CURTIS

Manual

DUAL DRIVE OPERATION

for Controller Models

1232E / 34E / 36E / 38E / 39E
and 1232SE / 34SE / 36SE / 38SE

» Software Version OS 31.0 «

Curtis Instruments, Inc.
200 Kisco Avenue
Mt. Kisco, NY 10549
www.curtisinstruments.com

Read Instructions Carefully!

53097 DD Supplement, os31 May 2017

TABLE OF CONTENTS

CHAPTERS

TABLES

FIGURES

The Curtis Difference
You feel it when you drive it

1—OVERVIEW

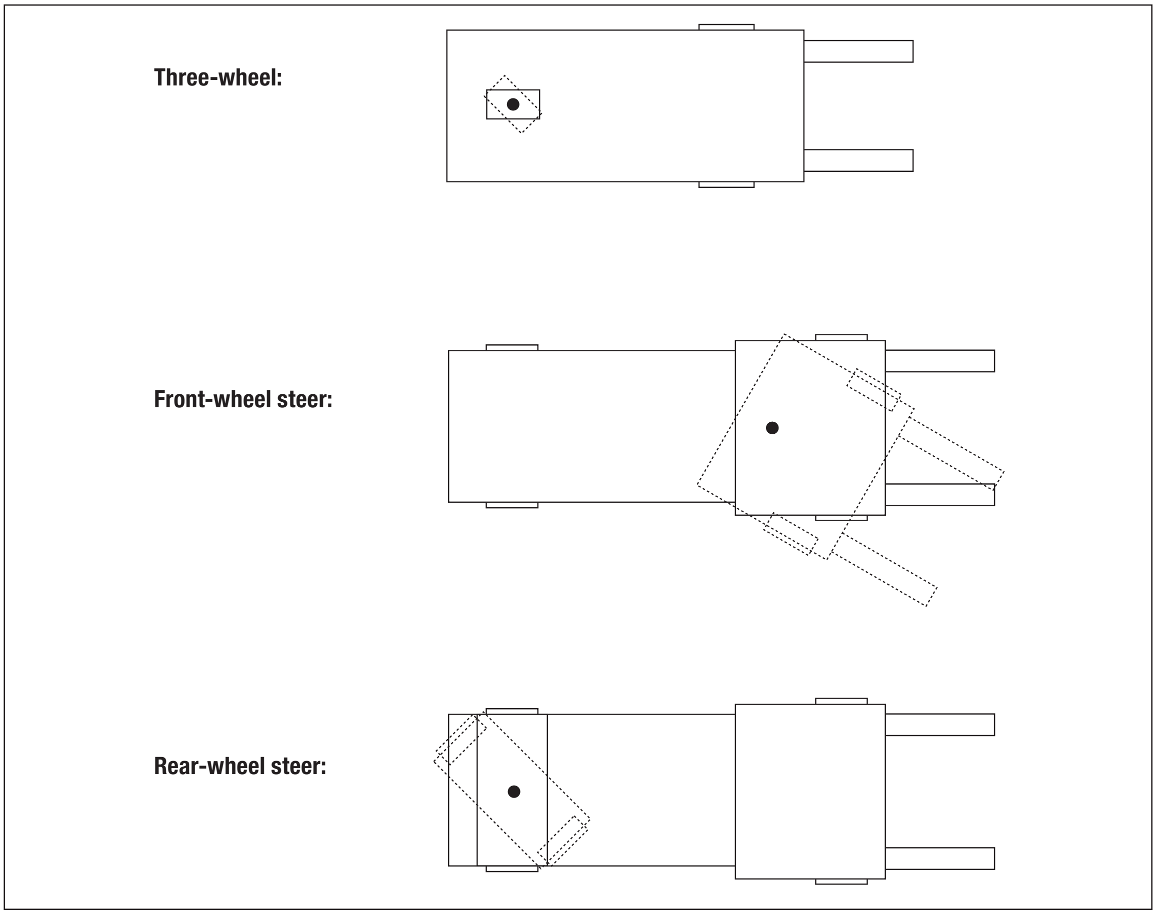
The Dual Drive feature of Curtis 1232E/SE, 1234E/SE, 1236E/SE, 1238E/SE, and 1239E controllers allows two controllers to work together in vehicles with dual fixed-axle drive motors, a steered wheel or axle, and an analog steer-angle sensor.

The two controllers must be the same size—for example, two 1234E-23XX controllers or two 1239E-65XX controllers. Non "E" controllers cannot be combined with "E" controllers.

The pair of controllers control motor speed on the inner and outer wheels during turns, as well as vehicle speed and acceleration while turning. Current is automatically balanced between the two traction motors when driving straight, and a limited operating strategy (LOS) allows limp-home in case of a steer angle sensor or single motor or controller failure.

Figure 1 shows three typical Dual Drive vehicle configurations.

Figure 1
Various Dual Drive vehicle configurations.



Dual Drive uses different speed maps for the two traction motors, one for the inner wheels and one for the outer wheels. These maps modify the throttle requests when the steering angle is outside the 10° deadband. Both are symmetrical around steer angle = 0°.

2 — WIRING

One of the two controllers is designated the master and the other the slave. The master controller operates the left motor and the slave operates the right motor. The throttle and brake inputs go to the master. The steering pot input goes to the Pot2 input on the slave controller.

A single main contactor is used, and is controlled by the master. The KSI, CAN H, and CAN L pins of the two controllers are connected together. B+ from the main contactor and the keyswitch are supplied to each controller through separate pairs of fuses to enable operation to continue if one side fails. See Figure 2a, below, for an overview of the common wiring between the two controllers, and Figures 2b and 2c for the detail in each controller.

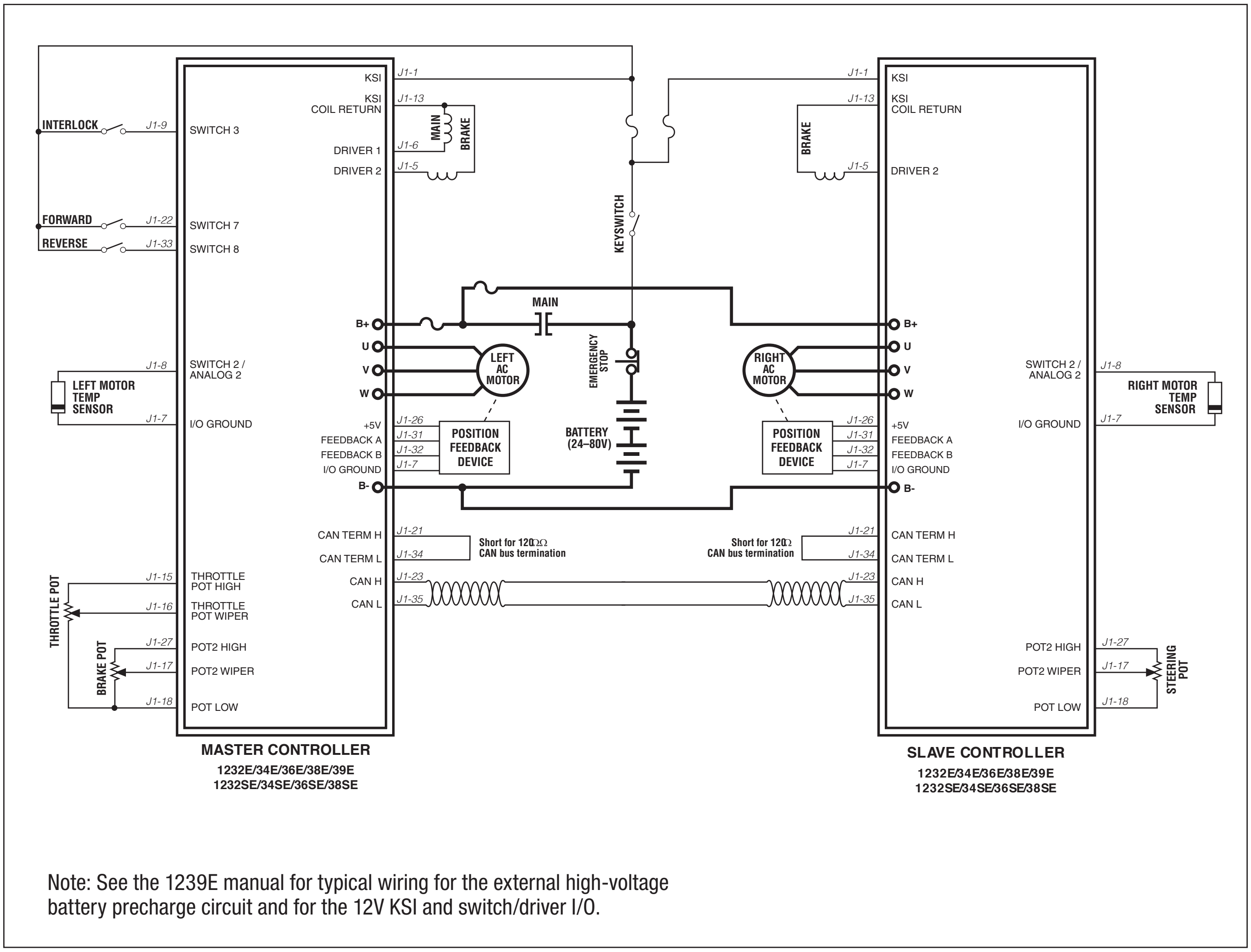


Figure 2a

Wiring between the master and slave Dual Drive traction controllers.

The master controller is wired to all the components except those related to the Right motor and the steering pot.

