s)** in the other direction. This time, doubled to provide a safety factor, should be used for the **Error Time**. With appropriate tuning, most applications should be able to use an **Error Time** of 0.5 – 0.8 seconds.

To test the following-error parameter settings, steer under worst case conditions (maximum weight on vehicle, rough floor, new tire) as follows:

a) Steer in one direction and then reverse and steer at an angle at least equal to the **Error Tolerance (deg)**. Then reverse (quickly!) and steer back at an angle at least equal to the **Error Tolerance (deg)** then reverse (quickly!) and steer back at an angle at least equal to the **Error Tolerance (deg)**. Continue doing this back and forth until a Following Error is triggered.

b) Steer, always as quickly as possible, from end stop to end stop, back and forth, until a Following Error is triggered.

While steering using these two procedures, slowly lower the **Error Time** until a Following Error is triggered.

Finally, verify that the original proposed setting of **Error Time** is a comfortable margin above the setting that began to trigger the fault. If a comfortable margin is not provided with the original proposed setting, increase the **Error Time** until a comfortable margin is obtained—but also verify that the **Error Time** is not too slow, which will create a delay in detection a real following error.

⑫ Set the remaining Supervision parameters

If **Position Feedback Device** = 1, leave the setting Supervision » **Encoder Position Tolerance** = 90°. This fault check is not used when the position feedback devices are encoders, so the setting of 90° disables this fault check.

For all other settings of **Position Feedback Device** (= 0 or = 2), observe the variable Monitor » Supervision » *Encoder Position Error (deg)* while changing the position; this will show the difference between Wheel Position and Encoder 3 Position. Find the maximum *Encoder Position Error (deg)*, and set Supervision » **Encoder Position Tolerance** to provide a comfortable margin above the maximum *Encoder Position Error (deg)* found.

Set Supervision » **Stall Steering Speed** and **Stall Timeout** to appropriate values that will not cause a fault during normal operation, but will trigger a fault during a real stall condition.

6 INTERFACE WITH MASTER CONTROLLER

The 1222 controller is a slave controller. The master controller is a Curtis AC traction controller. The controllers communicate with each other through the CAN bus.

CAN MESSAGES

The 1222 and the traction controller communicate with each other through the CAN bus, using PDO messages. The 1222 sends an emergency message to the traction controller any time a fault is set or cleared.

PDO Message Configuration

The traction controller sends PDO1_MOSI every 40 ms and the steering controller sends both PDO1_MISO and PDO2_MISO every 20 ms.

PDO1_MOSI — Received from traction controller every 40 ms
Byte 1 — TractionMotorRPMCAN (CAN Index 0x2080, Low Byte)
Byte 2 — TractionMotorRPMCAN (CAN Index 0x2080, High Byte)
Byte 3 — TractionIsReady (CAN Index 0x2081, Bit 0)
Byte 4 — CANInterlock (CAN Index 0x4447, Bit 0)
Byte 5 — Unused
Byte 6 — Unused
Byte 7 — Unused
Byte 8 — Unused

PDO1_MISO — Sent by the 1222 every 20 ms when in operational state
Byte 1 — WheelPosition (CAN Index 0x2000, Low Byte)
Byte 2 — WheelPosition (CAN Index 0x2000, High Byte)
Byte 3 — 0 (Reserved)
Byte 4 — TractionCutback (CAN Index 0x2003)
Byte 5 — TractionFaultAction (CAN Index 0x2005)
Byte 6 — EnableTraction (CAN Index 0x2001)
Byte 7 — 0
Byte 8 — 0

PDO2_MISO — Sent by the 1222 every 20 ms when in operational state
Byte 1 — EnableTractionInverted (CAN Index 0x2002)
Byte 2 — TractionCutbackInverted (CAN Index 0x2004)
Byte 3 — Switches (CAN Index 0x4475)
Byte 4 — 0
Byte 5 — 0
Byte 6 — 0
Byte 7 — 0
Byte 8 — 0

TractionMotorRPMCAN is the rpm of the traction motor and can be used to determine when to steer (see **Interlock Enabled Speed**, page 45).

TractionIsReady is used if programmed **Contactor Type** = 2; it has bit 0 = contactor is open, and bit 1 = contactor is closed.

CANInterlock is the interlock from the traction system that is used if programmed **Interlock Type** = 3; it has bit 0 = interlock is open, and bit 1 = interlock is closed.

WheelPosition is the position of the steered wheel, in degrees. This is used by the traction system to determine the maximum allowed speed.

TractionCutback is the percentage of its MaxSpeed that the traction controller is allowed to run.

TractionFaultAction has bit 0 = no fault, bit 1 = stop traction, bit 2 = reduce traction speed, and bit 3 = no action. See right-hand column in the troubleshooting chart (Table 6).

EnableTraction has bit 0 = stop and bit 1 = traction enabled.

EnableTractionInverted is the inverse of EnableTraction.

TractionCutbackInverted is the inverse of TractionCutback.

Switches has bit 0 = Interlock Input 1, bit 1 = Home Input 2, bit 2 = Interlock Input 3, and bit 3 = Home Input 4.

Emergency Message Configuration

The 1222 sends an emergency message any time a fault is set or cleared. For a description of the variables see the troubleshooting chart (Table 6) and the generic Curtis CANopen specification.

Byte 1 — ErrorCode (Low Byte)
Byte 2 — ErrorCode (High Byte)
Byte 3 — ErrorRegister (CAN Object 0x1001)
0x01 if any fault is present or 0x00 is no faults
Byte 4 — SubCode *See the troubleshooting chart*
Byte 5 — FlashCode *See the troubleshooting chart*
Byte 6 — TractionFaultAction *See the troubleshooting chart*
Byte 7 — Reserved
Byte 8 — Reserved

GENERIC AC TRACTION CONTROLLER SOFTWARE

IMPORTANT

Review your application's needs carefully to ensure they are met by the conditions described below and the signal flow diagram presented in Figure 17. If they are not, contact your local Curtis representative for assistance in reconfiguring the software.

The bulleted items below are based on AC_Traction_with_1222.vcl software features description for VCL App Version = 2.00.

- The 1222 software is limited to traction applications that use Speed Mode or Speed Mode Express. If your AC controller uses Torque Mode, you will need to make changes in the software. Contact your local Curtis representative.

- You must use 1222 software version OS 13.0 or later; earlier versions will not work.

- Steering CAN Comm Failure (AC controller fault code 51) is set when:
  - AC controller is unable to receive a CAN heartbeat from the 1222 on startup
  - neither PDO1_MISO nor PDO2_MISO arrives within 50 ms (PDO Timeout)
  - redundant 1222 CAN data (from PDO1_MISO and PDO2_MISO) mismatches for more than 100 ms.

- Severe Steering Fault (code 52) is set when the traction fault action sent from the 1222 to the AC controller (in either a PDO1_MISO or an emergency message) indicates Stop Traction (=1).

- Steering Fault (code 53) is set when the traction fault action sent from the 1222 to the AC controller (in either a PDO1_MISO or an emergency message) indicates Reduce Traction Speed (=2) or No Action (=3).

- The generic AC traction controller software contains a traction speed reduction map with the wheel position angle at different forward and reverse maximum speeds.

- PDO1_MOSI messages are sent every 40 ms; if you want a different frequency, you will need to change the AC traction controller software.

- The 1222 Traction Cutback (from PDO1_MISO) will reduce the traction speed by reducing the throttle command. **This method of traction speed reduction means that the traction Emergency Reverse function will not be speed-reduced by the 1222 Traction Cutback data.**

Note: The AC controller's Analog Output (pin 30) can be connected to the Curtis 1165 wheel position indicator to display the 1222 wheel position from PDO1_MISO.