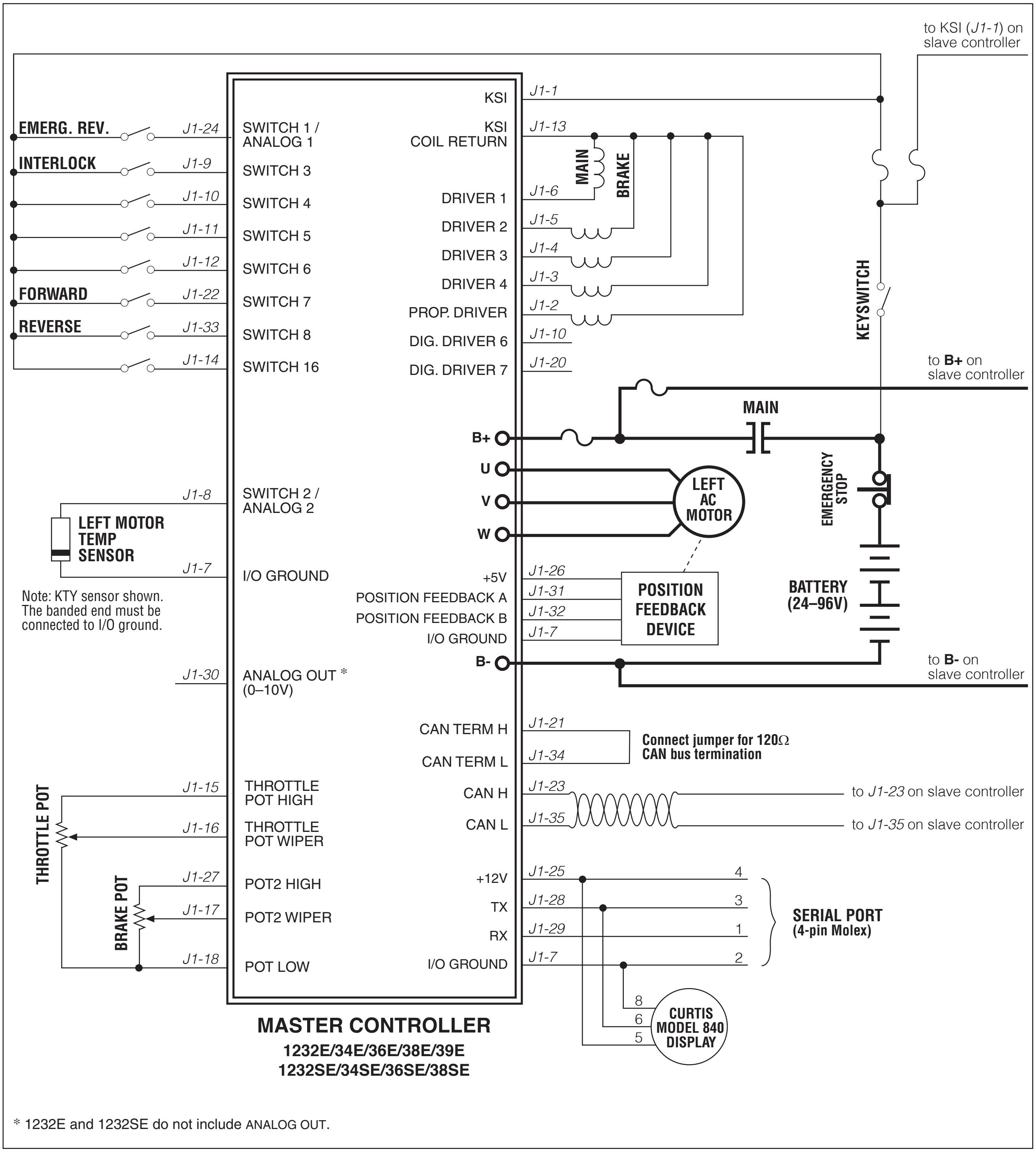


Figure 2b

Basic wiring diagram for master controller, Dual Drive operation.

The slave controller is wired only to the Right motor and its encoder and temperature sensor, the steering pot, CAN H, CAN L, KSI, B+/B–, and an electromagnetic brake.

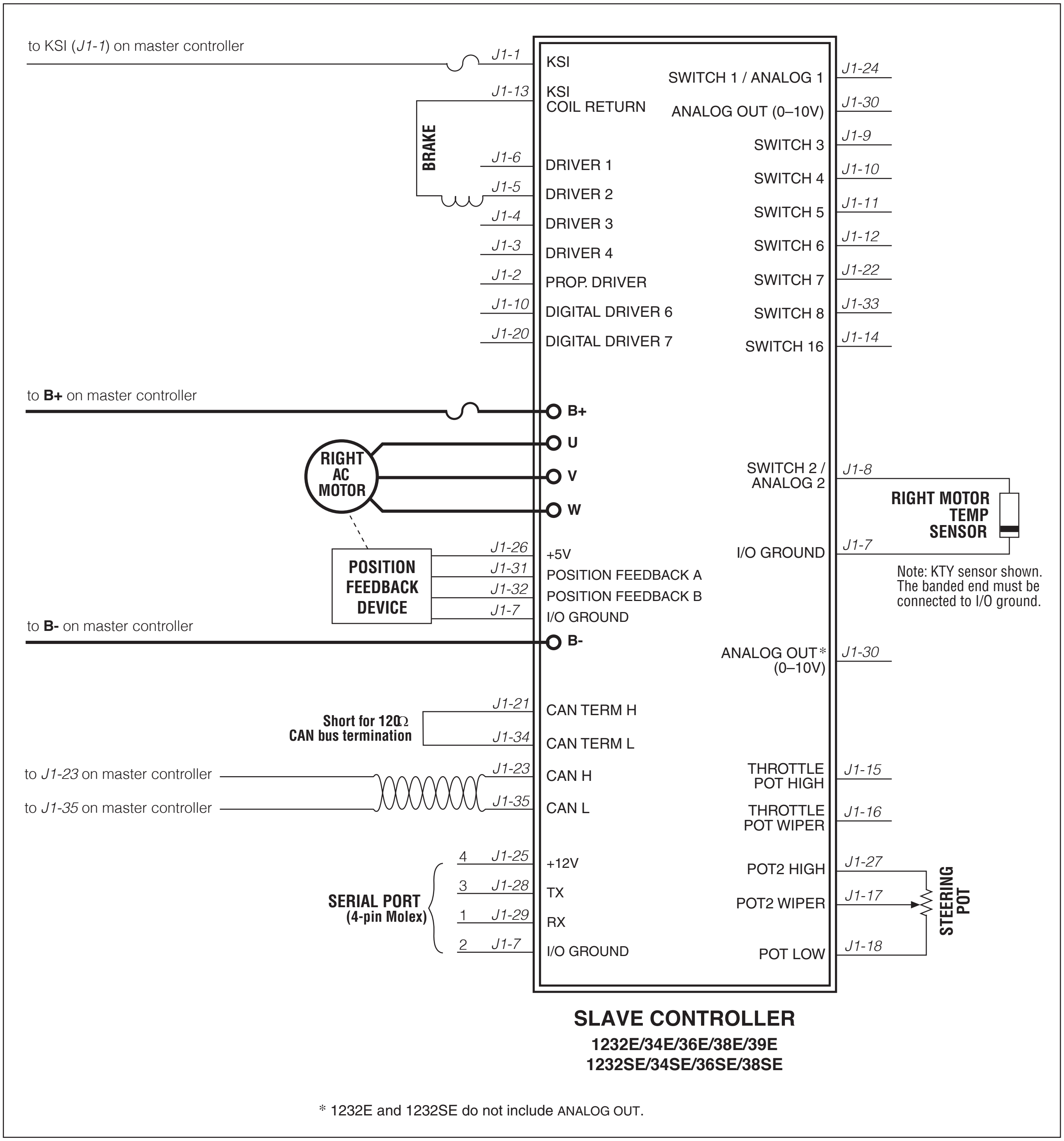


Figure 2c

Basic wiring diagram for slave controller, Dual Drive operation.

3 — PROGRAMMABLE PARAMETERS

The following programmable parameters are used to configure the Dual Drive feature. With only a very few exceptions, all the parameters on both the master and the slave controller should be set to the same values.

VCL is not required to operate in Dual Drive mode.

Table 1 Dual Drive Program Menus: 1311/1313 /1314 Programmer

DUAL DRIVE MENU........................... p. 6
— Dual Motor Enable
— Dual Motor Slave
— CAN Node ID Other
— LOS Max Speed

MASTER MENU................................ p. 7
—Steer Angle Max
—Turn Accel Rate
—Critical Angle
—Max Turn Speed
—Inner Wheel Speed
—Steer Type
—Steer Pot Min
—Steer Pot Zero
—Steer Pot Max
—VCL Steer Enable

SLAVE MENU.................................... p. 8
—Turn Accel Rate
—Critical Angle
—Steer Fault Min
—Steer Fault Max

TURN FEEDFORWARD MENU............ p. 8
—Turn Accel Rate
—Turn Kvff
—Turn ff Build Rate
—Turn ff Release Rate

PARAMETER CHANGE FAULTS

Parameters marked **PCF** in the menu charts will set a Parameter Change Fault (code 49) if they are changed while the motor bridge is enabled (interlock = On). Although the parameter will be changed, the fault will prevent motor control functions until the fault is cleared by cycling the keyswitch. If the motor bridge is disabled (interlock = Off), changing these parameters will not cause a fault and the changes will take effect immediately.

DUAL DRIVE MENU

PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Dual Motor Enable *Dual_Motor_Enable* *OptionBits4* **[Bit 2]** `0x306D 0x00`	On / Off *On / Off*	To turn on the Dual Drive feature, set this parameter On in both controllers.
Dual Motor Slave *Dual_Motor_Slave* *OptionBits4* **[Bit 3]** `0x306D 0x00`	On / Off *On / Off*	Set this parameter Off in the master controller and On in the slave controller.
CAN Node ID Other *Dual_CAN_Node_ID_Other* `0x330F 0x00`	1 – 127 *1 – 127*	The master and slave controllers must have different CAN Node IDs, and each must know the CAN Node ID of the “other” controller so they can talk to each other. Set this parameter to the slave controller’s CAN Node ID in the master controller, and set it to the master controller’s CAN Node ID in the slave controller.
LOS Max Speed *Dual_LOS_Max_Speed* `0x38A2 0x00`	100 – 8000 rpm *100 – 8000*	Defines the maximum speed when a Dual Drive controller is running in LOS (Limited Operating Strategy) mode.

DUAL DRIVE MASTER MENU

PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Steer Angle Max (deg) *Dual_Steer_Angle_Max* 0x38A3 0x00	45 – 90 deg *45 – 90*	Set this to the maximum steer angle that is physically possible on the vehicle. (Steer Angle is the angle-in-degrees that the steer wheel(s) "turn" from their center/straight-ahead or zero-degree position)
Turn Accel Rate *Dual_Turn_Accel_Rate* 0x38A8 0x00	0.1 – 30.0 s *100 – 30000*	As the steering angle increases from the edge of the deadband to the critical angle (Critical Angle), the acceleration rate is reduced linearly from the normal value to the programmed Turn Accel Rate (see Figure 6). Higher values represent slower acceleration. **This parameter appears in multiple places. Changing the value of this parameter affects all parameters listed below:** Program » Dual Drive » Slave » Turn Accel Rate Program » Dual Drive » Turn Feedforward » Turn Accel Rate
Critical Angle (deg) *Dual_Critical_Angle* 0x38A6 0x00	45 – 90 deg *45 – 90*	Set this parameter to the angle at which the vehicle pivots around its inner wheel. Use the equation on page 9 to determine the critical angle. **This parameter appears in multiple places. Changing the value of this parameter affects all parameters listed below:** Program » Dual Drive » Slave » Critical Angle (deg)
Max Turn Speed *Dual_Max_Turn_Speed* 0x38A7 0x00	0 – 100 % *0 – 32767*	As the steering angle increases from the edge of the deadband to the maximum steer angle (Steer Angle Max), maximum speed is reduced linearly from the normal value to the programmed Max Turn Speed (see Figure 6).
Inner Wheel Speed *Dual_Inner_Wheel_Speed* 0x38A9 0x00	–100.0 – 0.0 % *–32767 – 0*	Set this parameter to the Inner wheel speed as a percentage of outer wheel speed when the steer angle is 90 degrees. Use the equation on page 9 to determine the appropriate percentage.
Steer Type **PCF** *Dual_Steer_Type* 0x38AB 0x00	1 – 5 *1 – 5*	Set this parameter to the appropriate type for the steering pot you are using: 1. 2-wire rheostat, 5kΩ–0 input 2. Single-ended 3-wire 1kΩ–10kΩ potentiometer, 0–5V voltage source, or current source 3. 2-wire rheostat, 0–5kΩ input 4. (not applicable) 5. VCL input (VCL_Steer). NOTE: Do not change this parameter while the controller is powering the motor. Any time this parameter is changed a Parameter Change Fault (fault code 49) is set and must be cleared by cycling power; this protects the controller and the operator.
Steer Pot Min *Dual_Steer_Pot_Min* 0x38AC 0x00	0.00 – 6.25 V *0 – 32767*	Set Steer Pot Min to the voltage on the steering pot when steering as far as possible clockwise. Determine the value by reading the voltage on the pot when steering CW to the maximum position.
Steer Pot Zero *Dual_Steer_Pot_Zero* 0x38AD 0x00	0.00 – 6.25 V *0 – 32767*	Set Steer Pot Zero to the voltage on the steering pot when steering straight ahead. Determine the value by reading the voltage on the pot when steering straight.
Steer Pot Max *Dual_Steer_Pot_Max* 0x38AE 0x00	0.00 – 6.25 V *0 – 32767*	Set Steer Pot Max to the voltage on the steering pot when steering as far as possible counterclockwise. Determine the value by reading the voltage on the pot when steering CCW to the maximum position.
VCL Steer Enable |*VCL_Steer_Enable* |*VCL_Steer_Enable_Bit0* **[Bit 0]** 0x38A5 0x00	On / Off *On / Off*	Setting this to On allows VCL to be used for additional steering processing.

DUAL DRIVE SLAVE MENU

PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Turn Accel Rate *Dual_Turn_Accel_Rate* `0x38A8 0x00`	0.1 – 30.0 s *100 – 30000*	As the steering angle increases from the edge of the deadband to the critical angle (Critical Angle), the acceleration rate is reduced linearly from the normal value to the programmed Turn Accel Rate (see Figure 6). Higher values represent slower acceleration. **This parameter appears in multiple places. Changing the value of this parameter affects all parameters listed below:** Program » Dual Drive » Master » Turn Accel Rate Program » Dual Drive » Turn Feedforward » Turn Accel Rate
Critical Angle (deg) *Dual_Critical_Angle* `0x38A6 0x00`	45 – 90 deg *45 – 90*	Set this parameter to the angle at which the vehicle pivots around its inner wheel. Use the equation on page 9 to determine the critical angle. **This parameter appears in multiple places. Changing the value of this parameter affects all parameters listed below:** Program » Dual Drive » Master » Critical Angle (deg)
Steer Fault Min *Dual_Steer_Fault_Min* `0x38AF 0x00`	0.00 – 5.50 V *0 – 28864*	Sets the minimum threshold for the Dual Drive steering pot input. If the steering pot voltage goes below this threshold, a Dual Severe Fault (75) will be issued.
Steer Fault Max *Dual_Steer_Fault_Max* `0x38B0 0x00`	0.00 – 5.50 V *0 – 28864*	Sets the minimum threshold for the Dual Drive steering pot input. If the steering pot voltage goes below this threshold, a Dual Severe Fault (75) will be issued.

DUAL DRIVE TURN FEEDFORWARD MENU

PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Turn Accel Rate *Dual_Turn_Accel_Rate* `0x38A8 0x00`	0.1 – 30.0 s *100 – 30000*	As the steering angle increases from the edge of the deadband to the critical angle (Critical Angle), the acceleration rate is reduced linearly from the normal value to the programmed Turn Accel Rate (see Figure 6). Higher values represent slower acceleration. This parameter appears in multiple places. Changing the value of this parameter affects all parameters listed below: Program » Dual Drive » Master » Turn Accel Rate Program » Dual Drive » Slave » Turn Accel Rate
Turn Kvff *Dual_Turn_Kvff_SpdM* `0x38B2 0x00`	0 – 500 A *0 – 5000*	This parameter can be used to improve the responsiveness of the traction speed controller to changes in steer angle.
Turn ff Build Rate *Dual_Turn_ff_Build_Rate_SpdM* `0x38B3 0x00`	0.1 – 5.0 s *100 – 5000*	Defines how quickly the Kvff term builds up.
Turn ff Release Rate *Dual_Turn_ff_Build_Rate_SpdM* `0x38B4 0x00`	0.1 – 2.0 s *100 – 2000*	Defines how quickly the Kvff term releases. If the release seems too abupt, slowing the release rate (i.e., setting this parameter to a higher value) will soften the feel.

4 — DETERMINING CRITICAL ANGLE AND INNER WHEEL SPEED

The first step in setting up the Dual Drive feature is to determine the values of two parameters: *Critical Angle*, the angle at which the vehicle pivots with its inner wheel stationary, and *Inner Wheel Speed*, the desired inner-wheel speed at a 90° steer angle, expressed as a fraction of the outer-wheel speed in this condition.*

4-WHEEL APPLICATIONS

Typically the Inner Wheel Speed = 0 for 4-wheel applications, as there should be no counter-rotation with these vehicles. The Critical Angle is the angle at which the opposite wheels (front left and back right, or front right and back left) are perpendicular to each other.

3-WHEEL APPLICATIONS

The Critical Angle and Inner Wheel Speed can be determined empirically or calculated using the following equations, where *W*=wheelbase, *T*=track of the driven wheels, and *A*=distance between the steered axle and the pivot point (see Figures 3 and 4). For vehicles without a steered axle, use A=0.

Any units can be used (feet, meters, etc.) as long as they are the same for all dimensions.

$$\text{Critical Angle} = 90 - \arctan\left(\frac{T}{2(W-A)}\right) + \arcsin\left(\frac{A}{\sqrt{(T/2)^2 + (W-A)^2}}\right)$$

= Answer in degrees; must be between 45° and 90°.

$$\text{Inner Wheel Speed} = 100 \times \frac{A - T/2}{A + T/2}$$

= Answer in %; must be between –100% and 0.

Example: For T=4, W=6, and A=1,
Critical Angle = 79° and Inner Wheel Speed = -33%.

*If your vehicle has a Steer Angle Max of less than 90°, you should still use the equation presented here to calculate the proper value for Inner Wheel Speed. Measured inner wheel speed may be quite different from the parameter value you set; this is normal. Use the calculated value as the parameter setting.

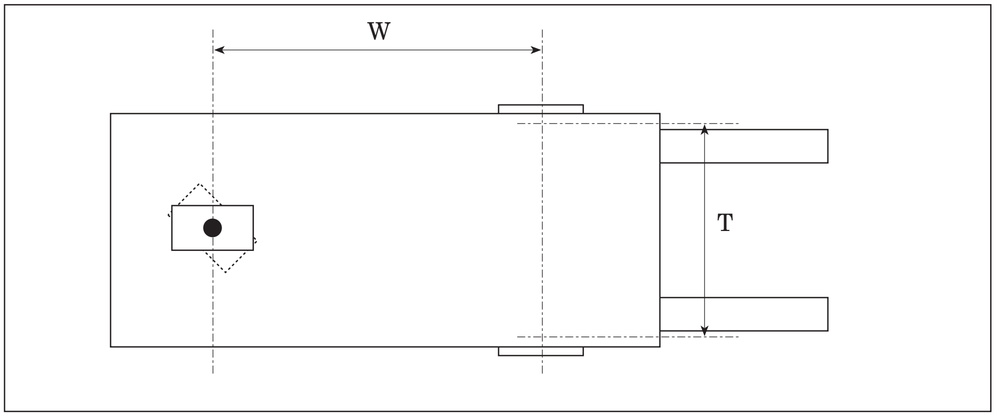


Figure 3
Typical 3-wheel Dual Drive vehicle geometry.

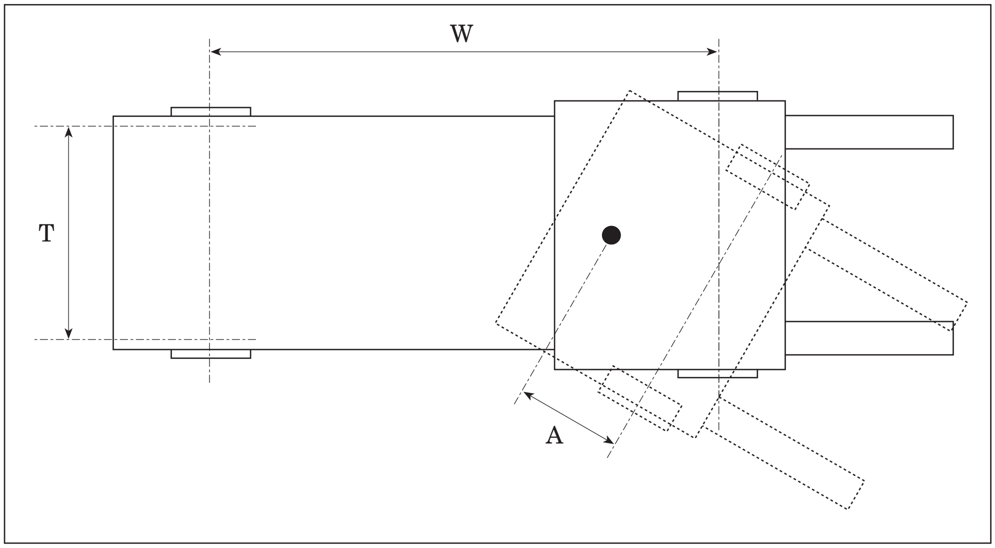
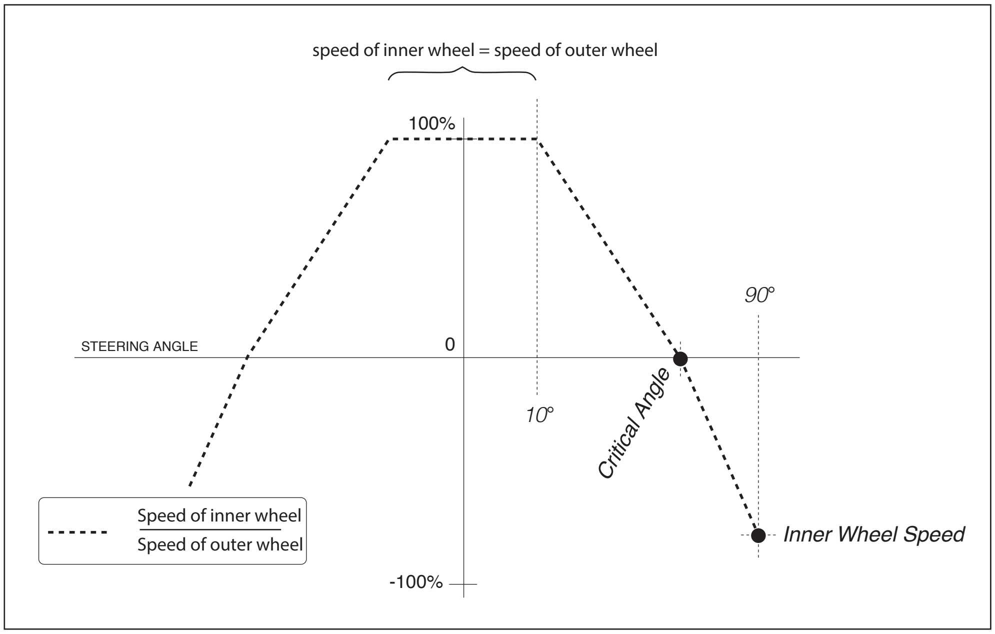


Figure 4
Typical articulated steering Dual Drive vehicle geometry.