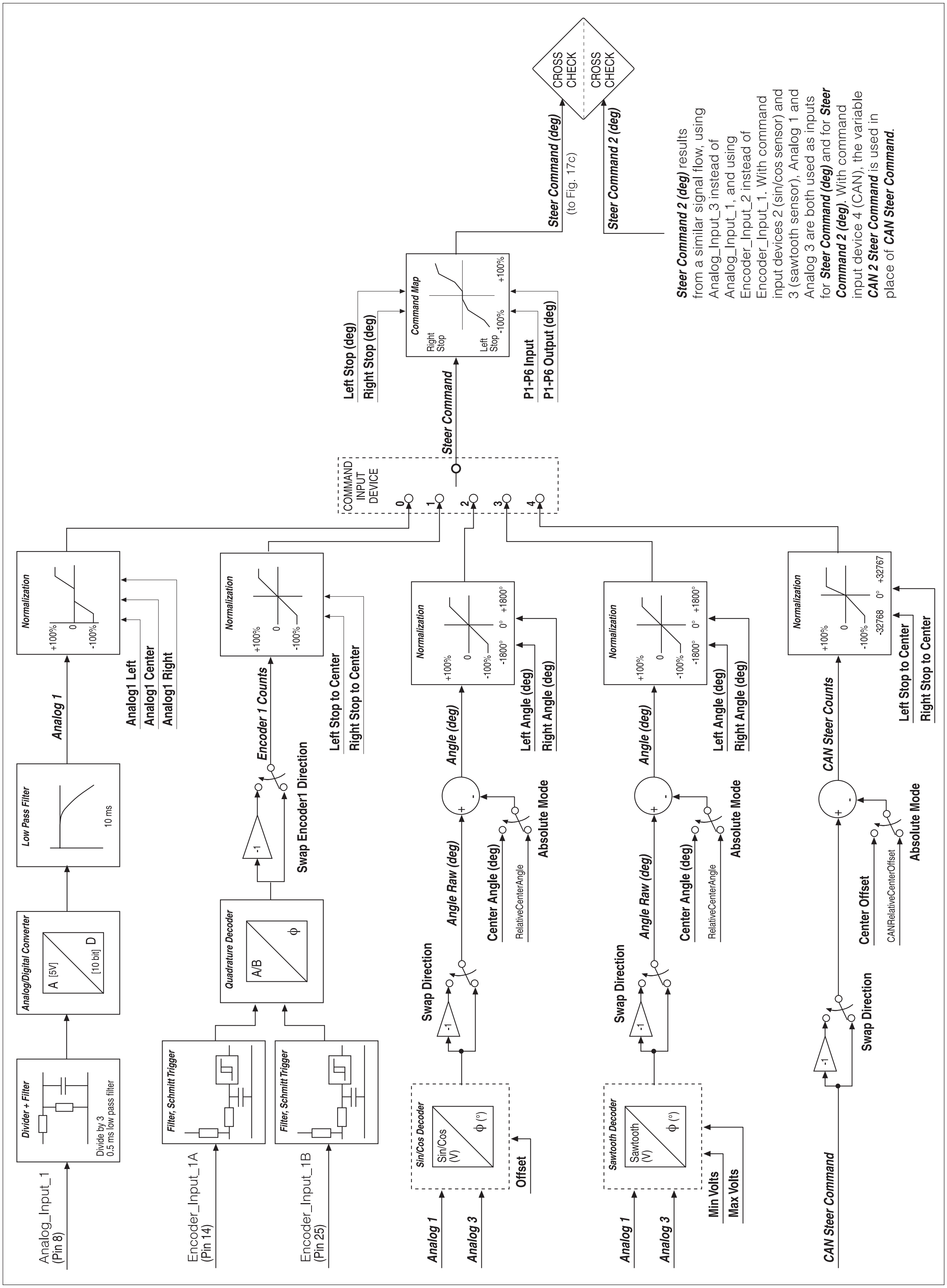


Fig. 17a *Input Command signal flow.*

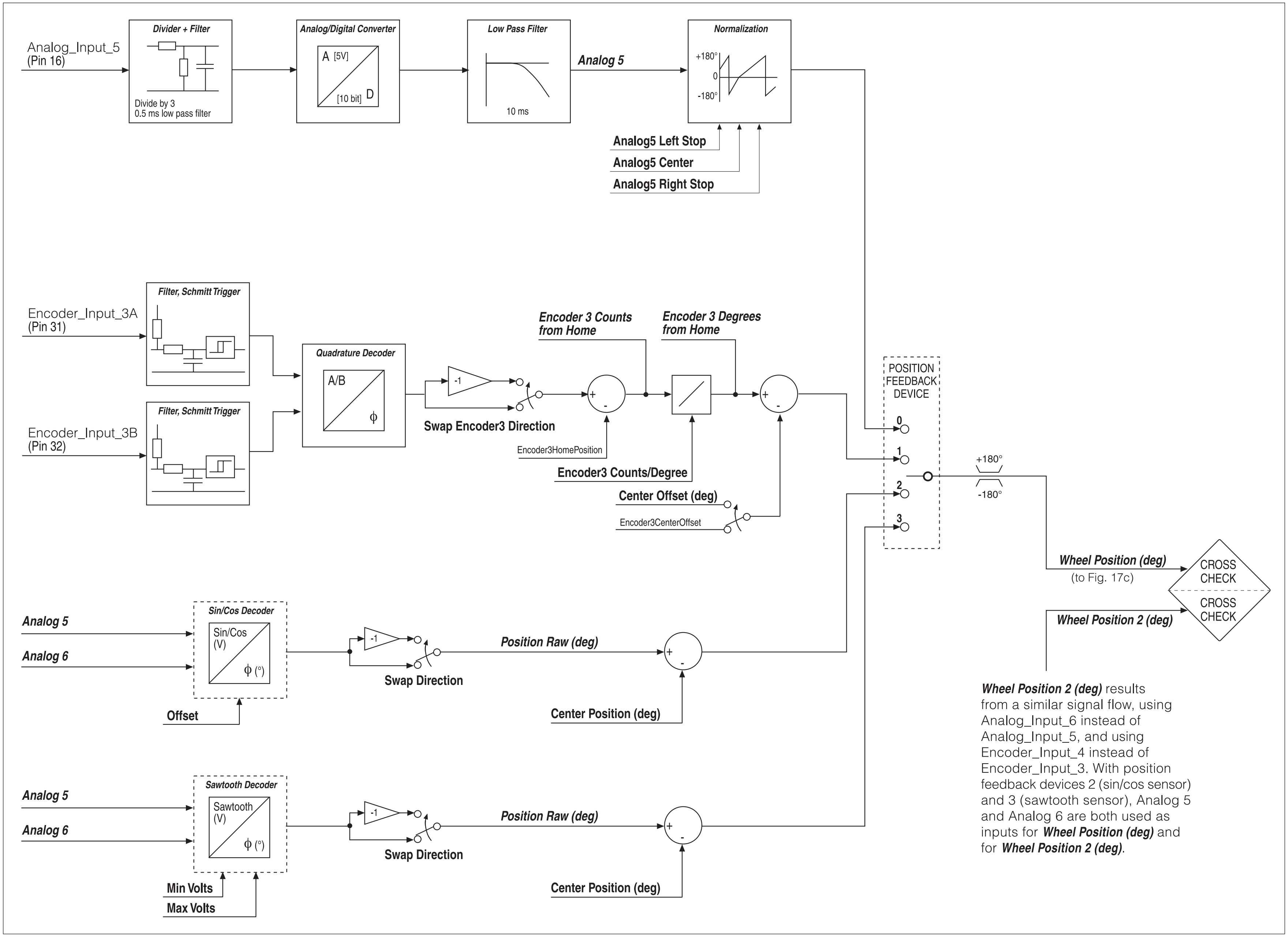


Fig. 17b *Position Feedback signal flow.*

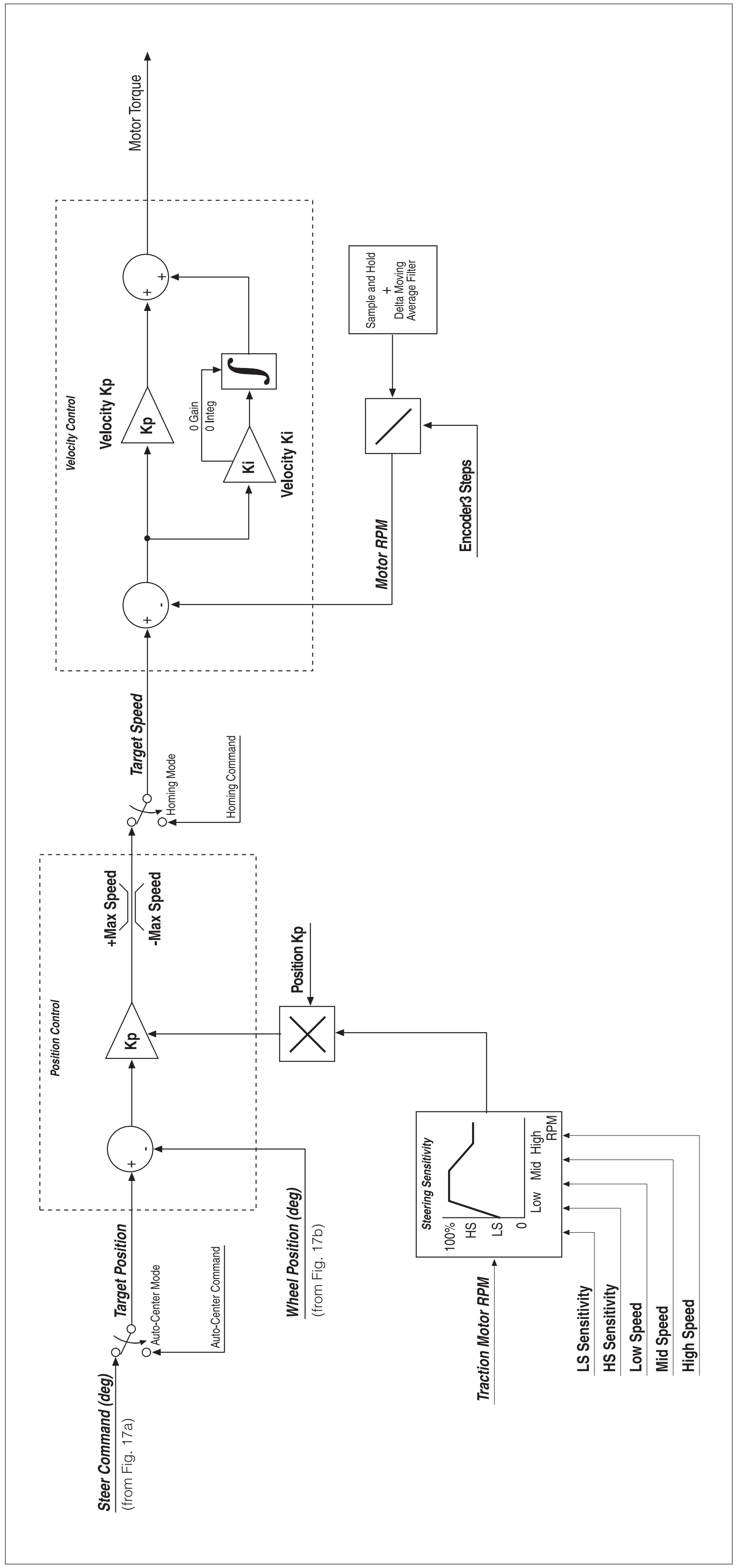


Fig. 17c *Position/Velocity Control signal flow.*

7 DIAGNOSTICS & TROUBLESHOOTING

The 1222 controller detects a wide variety of fault conditions. Faults with the steering controller typically affect the traction controller as well, as shown in the troubleshooting chart.

DIAGNOSTICS

Diagnostics information can be obtained in either of two ways: (1) by reading the display on a handheld programmer or (2) by observing the fault codes issued by the Status LEDs. See Table 4 for a summary of LED display formats.

The handheld programmer will display 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 programmer displays the faults by name.

The pair of LEDs built into the controller (one red, one yellow) produce flash codes displaying all the currently set faults in a repeating cycle. Each code consists of two digits. The red LED flashes once to indicate that the first digit of the code will follow; the yellow LED then flashes the appropriate number of times for the first digit. The red LED flashes twice to indicate that the second digit of the code will follow; the yellow LED flashes the appropriate number of times for the second digit.

Example: Command Analog3 Out of Range (code 42).

In the Fault menu of the handheld programmer, the words **Command Analog3 Out of Range** will be displayed;
the actual voltage is displayed in the Monitor menu (Command Input»Analog Input»*Analog 3*).

The controller's two LEDs will display this repeating pattern:

RED	YELLOW	RED	YELLOW
*	* * * *	* *	* *
(first digit)	(4)	(second digit)	(2)

The numerical codes used by the yellow LED are listed in the troubleshooting chart (Table 6), which also lists possible fault causes and describes the conditions that set and clear each fault.

Summary of LED display formats

The two LEDs have four different display modes, indicating the type of information they are providing.

Table 5 TYPES OF LED DISPLAY

DISPLAY	STATUS
Neither LED illuminated	Controller is not powered on; or vehicle has dead battery; or severe damage.
Yellow LED flashing	Controller is operating normally.
Both LEDs on solid	Controller is in Flash program mode.
Red LED and yellow LED flashing alternately	Controller has detected a fault. 2-digit code flashed by yellow LED identifies the specific fault; one or two flashes by red LED indicate whether first or second code digit will follow.

TROUBLESHOOTING

The troubleshooting chart, Table 6, provides the following information about each controller fault:

- fault code and sub-code
- fault name as displayed on the programmer's LCD
- possible causes of the fault
- fault *set* conditions and fault *clear* conditions
- steer fault action (effect of fault on steering)
- traction fault action (effect of fault on traction)

For each fault, the chart shows one of these four **Steer Fault actions:**

Warning Only — The 1222 still operates normally.

Shutdown — Immediate shutdown of the 1222 and turn-off of the fault output (pin 23).

Warning then Shutdown — The 1222 continues to operate until the traction motor comes to a stop or the timer (set by Fault Steering Timeout) expires. After this occurs, the Shutdown action takes place.

Hold then Shutdown — The 1222 tries to hold the existing wheel position regardless of operator input until the traction motor comes to a stop or the timer (set by Fault Steering Timeout) expires. After this occurs, the Shutdown action takes place.

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 6 TROUBLESHOOTING CHART

FLASH CODE	SUB CODE	NAME	POSSIBLE CAUSE	SET CONDITION	CLEAR CONDITION	STEER FAULT ACTION	TRACTION FAULT ACTION
11	1	Hardware Fault	An internal hardware error has been detected; controller defective.	Hardware error detected.	Cycle KSI.	Shutdown.	1 = Stop.
12	1	Controller Overcurrent 1	1. External short of phase U, V, or W motor connection. 2. Controller defective.	Controller hardware detected overcurrent condition.	Cycle KSI.	Shutdown.	1 = Stop.
12	2	Controller Overcurrent 2	1. External short of phase U, V, or W motor connection. 2. Motor parameters are mis-tuned. 3. Controller defective.	1. Phase current >120% of base current limit. 2. Phase current exceeded the current measurement limit.	Cycle KSI.	Shutdown.	1 = Stop.
13	1	Current Sensor Fault	1. Leakage to vehicle frame from phase U, V, or W (short in motor stator). 2. Controller defective.	Controller current sensors have invalid offset reading.	Cycle KSI.	Shutdown.	1 = Stop.
14	1	Precharge	1. External load on capacitor bank (B+ connection terminal) that prevents the capacitor bank from charging. 2. Controller defective.	Capacitor bank voltage does not complete the charge to minimum of 75% of the keyswitch voltage.	Cycle KSI.	Shutdown.	1 = Stop.
15	1	Controller Severe Undertemp	Controller is operating in an extreme environment.	Controller heatsink temperature is equal to or below -40°C.	Bring heatsink temp above -35°C.	Warning Only.	3 = No action.
16	1	Controller Severe Overtemp	1. Improper mounting of controller. 2. Excessive load on vehicle. 3. Controller is operating in an extreme environment.	Controller heatsink temperature is equal to or above 95°C.	Cycle KSI.	Warning then Shutdown.	1 = Stop.
17	1	Severe Undervoltage	1. Battery or battery cables or battery connections defective. 2. Excessive non-controller system drain on battery. 3. Battery disconnected while driving. 4. Blown B+ fuse or steer contactor did not close.	1. Capacitor bank voltage (B+ terminal) less than 12 V when Interlock = On. 2. Keyswitch voltage less than 12 V.	Cycle KSI.	Shutdown.	1 = Stop.
18	1	Severe Overvoltage	1. Battery or battery cable resistance too high for a given regen current. 2. Battery disconnected while regen braking.	Keyswitch or capacitor voltage (B+ terminal) greater than 65 V.	Cycle KSI.	Shutdown.	1 = Stop.