The inner wheel speed is determined by the outer wheel speed, as shown in Figure 5. It decreases from 100% of the outer wheel speed to zero at the programmed critical angle, and then from zero to the programmed Inner Wheel Speed value at the maximum steering angle.

Figure 5

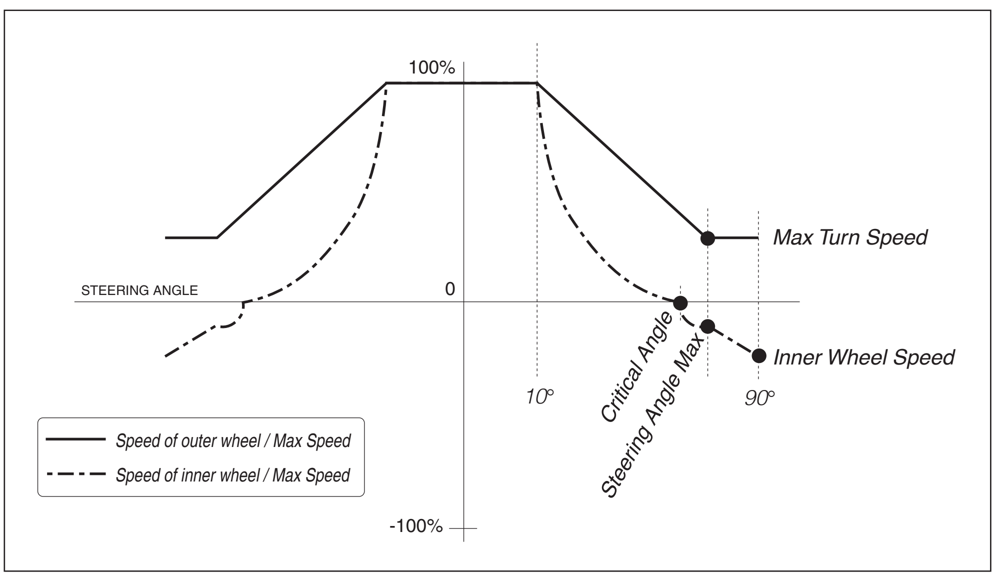
Ratio of inner-wheel speed to outer-wheel speed, assuming a 90° maximum steering angle.



The outer wheel speed is derived directly from the throttle request. As a result, the outer wheel speed decreases linearly with the steering angle as shown in Figure 6.

Figure 6

Inner-wheel and outer-wheel speed maps, assuming full throttle.



5 — DUAL DRIVE SETUP

First you should complete the setup procedures for the two controllers you are using as outlined in the 1232E/34E/36E/38E/39E & 1232SE/34SE/36SE/38SE os31 manuals.. Then proceed with these Dual Drive setup procedures.

⚠ CAUTION

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

1 – Installation confirmation

Make sure that the master controller is connected to the Left motor, and the slave controller is connected to the Right motor.

2 – Programming the master controller

The easiest method of programming is to set up the master first, clone it to the slave, and then make adjustments in the slave.

a. Set the master controller's CAN Node ID in the CAN Interface menu to the master controller's unique ID.

b. Adjust the settings of the parameters in the Dual Drive menu:

- Set Dual Motor Enable = On.
- Set Dual Motor Slave = Off.
- Set CAN Node ID Other = the slave controller's CAN Node ID.
- Set LOS Max Speed to the desired value.

c. Adjust the settings of all the parameters in the Dual Drive Master menu.

d. Set the Interlock Type.

3 – Cloning the master controller to the slave controller

Use the 1313 handheld programmer or the 1314 PC Programming Station for cloning.

4 – Programming the slave controller

After cloning the master controller parameter settings to the slave controller, the following changes must be made in the slave.

a. In the Dual Drive menu, set the slave controller's Dual Motor Slave parameter to On.

b. In the CAN Interface menu, set the slave controller's CAN Node ID to the slave controller's unique ID. Remember that this value must be the same as the Master's CAN Node ID Other parameter.

c. In the Dual Drive menu, set the slave controller's CAN Node ID Other to the master controller's CAN Node ID.

d. If the same phase and encoder wiring conventions are used for the master and slave, set Swap Two Phases and Swap Encoder Direction in the slave to values opposite those in the master (see Motor menu).

e. Adjust the settings of the two parameters in the Dual Drive Slave menu as desired.

f. Set Interlock Type = 2, because the Slave's interlock will be arriving over the CANbus.

5 – Setup confirmation

With the vehicle drive wheels still jacked up, apply interlock and throttle and verify that the wheels turn at the proper speed and direction as the steer angle changes. If either wheel turns in the wrong direction or appears to be "fighting itself" (struggling at full current while jerkily turning at very low speed), try changing the setting of the Swap Encoder Direction or Swap Two Phases parameters. (Refer to setup procedures in the 1232E/34E/36E/38E/39E & 1232SE/34SE/36SE/38SE Manuals for help resolving encoder issues.) If the motor still does not respond appropriately you should contact your Curtis customer support engineer to resolve any issues before continuing.

⚠ CAUTION

Do not take the vehicle down off the blocks until the motors are responding properly.

6 — VEHICLE CONTROL LANGUAGE & CAN

The motor command diagrams for the Dual Drive controllers are shown in Figure 7a (for the master controller, which controls the Left traction motor) and Figure 7b (for the slave controller, which controls the Right traction motor).

Dual Drive operation is initiated by the steer pot, which is connected to the slave controller. The steer pot wiper voltage is sent in a CAN message to the master controller (Fig. 7a point A) where the wiper voltage is converted to steer angle. The Steer_Angle and Mapped_Throttle are processed and produce a throttle value for the master traction controller and the slave traction controller (which is sent via a CAN message to the slave controller (Fig. 7b point B).

The throttle processing in the master controller is similar to the throttle processing in a non-dual-drive controller except for the additions of steer angle dual throttle processing and sending CAN messages to the slave controller for throttle and brake commands. The brake signal can be followed in the master from the brake pot input to the Brake_Command. The Dual_Slave_Brake_From_Master variable is sent from the master traction controller to the slave traction controller via a CAN message (Fig. 7a point B to Fig. 7b point B).

The throttle processing in the slave controller is different from the throttle processing in a non-dual drive controller because here the master controller is processing the throttle variables. The Dual_Slave_Throttle_From_Master (Fig. 7b point B) and Dual_Slave_Brake_From_Master (Fig. 7b point C) arrive from the master as shown. The Throttle Pot input on the slave is not used for throttle and may be programmed in VCL for other uses.

VCL is not required to implement the Dual Drive CAN feature. Meaning that for a system not using VCL, the dual drive master/slave controllers will operate as described above. However, when VCL is implemented, should the VCL CAN operation be stop or become idle*, use the VCL function INIT_DUAL_MOTOR_CAN() to restart (re-initialize) the Dual Drive CAN operation, besides using the STARTUP_CAN() for VCL CAN.

INIT_DUAL_MOTOR_CAN( )

This function initializes (restarts) the dual drive CAN functions.

Syntax:	`Init_Dual_Motor_CAN()`
Parameters:	None.
Returns:	None.
Error Codes:	None.

---

*VCL functions that either stop or idle the VCL CAN operation will require re-initializing of the dual drive CAN. Or, if the CANbus turns OFF or stops.

Examples:

1. The VCL function SETUP_CAN() in a VCL program will "stop" the Dual Drive CAN operation, because it leaves the VCL CAN system in an idle state.
2. The VCL function SHUTDOWN_CAN () in a VCL program will stop the dual drive CAN operation, because it stops the VCL CAN system.
3. If the variable can_error_status = 3, the CANbus is Off (reference SysInfo, "CAN/Nodes Bus Status Information" section).

NOTE: When using VCL with Dual Drive, the CAN mailboxes CAN3 – CAN6 are required to be reserved by the OS for Dual Drive operation. Refer to the "CAN Access IDs" section in the SysInfo file.