Table 6 TROUBLESHOOTING CHART, continued

FLASH CODE	SUB CODE	NAME	POSSIBLE CAUSE	SET CONDITION	CLEAR CONDITION	STEER FAULT ACTION	TRACTION FAULT ACTION
22	1	Controller Overtemp	1. Improper mounting or cooling of controller. 2. Excessive load on vehicle. 3. Controller operating in an extreme environment.	Controller heatsink temperature is equal to or above 85°C.	Heatsink temp < 85°C.	Warning Only.	2 = Reduce speed. (Max speed reduced linearly from 100% at 85°C to 0% at 95°C.)
25	1	5V Supply Failure	External load impedance on the +5V supply is too low.	5V supply is outside the 5V +/- 10% range.	Cycle KSI.	Hold then Shutdown.	1 = Stop.
26	1	10V Supply Failure	External load impedance on the +10V supply is too low.	10V supply is outside the 10V +/- 10% range.	Cycle KSI.	Warning then Shutdown.	1 = Stop.
27	1	Severe Motor Over Temp	1. Motor is operating in an extreme environment. 2. Motor Temperature Control parameters are mis-tuned.	Sensor Enable = On and steer motor temperature > programmed Temperature Max.	Cycle KSI.	Warning then Shutdown.	1 = Stop.
28	1	Motor Temp Hot Cutback	1. Motor is operating in an extreme environment. 2. Motor Temperature Control parameters are mis-tuned.	Sensor Enable = On and steer motor temperature > programmed Temperature Hot.	Steer motor temperature < programmed Temperature Hot.	Warning Only.	2 = Reduce speed. (Max speed reduced linearly from 100% at Temperature Hot to 0% at Temperature Max.)
29	1	Motor Temp Sensor Fault	1. Motor thermistor is not connected properly. 2. If the application does not use a motor thermistor, the Motor Temperature Sensor Enable parameter should be programmed Off.	Motor temperature input is at the voltage rail (0 or 5V).	Motor temp input within the normal operating range.	Warning Only.	2 = Reduce speed. (Max speed reduced to Sensor Fault Traction Cutback.)
31	1	Contactor Open/Short	1. Open or short on driver load. 2. Dirty connector pins. 3. Bad crimps or faulty wiring.	Steer contactor driver is either open or shorted. This fault is set only when Contactor Control Type = 1 and Checks Enable = On.	Cycle KSI.	Warning then Shutdown.	1 = Stop.

Table 6 TROUBLESHOOTING CHART, continued

FLASH CODE	SUB CODE	NAME	POSSIBLE CAUSE	SET CONDITION	CLEAR CONDITION	STEER FAULT ACTION	TRACTION FAULT ACTION
35	1	Fault Output Open/Short	1. External load impedance on the fault output is too low. 2. Controller defective.	The controller is unable to assert the fault output line: 1. The Fault Output = On and the fault output voltage is not within 5 V of the KSI voltage. 2. The Fault Output = Off and the fault output voltage is greater than 80% of KSI voltage. 3. The Fault Output = On and the fault output voltage is less than 4 V.	Cycle KSI.	Warning then Shutdown.	1 = Stop.
36	1	Motor Stalled	1. Stalled steer motor. 2. Steer motor encoder failure. 3. Bad crimps or faulty wiring. 4. Problems with power supply of the steer motor encoder.	The motor has been commanded to move at more than 25% of the Max Motor Speed or at more than 95% of the available motor current when the motor speed is less than the programmed Stall Speed for the programmed Stall Time.	Cycle KSI.	Warning then Shutdown.	1 = Stop.
37	1	Motor Open	1. Motor phase is open. 2. Bad crimps or faulty motor cable wiring. 3. Controller defective.	1. After the steer contactor closes but before operation starts, the motor is checked for an open phase by running a DC current out of phase U and ensuring the current is measured back on both phase V and phase W. The fault is set if the check fails. 2. When the motor is running, one phase averages less than 1 A while the other phases average more than 4 A for 256 ms when the electrical frequency is greater than 1 Hz and has not changed sign.	Cycle KSI.	Warning then Shutdown.	1 = Stop.
38	1	Contactor Welded	1. Steer contactor tips are welded closed. 2. An alternative voltage path (such as an external precharge resistor) is providing a current to the capacitor bank (B+ terminal).	The steer contactor tips are shorted when the contactor is supposed to be open. This fault is set only when Contactor Control Type = 1 and Checks Enable = On. The weld check is done in Steer Contactor State = 3 (Opening) when DC current is applied to the motor. The fault will be set if the difference between the capacitor bank and keyswitch voltages does not exceed 2 V.	Cycle KSI.	Shutdown.	1 = Stop.