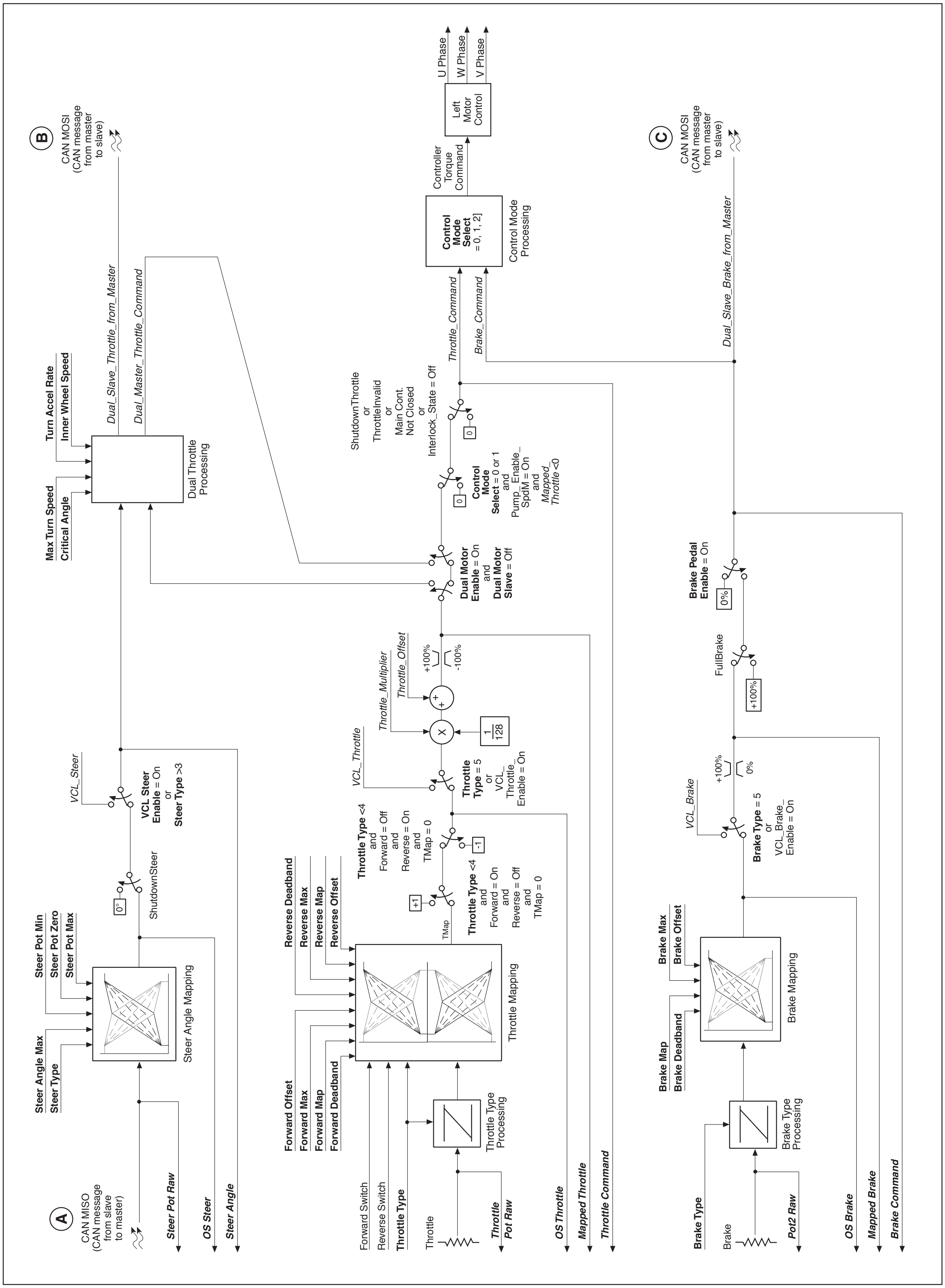


Figure 7a
Motor command diagram, master controller.

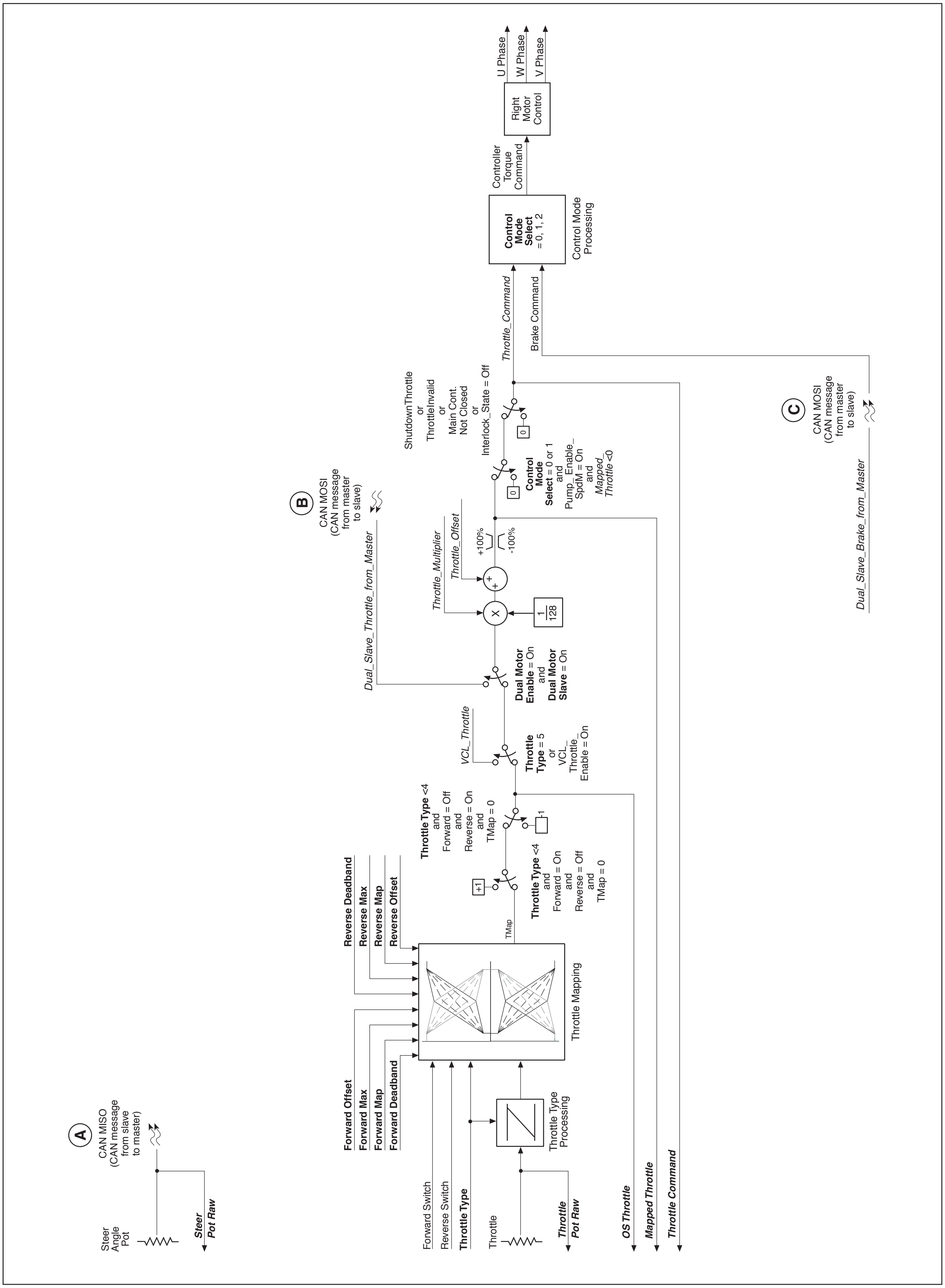


Figure 7b
Motor command diagram, slave controller.

CAN

The CAN messages indicated by the A, B, and C points in Figures 7a and 7b are shown in the byte maps below, along with the additional variables that are available (and CAN Index) to Dual Drive applications.

PDO3 MOSI Byte Map (*Sent by the master to the slave*).
MOSI is RX in CANopen nomenclature

```
B   Byte 1 = Dual_Slave_Throttle_from_Master (high byte) 0x38B6 0x00
             Slave throttle command from master.
B   Byte 2 = Dual_Slave_Throttle_from_Master (low byte) 0x38B6 0x00
    Byte 3 = Steer_Type_Master
             Steer Type parameter setting from master;
             used to set up proper pot type in the slave.
    Byte 4 = [Not used]
    Byte 5 = Flags_Master 0x38BC 0x00
             Used to synchronize inputs and outputs between master and slave.
    Byte 6 = [Not used]
    Byte 7 = [Not used]
C   Byte 8 = Dual_Slave_Brake_from_Master 0x38B5 0x00
             Slave brake command from master.
```

PDO3 MISO Byte Map (*Sent by the slave to the master*). MISO is TX in CANopen nomenclature

```
A   Byte 1 = IqReq_Slave (high byte)
             Used to balance the current load between master and slave.
A   Byte 2 = IqReq_Slave (low byte)
    Byte 3 = [Not used]
    Byte 4 = [Not used]
    Byte 5 = Flags_Slave 0x38BD 0x00
             Used to synchronize inputs and outputs between master and slave.
    Byte 6 = [Not used]
A   Byte 7 = Steer_Pot_Raw (high byte) 0x38BB 0x00
             Voltage from steer pot for master to use in calculating steer angle.
A   Byte 8 = Steer_Pot_Raw (low byte) 0x38BB 0x00
```

The contents of Flags_Slave and Flags_Master are as follows:

```
Bit1 = Dual_Motor_Interlock_Bit
          Used to synchronize the interlock between master and slave.
Bit2 = Request_Dual_Motor_Interlock_Bit
          Used to request the interlock between master and slave.
Bit3 = EM_Brake_Ready_To_Set
          Used to synchronize the EM brake between master and slave.
Bit4 = LOS_Speed_Flag
          Used to initiate LOS speed in the other traction controller.
Bit5 = Main_Sync_Flag
          Used to synchronize the Main Contactor states between master
          and slave.
Bit6 = Main_Closed_Flag
          Used to synchronize the Main Contactor "is closed" between master
          and slave.
Bit7 = LOS_Clear_Flag
          Used to clear LOS speed in the other traction controller.
Bit8 = Precharge_Sync_Master_Flag
          Used to synchronize the precharge between master and slave
```

The contents of Flags_Slave_More and Flags_Master_More are as follows:

```
Bit5 = Dual_Motor_EM_Brake_Throttle_Flag
          Used to synchronize the EM Brake and Throttle between master
          and slave.
Bit6 = Dual_Motor_Ready_To_Enter_Position_Hold_Flag
          Used to synchronize the Position Hold between master and slave.
Bit7 = Dual_Motor_In_Position_Hold_Flag
          Used to synchronize Position Hold between the master and slave.
Bits 1-4, 8 = [Not used]
```

7 — TROUBLESHOOTING

With Dual Drive systems there are two traction controllers, and when faults occur they usually affect both of the controllers.

The Dual Drive Troubleshooting Chart (Table 2) is written from the perspective of the controller that is issuing the fault. The effects on the other controller are shown as well.

DUAL DRIVE LIMITED OPERATING STRATEGY

When the Dual Drive Limited Operating Strategy (LOSDual) is initiated, the controller's motor(s)-speed will be clamped to the parameter **LOS Max Speed** setting (VCL parameter name *Dual_LOS_Max_Speed*), see page 6. Then, if the Throttle Command (see the Monitor»Inputs menu in the controller's manual, and 1313/1314) results in the motor-speed request exceeding the LOS Max Speed, the motor rpm will be clamped to the LOS Max Speed, subject to normal slewing constraints.

If the steer angle input is invalid, both controllers will use the Dual Drive's LOS Max Speed and assume that the steer angle is 0 degrees (also see the Monitor»Inputs menu in the controller's manual, and 1313/1314).

If the motor encoder is invalid on only one side (i.e., master or slave controller), that controller will have its bridge disabled, and the other controller will use the LOS Max Speed and assume that the steer angle is 0 degrees. If both encoder signals are invalid, the vehicle will not drive. (see Codes 36 and 73 in Table 2).

The fault actions (effect of fault) in Table 2 use the same bit-structure as the User_Fault_Action_xx listed in controller's manual (OEM-defined User Faults). The variable System_Action (available in the WinVCL Monitor, or TACT) returns the decimal number corresponding to the active fault action bit(s). The dual drive related fault actions, bits 12–15, are listed in this supplement.

System_Action Bit	Action
No Action	As noted in Table 2
Bit0 = ShutdownMotor	Disable the motor.
Bit1 = ShutdownMainContactor	Shut down the main contactor (only if Main Enable = On)
Bit2 = ShutdownEMBrake	Shut down the EM brake (only if EM Brake Disable Upon Fault = On).
Bit3 = ShutdownThrottle	Set the Throttle_Command = 0%.
Bit4 = ShutdownInterlock	Set the Interlock_State = Off.
Bit5 = ShutdownDriverl	Shut down Driver1.
Bit6 = ShutdownDriver2	Shut down Driver2.
Bit7 = ShutdownDriver3	Shut down Driver3.
Bit8 = ShutdownDriver4	Shut down Driver4.
Bit9 = ShutdownPD	Shut down Proportional Driver
Bit10 = FullBrake	Set the Brake_Command = 100%.
Bit11 = [reserved]	N/A (for 1232-1238E/SE, and 1239E controllers)
Bit12 = TrimDisable	Disable Dual Drive trim calculation.
Bit13 = SevereDual	For Dual Drive system, one controller has a severe fault but the main contactor must stay closed so the other controller can continue to operate.
Bit14 = ShutdownSteer	Steer angle = 0° (DD applicable).
Bit15 = LOSDual	For Dual Drive system, set the max speed to Dual_LOS_Max_Speed parameter for operation in Limited Operating Strategy.

Example:

```
HPD/Sequencing Fault, Flash Code 47.
Effect of fault = Shutdown Throttle.
System_Action = 8 (equates to Bit3 set: 0000 0000 0000 1000)
```

Table 2 DUAL DRIVE TROUBLESHOOTING CHART

CODE	PROGRAMMER LCD DISPLAY *EFFECT OF FAULT*	POSSIBLE CAUSE	SET / CLEAR CONDITIONS
12	**Controller Overcurrent** *ShutdownMotor;* *ShutdownMainContactor;* *ShutdownEMBrake;* *ShutdownThrottle;* *FullBrake.* *Other controller:* *Same effects as this controller.*	1. External short of phase U,V, or W motor connections. 2. Motor parameters are mis-tuned. 3. Controller defective. 4. Speed encoder noise problems.	*Set:* Phase current exceeded the current measurement limit. *Clear:* Cycle KSI.
13	**Current Sensor Fault** *ShutdownMotor;* *ShutdownMainContactor;* *ShutdownEMBrake;* *ShutdownThrottle;* *FullBrake.* *Other controller:* *Same effects as this controller.*	1. Leakage to vehicle frame from phase U, V, or W (short in motor stator). 2. Controller defective.	*Set:* Controller current sensors have invalid offset reading. *Clear:* Cycle KSI.
14	**Precharge Failed** *ShutdownMotor;* *ShutdownMainContactor;* *ShutdownEMBrake;* *ShutdownThrottle;* *FullBrake.* *Other controller:* *Same effects as this controller.*	1. See Monitor menu » Battery: Capacitor Voltage. 2. External load on capacitor bank (B+ connection terminal) that prevents the capacitor bank from charging.	*Set:* Precharge failed to charge the capacitor bank to the KSI voltage. 1239E DD applicable: Precharge failed to charge the capacitor bank from the external precharge resistor. *Clear:* Cycle Interlock input or use VCL function *Enable_Precharge().*
15	**Controller Severe Undertemp** *ShutdownMotor;* *SevereDual.* *Other controller:* *SevereDual;* *LOSDual;* *TrimDisable.*	1. See Monitor menu » Controller: Temperature. 2. Controller is operating in an extreme environment.	*Set:* Heatsink temperature below -40°C. *Clear:* Bring heatsink temperature above -40°C, and cycle interlock or KSI.
16	**Controller Severe Overtemp** *ShutdownMotor;* *ShutdownMainContactor;* *ShutdownEMBrake;* *ShutdownThrottle;* *FullBrake.* *Other controller:* *Same effects as this controller.*	1. See Monitor menu » Controller: Temperature. 2. Controller is operating in an extreme environment. 3. Excessive load on vehicle. 4. Improper mounting of controller.	*Set:* Heatsink temperature above +95°C. *Clear:* Bring heatsink temperature below +95°C, and cycle interlock or KSI.
17	**Severe B+ Undervoltage** *No drive torque,* *TrimDisable.* *Other controller:* *Same effects as this controller.*	1. Battery parameters are misadjusted. 2. Non-controller system drain on battery. 3. Battery resistance too high. 4. Battery disconnected while driving. 5. See Monitor menu » Battery: Capacitor Voltage. 6. Blown B+ fuse or main contactor did not close.	*Set:* Capacitor bank voltage dropped below the Severe Undervoltage limit with FET bridge enabled. *Clear:* Bring capacitor voltage above Severe Undervoltage limit.
17	**Severe KSI Undervoltage** *No action.* *1239E DD applicable: If below brownout voltage, motor current is switched off and reset may occur.* *Other controller:* *Same effects as this controller.*	1. See Monitor menu » Battery: Keyswitch Voltage. 2. Non-controller system drain on battery/ KSI circuit wiring. 3. KSI disconnected while driving. 4. Blown KSI fuse.	*Set:* When below Brownout Voltage for 2 seconds (see Table D-1). 1239E DD applicable: KSI voltage dropped below 8.4 V (Brownout occurs at 8.0 V.) *Clear:* Bring KSI voltage above Brownout Voltage. 1239E DD applicable: Bring KSI voltage above 8.4 volts.

Table 2 DUAL DRIVE TROUBLESHOOTING CHART cont'd

CODE	PROGRAMMER LCD DISPLAY *EFFECT OF FAULT*	POSSIBLE CAUSE	SET / CLEAR CONDITIONS
18	**Severe B+ Overvoltage** *ShutdownMotor;* *SevereDual.* *Other controller:* *SevereDual;* *LOSDual;* *TrimDisable.*	1. See Monitor menu » Battery: Capacitor Voltage. 2. Battery parameters are misadjusted. 3. Battery resistance too high for given regen current. 4. Battery disconnected while regen braking.	*Set:* Capacitor bank voltage exceeded the Severe Overvoltage limit with FET bridge enabled. *Clear:* Bring capacitor voltage below Severe Overvoltage limit, and then cycle KSI.
18	**Severe KSI Overvoltage** *1239E DD applicable:* *ShutdownMotor;* *SevereDual.* *Other controller:* *SevereDual;* *LOSDual;* *TrimDisable.*	1. Incorrect (to high) battery-voltage applied to KSI (pin 1). 2. See Monitor menu » Battery: Keyswitch Voltage.	*Set:* KSI voltage exceeded Severe Overvoltage limiit. *Clear:* Bring KSI voltage below the Severe Overvoltage limit.
22	**Controller Overtemp Cutback** *Reduced drive torque;* *TrimDisable.* *Other controller:* *TrimDisable.*	1. See Monitor menu » Controller: Temperature. 2. Controller is performance-limited at this temperature. 3. Controller is operating in an extreme environment. 4. Excessive load on vehicle. 5. Improper mounting of controller.	*Set:* Heatsink temperature exceeded 85°C. *Clear:* Bring heatsink temperature below 85°C.
23	**B+ Undervoltage Cutback** *Reduced drive torque;* *TrimDisable.* *Other controller:* *TrimDisable.*	1. Normal operation. Fault indicates the batteries need recharging. Controller is performance limited at this voltage. 2. Battery parameters are misadjusted. 3. Non-controller system drain on battery. 4. Battery resistance too high. 5. Battery disconnected while driving. 6. See Monitor menu » Battery: Capacitor Voltage. 7. Blown B+ fuse or main contactor did not close.	*Set:* Capacitor bank voltage dropped below the Undervoltage limit with the FET bridge enabled. *Clear:* Bring capacitor voltage above the Undervoltage limit.
24	**B+ Overvoltage Cutback** *Reduced drive torque;* *TrimDisable.* *Other controller:* *TrimDisable.*	1. Normal operation. Fault shows that regen braking currents elevated the battery voltage during regen braking. Controller is performance limited at this voltage. 2. Battery parameters are misadjusted. 3. Battery resistance too high for given regen current. 4. Battery disconnected while regen braking. 5. See Monitor menu » Battery: Capacitor Voltage.	*Set:* Capacitor bank voltage exceeded the Overvoltage limit with the FET bridge enabled. *Clear:* Bring capacitor voltage below the Overvoltage limit.
25	**+5V Supply Failure** *None, unless a fault action is programmed in VCL.* *Other controller:* *Same effects as this controller.*	1. External load impedance on the +5V supply (pin 26) is too low. 2. See Monitor menu » outputs: 5 Volts and Ext Supply Current.	*Set:* +5V supply (pin 26) outside the 5 V±10% range. *Clear:* Bring voltage within range.
26	**Digital Out 6 Open/Short** *Digital Output 6 driver will not turn on.* *Other controller:* *None.*	1. External load impedance on Digital Output 6 driver (pin 19) is too low.	*Set:* Digital Output 6 (pin 19) current exceeded 1 Amp. *Clear:* Remedy the overcurrent cause and use the VCL function *Set_DigOut()* to turn the driver on again.

Table 2 DUAL DRIVE TROUBLESHOOTING CHART cont'd

CODE	PROGRAMMER LCD DISPLAY *EFFECT OF FAULT*	POSSIBLE CAUSE	SET / CLEAR CONDITIONS
27	**Digital Out 7 Open/Short** *Digital Output 7 driver will not turn on.* *Other controller:* *None.*	1. External load impedance on Digital Output 7 driver (pin 20) is too low.	*Set:* Digital Output 7 (pin 20) current exceeded 1 Amp. *Clear:* Remedy the overcurrent cause and use the VCL function *Set_DigOut()* to turn the driver on again.
28	**Motor Temp Hot Cutback** *Reduced drive torque; TrimDisable.* *Other controller:* *TrimDisable.*	2. Motor temperature is at or above the programmed Temperature Hot setting, and the current is being cut back. 3. Motor Temperature Control Menu parameters are mis-tuned. 4. See Monitor menu » Motor: Temperature and » Inputs: Analog2. 5. If the application doesn't use a motor thermistor, Temp Compensation and Temp Cutback should be programmed Off.	*Set:* Motor temperature is at or above the Temperature Hot parameter setting. *Clear:* Bring the motor temperature within range.
29	**Motor Temp Sensor Fault** *LOSDual and motor temperature cutback disabled.* *Other controller:* *MaxSpeed reduced to LOSDual.*	1. Motor thermistor is not connected properly. 2. If the application doesn't use a motor thermistor, Motor Temp Sensor Enable should be programmed Off. 3. See Monitor menu » Motor: Temperature and » Inputs: Analog2.	*Set:* Motor thermistor input (pin 8) is at the voltage rail (0 V or 10 V). *Clear:* Bring the motor thermistor input voltage within range.
31	**Coil1 Driver Open/Short** *ShutdownDriver1.* *Other controller:* *None.*	1. Open or short on driver load. 2. Dirty connector pins. 3. Bad crimps or faulty wiring.	*Set:* Driver 1 (pin 6) is either open or shorted. This fault can be set only when Main Enable = Off. *Clear:* Correct open or short, and cycle driver.
31	**Main Open/Short** *ShutdownMotor; ShutdownMainContactor; ShutdownEMBrake; ShutdownThrottle; FullBrake.* *Other controller:* *Same effects as this controller.*	1. Open or short on driver load. 2. Dirty connector pins. 3. Bad crimps or faulty wiring.	*Set:* Main contactor driver (pin 6) is either open or shorted. This fault can be set only when Main Enable = On. *Clear:* Correct open or short, and cycle driver
32	**Coil2 Driver Open/Short** *ShutdownDriver2.* *Other controller:* *None.*	1. Open or short on driver load. 2. Dirty connector pins. 3. Bad crimps or faulty wiring.	*Set:* Driver 2 (pin 5) is either open or shorted. This fault can be set only when EM Brake Type = 0. *Clear:* Correct open or short, and cycle driver.
32	**EMBrake Open/Short** *ShutdownEMBrake; ShutdownThrottle; FullBrake.* *Other controller:* *Same effects as this controller.*	1. Open or short on driver load. 2. Dirty connector pins. 3. Bad crimps or faulty wiring.	*Set:* Electromagnetic brake driver (pin 5) is either open or shorted. This fault can be set only when EM Brake Type >0. *Clear:* Correct open or short, and cycle driver.
33	**Coil3 Driver Open/Short** *ShutdownDriver3.* *Other controller:* *None.*	1. Open or short on driver load. 2. Dirty connector pins. 3. Bad crimps or faulty wiring.	*Set:* Driver 3 (pin 4) is either open or shorted. *Clear:* Correct open or short, and cycle driver.
34	**Coil4 Driver Open/Short** *ShutdownDriver4.* *Other controller:* *None.*	1. Open or short on driver load. 2. Dirty connector pins. 3. Bad crimps or faulty wiring.	*Set:* Driver 4 (pin 3) is either open or shorted. *Clear:* Correct open or short, and cycle driver.