Table 6 TROUBLESHOOTING CHART, continued

FLASH CODE	SUB CODE	NAME	POSSIBLE CAUSE	SET CONDITION	CLEAR CONDITION	STEER FAULT ACTION	TRACTION FAULT ACTION
39	1	Contactor Opened	1. Steer contactor was closed temporarily, but then opened. 2. Steer contactor tips are oxidized. 3. An external load on the capacitor bank (B+ terminal) that prevents the bank from charging.	The steer contactor was closed, but detected open. This fault is set only when Contactor Control Type = 1 and Checks Enable = On. In Contactor State = 2 (Closed), the fault will be set if the capacitor bank and keyswitch voltages differ by more than 5 V.	Cycle KSI.	Warning then Shutdown.	1 = Stop.
39	2	Contactor Did Not Close	1. Steer contactor did not close. 2. Steer contactor tips are oxidized. 3. An external load on the capacitor bank (B+ terminal) that prevents the bank from charging.	The steer contactor did not close when commanded. This fault is set only when Contactor Control Type = 1 and Checks Enable = On. In Contactor State = 1 (Closing), the fault will be set if the capacitor bank and keyswitch voltages differ by more than 2 V.	Cycle KSI.	Shutdown.	1 = Stop.
41	1	Command Analog1 Out of Range	Command input device's Analog 3 input (pin 8) is out of range.	Analog1 voltage > Analog1 Fault Max or Analog1 voltage < Analog1 Fault Min. The fault is checked only if Command Input Device = 0, 2, or 3.	Cycle KSI.	Hold then Shutdown.	1 = Stop.
42	1	Command Analog3 Out of Range	Command input device's Analog 3 input (pin 19) is out of range.	Analog3 voltage > Analog3 Fault Max or Analog3 voltage < Analog3 Fault Min. The fault is checked only if Command Input Device = 0, 2, or 3.	Cycle KSI.	Hold then Shutdown.	1 = Stop.
43	1	Feedback Analog5 Out of Range	Position feedback device's Analog 5 input (pin 16) is out of range.	Analog5 voltage > Analog5 Fault Max or Analog5 voltage < Analog5 Fault Min. The fault is checked only if Position Feedback Device = 0, 2, or 3.	Cycle KSI.	Hold then Shutdown.	1 = Stop.
44	1	Feedback Analog6 Out of Range	Position feedback device's Analog 6 input (pin 17) is out of range.	Analog6 voltage > Analog6 Fault Max or Analog6 voltage < Analog6 Fault Min. The fault is checked only if Position Feedback Device = 0, 2, or 3.	Cycle KSI.	Hold then Shutdown.	1 = Stop.
45	1	CAN Not Operational	1222 CAN NMT State did not go operational within 80 ms of interlock being applied.	This check is made only when the parameter CAN Required = On. With Interlock = On for 80 ms, the CAN NMT State is <> Operational.	Cycle KSI.	Warning and drop fault output.	1 = Stop.

Table 6 TROUBLESHOOTING CHART, continued

FLASH CODE	SUB CODE	NAME	POSSIBLE CAUSE	SET CONDITION	CLEAR CONDITION	STEER FAULT ACTION	TRACTION FAULT ACTION
46	1	EEPROM CRC Fault	1. New software loaded into EEPROM memory. 2. Try using function "Restore to Factory Defaults" to clear fault. 3. Controller defective.	Error in EEPROM CRC calculation.	Cycle KSI.	Shutdown.	1 = Stop.
47	1	Sin/Cos Command Sensor	1. Sin/Cos Sensor defective. 2. Sin/Cos Sensor parameters are mis-tuned.	The Analog 1 and Analog 3 inputs do not match the expected sine and cosine signals. They must be within the parameter Fault Volts of the ideal waveform as defined by the Gain and Offset parameters.	Cycle KSI.	Hold then Shutdown.	1 = Stop.
47	2	Sawtooth Command Sensor	1. Sawtooth Sensor defective. 2. Sawtooth Sensor parameters are mis-tuned.	The Analog 1 and Analog 3 inputs do not match the expected sawtooth waveform. They must be within the parameter Command Device » 3-Sawtooth Sensor » Tolerance of the ideal 180° offset. ABS(ABS(Analog1-Analog3)-0.5*(MaxVolts +MinVolts))>Sawtooth Tolerance for 60 ms.	Cycle KSI.	Hold then Shutdown.	1 = Stop.
48	1	Sin/Cos Feedback Sensor	1. Sin/Cos Sensor defective. 2. Sin/Cos Sensor parameters are mis-tuned.	The Analog 5 and Analog 6 inputs do not match the expected sine and cosine signals. They must be within the parameter Fault Volts of the ideal waveform as defined by the Gain and Offset parameters.	Cycle KSI.	Hold then Shutdown.	1 = Stop.
48	2	Sawtooth Feedback Sensor	1. Sawtooth Sensor defective. 2. Sawtooth Sensor parameters are mis-tuned.	The Analog 5 and Analog 6 inputs do not match the expected sawtooth waveform. They must be within the parameter Feedback Device » 3-Sawtooth Sensor » Tolerance of the ideal 180° offset. ABS(ABS(Analog5-Analog6)-0.5*(MaxVolts +MinVolts))>Sawtooth Tolerance for 60 ms.	Cycle KSI.	Hold then Shutdown.	1 = Stop.

Table 6 TROUBLESHOOTING CHART, continued

FLASH CODE	SUB CODE	NAME	POSSIBLE CAUSE	SET CONDITION	CLEAR CONDITION	STEER FAULT ACTION	TRACTION FAULT ACTION
49	1	Parameter Change Fault	A parameter value or the software was changed that required a power cycle. This fault is set automatically to force the vehicle operator to cycle power, for safety purposes.	1. A parameter was changed that requires a power cycle. See PCF column in Sec. 3 (Programmable Parameter Menus) to identify the parameters that will cause a parameter change fault. 2. A new software application was loaded that caused the parameter values to be overwritten, requiring a power cycle. 3. A device using the serial interface (such as the 1313) is requesting an out-of-range parameter change.	Cycle KSI.	Shutdown.	1 = Stop.
51	1	Interlock Switch Supervision	1. When the interlock switch inputs are a crossed configuration (N.O. and N.C.), the two inputs are checked. A fault is set if Switch 1 (pin 9) = Switch 3 (pin 11). 2. Interlock switch defective.	Interlock Input 1 = Interlock Input 3. The fault is checked only when Interlock Type = 2 (crossed polarity).	Interlock Input 1 <> Interlock Input 3.	Interlock = Off.	1 = Stop.
52	1	Home Switch Supervision	1. When the wheel position is not close to home, the redundant home switch inputs are checked and a fault is set if they disagree. 2. Home switch defective. 3. For 360° steering, parameter Homing Cam Angle (deg) not set correctly.	1. Homing Input Type = 1 (crossed polarity) and Switch2 = Switch4 and the position from home is >Home Reference Tolerance. 2. Homing Input Type = 2 (same polarity) and Switch2 <> Switch4 and the position from home is >Home Reference Tolerance.	Cycle KSI.	Warning then Shutdown.	1 = Stop.
53	1	Home Position Not Found	Home switch defective.	During homing (Steer Command State = 2), the home position was not found after traveling 180° (360° in the case of 360° steering) or within the programmed Homing Timeout time.	Cycle KSI.	Shutdown.	1 = Stop.
54	1	Home Reference Tolerance Fault	1. Home switch defective. 2. For 360° steering, parameter Homing Cam Angle (deg) not set correctly.	During steering (Steer Command State = 4), the wheel position at which the Home variable changes is further than the parameter Supervision » Home Reference Tolerance from the original position found during homing.	Cycle KSI.	Warning then Shutdown.	1 = Stop.

Table 6 TROUBLESHOOTING CHART, continued

FLASH CODE	SUB CODE	NAME	POSSIBLE CAUSE	SET CONDITION	CLEAR CONDITION	STEER FAULT ACTION	TRACTION FAULT ACTION
55	1	Steer Command Supervision	Command input device defective.	Steer Command differs from Steer Command2 by more than the programmed Steer Command Tolerance. These command signals are checked by both the main and supervisor processors if the Device State = 5 (Operation Enabled). Note: This check is not performed if Supervision Input Device = 5.	Cycle KSI.	Hold then Shutdown.	1 = Stop.
56	1	Wheel Position Supervision	Position feedback device defective.	1. Wheel Position differs from Wheel Position2 by more than the Wheel Position Tolerance for 80 ms. These feedback signals are checked by both the main and supervisor processors if the Device State = 5 (Operation Enabled). 2. Wheel Position differs from Encoder3 Position by more than the Encoder Position Tolerance. These feedback signals are checked by only the main processor if the Device State = 5 (Operation Enabled). Note: This check is not performed if Supervision Feedback Device = 4.	Cycle KSI.	Hold then Shutdown.	1 = Stop.
69	1	5V Current Out of Range	The external load on the 5V supply is drawing either too much or too little current.	The measured current of the +5V supply (pins 21 and 34) is less than the parameter 5V Current Min or greater than the parameter 5V Current Max.	Cycle KSI.	Hold then Shutdown.	1 = Stop.
71	1	Software Fault 1	Reserved for future use.	—	—	—	—
71	2	Software Fault 2	1. Software defective. 2. Controller defective.	1. Unexpected software value. 2. Failure to send a CAN SDO message response.	Cycle KSI.	Shutdown.	1 = Stop.
71	3	Software Fault 3	Reserved for future use.	—	—	—	—
71	4	Software Fault 4	1. Software defective. 2. Controller defective.	Task overrun.	Cycle KSI.	Shutdown.	1 = Stop.

Table 6 TROUBLESHOOTING CHART, continued

FLASH CODE	SUB CODE	NAME	POSSIBLE CAUSE	SET CONDITION	CLEAR CONDITION	STEER FAULT ACTION	TRACTION FAULT ACTION
71	5	Software Fault 5	1. Software defective. 2. Controller defective.	An internal micro-to-micro communication error.	Cycle KSI.	Shutdown.	1 = Stop.
72	1	PDO1 Timeout	Communication between the traction controller and the 1222 has halted.	Time between PDO1 messages received exceeds the PDO1 TimeoutTime.	Cycle KSI.	Warning then Shutdown.	1 = Stop.
72	2	PDO2 Timeout	Communication from the CAN device sending the PDO2 message to the 1222 has halted.	Time between PDO2 messages received exceeds the PDO2 TimeoutTime.	Cycle KSI.	Warning then Shutdown.	1 = Stop.
72	3	PDO3 Timeout	Communication from the CAN device sending the PDO3 message to the 1222 has halted.	Time between PDO3 messages received exceeds the PDO3 TimeoutTime.	Cycle KSI.	Warning then Shutdown.	1 = Stop.
72	4	PDO4 Timeout	Communication from the CAN device sending the PDO4 message to the 1222 has halted.	Time between PDO4 messages received exceeds the PDO4 TimeoutTime.	Cycle KSI.	Warning then Shutdown.	1 = Stop.
73	1	Following Error	1. Position feedback device defective. 2. Steer motor stalled. 3. Steer motor encoder failed.	This fault is checked by the main micro only when the Steering Command State = 4 (Steering). A fault is set if the Error Tolerance (deg) is exceeded **and** the steered wheel is not moving in the right direction with a Wheel Speed (deg/s) equal to or greater than the Speed Tolerance (deg/s) for longer than the Following Error Time.	Cycle KSI.	Warning then Shutdown.	1 = Stop.
74	1	Hardware Software Mismatch	1. New software loaded. 2. Controller hardware cannot use the loaded software.	1. The software is not compatible with the controller hardware. 2. The software loaded into either or both microprocessors in incorrect.	Cycle KSI.	Shutdown.	1 = Stop.

Table 6 TROUBLESHOOTING CHART, continued

FLASH CODE	SUB CODE	NAME	POSSIBLE CAUSE	SET CONDITION	CLEAR CONDITION	STEER FAULT ACTION	TRACTION FAULT ACTION
75	1	Parameter Conflict	1. Parameter settings are in conflict with each other. 2. Parameter setting out of range.	1. Command Input Device = 1 and Vehicle Configuration » Traction Speed Input » Input Type = 1. 2. Vehicle Configuration » Nominal Voltage is out of range (24–48 V). 3. Motor Control Tuning » Motor Type is out of range (0–22). 4. Motor » Temperature Control » Sensor Type is out of range (0–5). 5. Command Input Device » 0-Analog1 and 3 » Analog1 Left, Center, and Right must be in ascending or descending order. 6. Command Input Device » 0-Analog1 and 3 » Analog3 Left, Center, and Right must be in ascending or descending order. 7. Feedback Device » 0-Analog5 and 6 » Analog5 Left Stop, Center, and Right Stop must be in ascending or descending order. 8. Feedback Device » 0-Analog5 and 6 » Analog6 Left Stop, Center, and Right Stop must be in ascending or descending order. 9. Command Device » Command Map » Left Stop (deg) or Right Stop (deg) = 0.	Cycle KSI.	Shutdown.	1 = Stop.