Table 2 DUAL DRIVE TROUBLESHOOTING CHART cont'd

CODE	PROGRAMMER LCD DISPLAY *EFFECT OF FAULT*	POSSIBLE CAUSE	SET / CLEAR CONDITIONS
35	**PD Open/Short** *ShutdownPD.* *Other controller:* *Same effects as this controller.*	1. Open or short on driver load. 2. Dirty connector pins. 3. Bad crimps or faulty wiring.	*Set:* Proportional driver (pin 2) is either open or shorted. *Clear:* Correct open or short, and cycle driver.
36	**Encoder Fault** *SevereDual;* Motor disabled. *Other controller:* *TrimDisable;* *SevereDual;* *LOSDual.*	1. Motor encoder failure. 2. Bad crimps or faulty wiring. 3. See Monitor menu » Motor: Motor RPM.	*Set:* Motor encoder phase or signal failure detected. *Clear:* Either cycle KSI, or controller detects valid motor encoder signals while operation in LOSDual mode and return Throttle Command = 0 and Motor RPM = 0.
36	**Sin/Cos Sensor Fault** *ShutdownEMBrake;* *ShutdownThrottle.* *Other controller:* *None.*	1. Sin/cos sensor failure. 2. Bad crimps or faulty wiring. 3. See Monitor menu » Motor: Motor RPM.	*Set:* Greater than Sin_Cos_Fault_Threshold % difference from expected value between two phases seen 5 times within one second. *Clear:* Cycle KSI, or VCL reset.
37	**Motor Open** *ShutdownMotor;* *SevereDual.* *Other controller:* *SevereDual;* *LOSDual;* *TrimDisable.*	1. Motor phase is open. 2. Bad crimps or faulty wiring.	*Set:* Motor phase U, V, or W detected open. *Clear:* Cycle KSI.
38	**Main Contactor Welded** *ShutdownMotor;* *ShutdownMainContactor;* *ShutdownEMBrake;* *ShutdownThrottle;* *FullBrake.* *Other controller:* *Same effects as this controller.*	1. Main contactor tips are welded closed. 2. Motor phase U or V is disconnected or open. 3. An alternate voltage path (such as an external precharge resistor) is providing a current to the capacitor bank (B+ connection terminal).	*Set:* Just prior to the main contactor closing, the capacitor bank voltage (B+ connection terminal) was loaded for a short time and the voltage did not discharge. *Clear:* Cycle KSI
39	**Main Contactor Did Not Close** *ShutdownMotor;* *ShutdownMainContactor;* *ShutdownEMBrake;* *ShutdownThrottle;* *FullBrake.* *Other controller:* *Same effects as this controller.*	1. Main contactor did not close. 2. Main contactor tips are oxidized, burned, or not making good contact.* 3. External load on capacitor bank (B+ connection terminal) that prevents capacitor bank from charging. 4. Blown B+ fuse.	*Set:* With the main contactor commanded closed, the capacitor bank voltage (B+ connection terminal) did not charge to B+. *Clear:* Cycle KSI. *New contactors may need to be cycled electrically & mechanically to remove any non-conductive material on the tips. Use reduced voltage (e.g., 12V) to prevent tip damage through excessive arcing.
41	**Throttle Wiper High** *ShutdownThrottle.* *Other controller:* *Same effects as this controller.*	1. See Monitor menu » Inputs: Throttle Pot. 2. Throttle pot wiper voltage too high.	*Set:* Throttle pot wiper (pin 16) voltage is higher than the high fault threshold (can be changed with the VCL function *Setup_Pot_Faults()*). *Clear:* Bring throttle pot wiper voltage below the fault threshold.
42	**Throttle Wiper Low** *ShutdownThrottle.* *Other controller:* *Same effects as this controller.*	1. See Monitor menu » Inputs: Throttle Pot. 2. Throttle pot wiper voltage too low.	*Set:* Throttle pot wiper (pin 16) voltage is lower than the low fault threshold (can be changed with the VCL function *Setup_Pot_Faults()*). *Clear:* Bring throttle pot wiper voltage above the fault threshold.

Table 2 DUAL DRIVE TROUBLESHOOTING CHART cont'd

CODE	PROGRAMMER LCD DISPLAY *EFFECT OF FAULT*	POSSIBLE CAUSE	SET / CLEAR CONDITIONS
43	**Pot2 Wiper High** *ShutdownSteer;* MaxSpeed reduced to LOSDual *Other controller:* *Same effects as this controller.*	1. See Monitor menu » Inputs: Pot2 Raw. 2. Pot2 wiper voltage too high.	*Set:* Pot2 wiper (pin 17) voltage is higher than the high fault threshold (can be changed with the VCL function *Setup_Pot_Faults()*). *Clear:* Bring Pot2 wiper voltage below the fault threshold.
44	**Pot2 Wiper Low** *ShutdownSteer;* MaxSpeed reduced to LOSDual *Other controller:* *Same effects as this controller.*	1. See Monitor menu » Inputs: Pot2 Raw. 2. Pot2 wiper voltage too low.	*Set:* Pot2 wiper (pin 17) voltage is lower than the low fault threshold (can be changed with the VCL function *Setup_Pot_Faults()*). *Clear:* Bring Pot2 wiper voltage above the fault threshold.
45	**Pot Low OverCurrent** *ShutdownThrottle;* *FullBrake.* *Other controller:* *Same effects as this controller.*	1. See Monitor menu » Outputs: Pot Low. 2. Combined pot resistance connected to pot low is too low.	*Set:* Pot low (pin 18) current exceeds 10 mA. *Clear:* Clear pot low overcurrent condition and cycle KSI.
46	**EEPROM Failure** *ShutdownMotor;* *ShutdownMainContactor;* *ShutdownEMBrake;* *ShutdownThrottle;* *ShutdownInterlock;* *ShutdownDriver1;* *ShutdownDriver2;* *ShutdownDriver3;* *ShutdownDriver4;* *ShutdownPD;* *FullBrake;* *TrimDisable;* *SevereDual;* *ShutdownSteer;* *LOSDual.* *Other controller:* *Same effects as this controller.*	1. Failure to write to EEPROM memory. This can be caused by EEPROM memory writes initiated by VCL, by the CAN bus, by adjusting parameters with the programmer, or by loading new software into the controller.	*Set:* Controller operating system tried to write to EEPROM memory and failed. *Clear:* Download the correct software (OS) and matching parameter default settings into the controller and cycle KSI.
47	**HPD/Sequencing Fault** *ShutdownThrottle.* *Other controller:* *Same effects as this controller.*	1. KSI, interlock, direction, and throttle inputs applied in incorrect sequence. 2. Faulty wiring, crimps, or switches at KSI, interlock, direction, or throttle inputs. 3. See Monitor menu » Inputs.	*Set:* HPD (High Pedal Disable) or sequencing fault caused by incorrect sequence of KSI, interlock, direction, and throttle inputs. *Clear:* Reapply inputs in correct sequence.
47	**Emer Rev HPD** *ShutdownThrottle;* *ShutdownEMBrake.* *Other controller:* *Same effects as this controller.*	1. Emergency Reverse operation has concluded, but the throttle, forward and reverse inputs, and interlock have not been returned to neutral.	*Set:* At the conclusion of Emergency Reverse, the fault was set because various inputs were not returned to neutral. *Clear:* If EMR_Interlock = On, clear the interlock, throttle, and direction inputs. If EMR_Interlock = Off, clear the throttle and direction inputs.
49	**Parameter Change Fault** *ShutdownMotor;* *ShutdownMainContactor;* *ShutdownEMBrake;* *ShutdownThrottle;* *FullBrake.* *Other controller:* *Same effects as this controller.*	1. This is a safety fault caused by a change in certain parameter settings so that the vehicle will not operate until KSI is cycled. For example, if a user changes the Throttle Type this fault will appear and require cycling KSI before the vehicle can operate.	*Set:* Adjustment of a parameter setting that requires cycling of KSI. *Clear:* Cycle KSI.
51-67	**OEM Faults** *(See OEM documentation.)*	1. These faults can be defined by the OEM and are implemented in the application-specific VCL code. See OEM documentation.	*Set:* See OEM documentation. *Clear:* See OEM documentation.

Table 2 DUAL DRIVE TROUBLESHOOTING CHART cont'd

CODE	PROGRAMMER LCD DISPLAY *EFFECT OF FAULT*	POSSIBLE CAUSE	SET / CLEAR CONDITIONS
68	**VCL Run Time Error** *ShutdownMotor;* *ShutdownMainContactor;* *ShutdownEMBrake;* *ShutdownThrottle;* *ShutdownInterlock;* *ShutdownDriver1;* *ShutdownDriver2;* *ShutdownDriver3;* *ShutdownDriver4;* *ShutdownPD;* *FullBrake;* *TrimDisable;* *SevereDual;* *ShutdownSteer;* *LOSDual.* *Other controller:* *Same effects as this controller.*	1. VCL code encountered a runtime VCL error. 2. See Monitor menu » Controller: VCL Error Module and VCL Error. This error can then be compared to the runtime VCL module ID and error code definitions found in the specific OS system information file.	*Set:* Runtime VCL code error condition. *Clear:* Edit VCL application software to fix this error condition; flash the new compiled software and matching parameter defaults; cycle KSI.
69	**External Supply Out of Range** *None, unless a fault action is programmed in VCL.* *Other controller:* *Same effects as this controller.*	1. External load on the 5V and 12V supplies draws either too much or too little current. 2. Fault Checking Menu parameters Ext Supply Max and Ext Supply Min are mis-tuned. 3. See Monitor menu » Outputs: Ext Supply Current.	*Set:* The external supply current (combined current used by the 5V supply [pin 26] and 12V supply [pin 25]) is either greater than the upper current threshold or lower than the lower current threshold. The two thresholds are defined by the External Supply Max and External Supply Min parameter settings. *Clear:* Bring the external supply current within range.
71	**OS General** *ShutdownMotor;* *ShutdownMainContactor;* *ShutdownEMBrake;* *ShutdownThrottle;* *ShutdownInterlock;* *ShutdownDriver1;* *ShutdownDriver2;* *ShutdownDriver3;* *ShutdownDriver4;* *ShutdownPD;* *FullBrake;* *TrimDisable;* *SevereDual;* *ShutdownSteer;* *LOSDual.* *Other controller:* *Same effects as this controller.*	1. Internal controller fault.	*Set:* Internal controller fault detected. *Clear:* Cycle KSI.
72	**PDO Timeout** *ShutdownInterlock;* CAN NMT State set to Pre-operational. *Other controller:* *Same effects as this controller.*	1. Time between CAN PDO messages received exceeded the PDO Timeout Period.	*Set:* Time between CAN PDO messages received exceeded the PDO Timeout Period. *Clear:* Cycle KSI or receive CAN NMT message.
73	**Stall Detected** *SevereDual;* Motor disabled. *Other controller:* *TrimDisable;* *SevereDual;* *LOSDual.*	1. Stalled motor. 2. Motor encoder failure. 3. Bad crimps or faulty wiring. 4. Problems with power supply for the motor encoder. 5. See Monitor menu » Motor: Motor RPM.	*Set:* No motor encoder movement detected. *Clear:* Either cycle KSI, or controller detects valid motor encoder signals while operation in LOSDual mode and return Throttle Command = 0 and Motor RPM = 0.

Table 2 DUAL DRIVE TROUBLESHOOTING CHART cont'd

CODE	PROGRAMMER LCD DISPLAY *EFFECT OF FAULT*	POSSIBLE CAUSE	SET / CLEAR CONDITIONS
74	**Fault On Other Traction Controller** For information on this fault, plug the 1313/1314 programmer into the other controller.	1. A fault is active on the other traction controller.	*Set*: In a Dual Drive traction system, any fault in the other traction controller will cause this fault to be set. *Clear*: Clear all the active faults in the other traction controller.
75	**Dual Severe Fault** *ShutdownMotor;* *ShutdownMainContactor;* *ShutdownEMBrake;* *ShutdownThrottle;* *FullBrake.* *Other controller:* *Same effects as this controller.*	1. Both traction controllers have active severe faults and therefore both will be disabled.	*Set:* A severe fault in each traction controller will cause this fault to be set. *Clear:* Correct the severe fault(s) in either controller to clear the Dual Severe Fault. Clear all the faults on both controllers.
77	**Supervisor Fault** *ShutdownMotor;* *ShutdownMainContactor;* *ShutdownEMBrake;* *ShutdownThrottle;* *ShutdownInterlock;* *ShutdownDriver1;* *ShutdownDriver2;* *ShutdownDriver3;* *ShutdownDriver4;* *ShutdownPD;* *FullBrake;* *TrimDisable;* *SevereDual;* *ShutdownSteer;* *LOSDual.* *Other controller:* *Same effects as this controller.*	1. The Supervisor has detected a mismatch in redundant readings. 2. Internal damage to Supervisor microprocessor. 3. Switch inputs allowed to be within upper and lower thresholds for over 100 milliseconds.	*Set:* Mismatched redundant readings; damaged Supervisor; illegal switch inputs. *Clear:* Check for noise or voltage drift in all switch inputs; check connections; cycle KSI.
78	**Supervisor Incompatible** *ShutdownMotor;* *ShutdownMainContactor;* *ShutdownEMBrake;* *ShutdownThrottle;* *ShutdownInterlock;* *ShutdownDriver1;* *ShutdownDriver2;* *ShutdownDriver3;* *ShutdownDriver4;* *ShutdownPD;* *FullBrake;* *TrimDisable;* *SevereDual;* *ShutdownSteer;* *LOSDual.* *Other controller:* *Same effects as this controller.*	1. The main OS is not compatible with the Supervisor OS.	*Set:* Incompatible software. *Clear:* Load properly matched OS code or update the Supervisor code; cycle KSI.
82	**Bad Calibrations** *ShutdownMotor;* *ShutdownMainContactor;* *ShutdownEMBrake;* *ShutdownThrottle;* *FullBrake.* *Other controller:* *Same effects as this controller.*	1. Internal controller fault.	*Set:* Internal controller fault detection. *Clear:* Cycle KSI.

Table 2 DUAL DRIVE TROUBLESHOOTING CHART cont'd

CODE	PROGRAMMER LCD DISPLAY *EFFECT OF FAULT*	POSSIBLE CAUSE	SET / CLEAR CONDITIONS
83	**Driver Supply** *ShutdownMotor;* *ShutdownMainContactor;* *ShutdownEMBrake;* *ShutdownThrottle;* *FullBrake.* *Other controller:* *Same effects as this controller.*	1. Internal controller fault in the voltage supply for the driver circuits.	*Set:* Internal controller fault detection. *Clear:* Cycle KSI.
87	**Motor Characterization Fault** *ShutdownMotor;* *ShutdownMainContactor;* *ShutdownEMBrake;* *ShutdownThrottle;* *FullBrake.* *Other controller:* *Same effects as this controller.*	1. Motor characterization failed during characterization process. See Monitor menu » Controller: Motor Characterization Error for cause: 0 = sequencing error. Normally caused by turning off Motor Characterization Test Enable before running the test. 1 = encoder signal seen but step size not auto-detected; set up Encoder Steps manually 2 = motor temp sensor fault 3 = motor temp hot cutback fault 4 = controller overtemp cutback fault 5 = controller undertemp cutback fault 6 = undervoltage cutback fault 7 = severe overvoltage fault 8 = encoder signal not seen, or one or both channels missing 9 = motor parameters out of characterization range 20 = sin/cos sensor not found 21 = phasing not detected 22 = sin/cos sensor characterization failure 23 = started characterization procedure while motor rotating.	*Set:* Motor characterization failed during the motor characterization process. Normally caused by turning off Motor_Characterization_Test_Enable before running test. Needs controller reset. *Clear:* Correct fault; cycle KSI, or VCL reset.
88	**Encoder Pulse Count Fault** *ShutdownMotor;* *ShutdownMainContactor;* *ShutdownEMBrake;* *ShutdownThrottle;* *ShutdownInterlock;* *ShutdownDriver1;* *ShutdownDriver2;* *ShutdownDriver3;* *ShutdownDriver4;* *ShutdownPD;* *FullBrake;* *TrimDisable;* *SevereDual;* *ShutdownSteer;* *LOSDual.* *Other controller:* *Same effects as this controller.*	1. Encoder Steps parameter does not match the actual motor encoder.	*Set:* Motor lost IFO control and accelerated without throttle command. *Clear:* Ensure the Encoder Steps parameter matches the actual encoder; cycle KSI.

Table 2 DUAL DRIVE TROUBLESHOOTING CHART cont'd

CODE	PROGRAMMER LCD DISPLAY *EFFECT OF FAULT*	POSSIBLE CAUSE	SET / CLEAR CONDITIONS
89	**Motor Type Fault** *ShutdownMotor;* *ShutdownMainContactor;* *ShutdownEMBrake;* *ShutdownThrottle;* *FullBrake.* *Other controller:* *Same effects as this controller.*	2. The Motor_Type parameter value is out of range.	*Set:* Motor_Type parameter is set to an illegal value. *Clear:* Set Motor_Type to correct value and cycle KSI.
91	**VCL/OS Mismatch** *ShutdownMotor;* *ShutdownMainContactor;* *ShutdownEMBrake;* *ShutdownThrottle;* *ShutdownInterlock;* *ShutdownDriver1;* *ShutdownDriver2;* *ShutdownDriver3;* *ShutdownDriver4;* *ShutdownPD;* *FullBrake;* *TrimDisable;* *SevereDual;* *ShutdownSteer;* *LOSDual.* *Other controller:* *Same effects as this controller.*	1. The VCL software in the controller does not match the OS software in the controller.	*Set:* VCL and OS software do not match; when KSI cycles, a check is made to verify that they match and a fault is issued when they do not. *Clear:* Download the correct VCL and OS software into the controller.
92	**EM Brake Failed to Set** *ShutdownEMBrake;* *ShutdownThrottle.* *Position Hold is engaged when Interlock = On.* *Other controller:* *Same effects as this controller.*	1. Vehicle movement sensed after the EM Brake has been commanded to set. 2. EM Brake will not hold the motor from rotating.	*Set:* After the EM Brake was commanded to set and time has elapsed to allow the brake to fully engage, vehicle movement has been sensed. *Clear:* 1. Activate the Throttle (EM Brake type 2). 2. Activate the Interlock (EM Brake type 1).
94	**EMR Rev Timeout** *ShutdownEMBrake;* *ShutdownThrottle.* *Other controller:* *Same effects as this controller.*	1. Emergency Reverse was activated and concluded because the EMR Timeout timer has expired. 2. The emergency reverse input is stuck On.	*Set:* Emergency Reverse was activated and ran until the EMR Timeout timer expired. *Clear:* Turn the emergency reverse input Off.
98	**Illegal Model Number** *ShutdownMotor;* *ShutdownMainContactor;* *ShutdownEMBrake;* *ShutdownThrottle;* *FullBrake.* *Other controller:* *Same effects as this controller.*	1. Model_Number variable contains illegal value. 2. Software and hardware do not match. 3. Controller defective.	*Set:* Illegal Model_Number variable; when KSI cycles, a check is made to confirm a legal Model_Number, and a fault is issued if one is not found. *Clear:* Download appropriate software for your controller model.
99	**Parameter Mismatch** *ShutdownMotor;* *ShutdownMainContactor;* *ShutdownEMBrake;* *ShutdownThrottle;* *FullBrake.* *Other controller:* *Same effects as this controller.*	1. Dual Motor Enable parameter is set On and Control Mode Select parameter not set to 1 (Speed Mode Express) or 2 (Speed Mode). 2. Motor Technology and Feedback Type parameters do not match.	*Set:* When the Dual Drive software is enabled, the controller must be set to either Speed Mode Express or Speed Mode; otherwise this fault is set. Motor Techology=0 must be paired with Feedback Type=1, and Motor Technology=1 must be paired with Feedback Type=2; otherwise this fault is set. *Clear:* Adjust parameters to appropriate values and cycle KSI.