8 MAINTENANCE

There are no user serviceable parts in Curtis 1222 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. Ensure the capacitor bank is fully discharged by connecting a load (such as a contactor coil) across the controller's **B+** and **B-** terminals until a meter reads 0 V.
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.

REMOVAL

Troubleshooting, repair, or decommissioning of the vehicle may require removal of the controller. Use the following procedure for safe removal of a controller If disposal is required, do so in accordance with local regulations.

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.

1. Remove power by disconnecting the battery.
2. Ensure the capacitor bank is fully discharged by connecting a load (such as a contactor coil) across the controller's **B+** and **B-** terminals until a meter reads 0 V.

3. Lift the locking latch on the logic connector and pull the connector out by the shell, not by the wires.
4. Remove the five high-power terminal bolts and four mounting bolts to remove the controller from the vehicle.

FAULT HISTORY

The handheld 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

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 potentiometer. Thus immunity is generally achieved by preventing the external RF energy from coupling into sensitive circuitry. This RF energy can get into the controller circuitry via conducted paths and 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 B

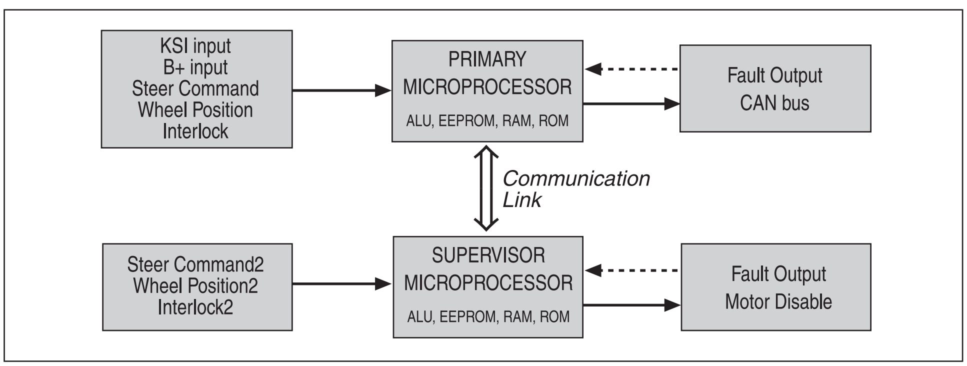
EN13849 COMPLIANCE

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 1222 Steering Controllers comply with these directives using advanced active supervisory techniques. A Supervisor microcontroller continuously tests the safety related parts of the control system; see the simplified block diagram in Figure B-1.

Fig. B-1 *Supervisory system in Curtis 1222 Steering Controllers.*



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, 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 be detected within 100 ms.

The Type C standards of EN1175 define the hazards that must be analyzed. Four of the listed hazards are relevant to the Curtis 1222 Steering Controller: (1) crushing, due to unintended or uncontrolled movement; (2) loss of stability, due to uncontrolled movement at speed, (3) failure of energy supply, resulting in unintended steering or loss of steering; and (4) failure of control system, resulting in unintended steering or loss of steering. The mitigating Safety Function for these four hazards is "Prevention of Unintended Steering or Loss of Steering."

Curtis has analyzed each hazard 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 1222 is summarized as follows:

Safety Function	Designated Architecture	MTTFd	DC	CCF Score	PL
Prevention of unintended steering or loss of steering	Category 3	≥13 yrs	≥90%	≥65	d

EN1175 specifies that electronic steer control systems must use Designated Architecture Category 3 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. All circuits used by a safety function must be designed in such a way as to score 65 or better on the CCF score sheet as provided by EN13849 table F.1.

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 C
PROGRAMMING DEVICES

Curtis programmers provide programming, diagnostic, and test capabilities for the 1222 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 files and also to update the system software (not available on the 1311).

Favorites — allows you to create shortcuts to your frequently-used adjustable parameters and monitor variables (not available on the 1311).

APPENDIX D

SPECIFICATIONS

Table D-1 SPECIFICATIONS: 1222 CONTROLLERS

Nominal input voltage	24–48 V
PWM operating frequency	16 kHz
Maximum encoder frequency	10 kHz
Maximum controller output frequency	200 Hz
Electrical isolation to heatsink	500 V (minimum)
Storage ambient temperature range	-40°C to 95°C (-40°F to 203°F)
Operating ambient temperature range	-40°C to 50°C (-40°F to 122°F)
Internal heatsink operating temp. range	-40°C to 95°C (-40°F to 203°F)
Package environmental rating	IP65 per IEC 529 (Note: Compliance requires AMPSEAL 35-pin connector header)
Weight	1.3 kg (3.0 lbs)
Dimensions, W×L×H	146 × 164 × 60 mm (5.7" × 6.5" × 2.3")
EMC	Designed to the requirements of EN 12895:2000
Safety	Designed to the requirements of: EN 1175-1:1998+A1:2010 EN ISO 13849-1:2008
UL	UL recognized component per UL583

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

MODEL NUMBER	NOMINAL BATTERY VOLTAGE (volts)	2 MIN RATING (amps)	CONTINUOUS RATING (amps)	LIFETIME RATING (hours)
1222-51XX	24–48	70	40	20,000

Notes: All current ratings are rms values per motor phase. Internal algorithms automatically reduce maximum current limit when heatsink temperature is >85°C or battery voltage is outside the allowed limits. Heatsink temperature is measured internally near the power MOSFETs.

The 2-minute rating is based on an initial controller heatsink temperature of 25°C and a maximum heatsink temperature of 85°C. No additional external heatsink is used for the 2-minute rating test.

Operation at or below the continuous rating is required to achieve the lifetime rating.

Ratings are based on the more conservative result of an airflow test and a power capacitor lifetime calculation. For the airflow test, the controller is mounted on a 6mm thick square steel plate (0.25m^2) in a 6km/hr airflow at 25°C temperature. Rated current is when the controller baseplate temperature reaches 85°C (thermal cutback). The capacitor lifetime calculation assumes internal controller temperature = 70°C (same as baseplate temperature), modulation index = 60%, and power factor = 0.866.