Note: The information contained herein is intended to assist OEM’s, Dealers and Users of electric vehicles in the application, installation and service of GE solid-state controllers. This manual does not purport to cover all variations in OEM vehicle types. Nor does it provide for every possible contingency to be met involving vehicle installation, operation or maintenance. For additional information and/or problem resolution, please refer the matter to the OEM vehicle manufacturer through his normal field service channels. Do not contact GE directly for this assistance.

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Section 1. INTRODUCTION

Section 1.1 Motor Characteristics

The level of sophistication in the controllability of traction motors has changed greatly over the past several years. Vehicle manufacturers and users are continuing to expect more value and flexibility in electric vehicle motor and control systems as they are applied today. In order to respond to these market demands, traction system designers have been forced to develop new approaches to reduce cost and improve functions and features of the overall system. Development is being done in a multi-generational format that allows the market to take advantage of today’s technology, while looking forward to new advances on the horizon. GE has introduced a second generation system using separately excited DC shunt wound motors. The separately excited DC motor system offers many of the features that are generally found on the advanced AC systems. Historically, most electric vehicles have relied on series motor designs because of their ability to produce very high levels of torque at low speeds. But, as the demand for high efficiency systems increases, i.e., systems that are more closely applied to customers’ specific torque requirements, shunt motors are now often being considered over series motors. In most applications, by independently controlling the field and armature currents in the separately excited motor, the best attributes of both the series and the shunt wound motors can be combined.

As shown in the typical performance curves of Figure 1, the high torque at low speed characteristic of the series motor is evident.

In a shunt motor, the field is connected directly across the voltage source and is therefore independent of variations in load and armature current. If field strength is held constant, the torque developed will vary directly with the armature current. If the mechanical load on the motor increases, the motor slows down, reducing the back EMF (which depends on the speed, as well as the constant field strength). The reduced back EMF allows the armature current to increase, providing the greater torque needed to drive the increased mechanical load. If the mechanical load is decreased, the process reverses. The motor speed and the back EMF increase, while the armature current and the torque developed decrease. Thus, whenever the load changes, the speed changes also, until the motor is again in electrical balance.

In a shunt motor, the variation of speed from no load to normal full load on level ground is less than 10%. For this reason, shunt motors are considered to be constant speed motors (Figure 2).

In the separately excited motor, the motor is operated as a fixed field shunt motor in the normal running range. However, when additional torque is required, for example, to climb non-level terrain, such as ramps and the like, the field current is increased to provide the higher level of torque. In most cases, the armature to field ampere turn ratio can be very similar to that of a comparable size series motor (Figure 3.)

Aside from the constant horsepower characteristics described above, there are many other features that provide increased performance and lower cost. The
following description provides a brief introduction to examples of some of these features.

**Section 1.2 Solid-State Reversing**

The direction of armature rotation on a shunt motor is determined by the direction in which current flows through the field windings. Because the shunt motor field only typically requires about 10% of the armature current at full torque, it is normally cost effective to replace the double-pole, double-throw reversing contactor with a low power transistor H-Bridge circuit (Figure 4).

By energizing the transistors in pairs, current can be made to flow in either direction in the field. The field control circuit operates at 2 KHZ, and the armature control circuit typically operates at 12 KHZ, a frequency normally above human hearing. This high frequency coupled with the elimination of directional contactors, provides very quiet vehicle operation.

The line contactor is normally the only contactor required for the shunt motor traction circuit. This contactor is used for both pre-charge of the line capacitors and for emergency shut down of the motor circuit, in case of problems that would cause a full motor torque condition. The line can be energized and de-energized by the various logic combinations of the vehicle, i.e. activate on key, seat or start switch closure, and de-energize on time out of idle vehicle. Again, these options add to the quiet operation of the vehicle.

**Section 1.3 Flexible System Application**

Because the shunt motor controller has the ability to control both the armature and field circuits independently, the system can normally be adjusted for maximum system efficiencies at certain operating parameters. Generally speaking, with the ability of independent field and armature, the motor performance curve can be maximized through proper control application.

**Section 1.4 More Features with Fewer Components**

Field weakening with a series wound motor is accomplished by placing a resistor in parallel with the field winding of the motor. Bypassing some of the current flowing in the field into the resistor causes the field current to be less, or weakened. With the field weakened, the motor speed will increase, giving the effect of “overdrive”. To change the “overdrive speed”, it is necessary to change the resistor value. In a separately excited motor, independent control of the field current provides for infinite adjustments of “overdrive” levels, between motor base speed and maximum weak field. The desirability of this feature is enhanced by the elimination of the contactor and resistor required for field weakening with a series motor.

With a separately excited motor, overhauling speed limit, or downhill speed, will also be more constant. By its nature, the shunt motor will try to maintain a constant speed downhill. This characteristic can be enhanced by increasing the field strength with the control. Overhauling load control works in just the opposite way of field weakening, armature rotation slows with the increase of current in the field. An extension of this feature is a zero-speed detect feature which prevents the vehicle from free-wheeling down an incline, should the operator neglect to set the brake.

Regenerative braking (braking energy returned to the battery) may be accomplished completely with solid-state technology. The main advantage of regenerative braking is increased motor life. Motor current is reduced by 50% or more during braking while maintaining the same braking torque as electrical braking with a diode clamp around the armature. The lower current translates into longer brush life and reduced motor heating. Solid state regenerative braking also eliminates a power diode, current sensor and contactor from the circuit.

For GE, the future is now as we make available a new generation of electric traction motor systems for electric vehicles having separately excited DC shunt motors and controls. Features that were once thought to be only available on future AC or brushless DC technology vehicles systems are now achievable and affordable.
Section 2. FEATURES OF SX FAMILY OF TRANSISTOR MOTOR CONTROLLERS

Section 2.1 Performance

Section 2.1.1 Oscillator Card Features

Section 2.1.1.a Standard Operation

The oscillator section of the card has two adjustable features, creep speed and minimum field current. With the accelerator at maximum ohms or volts, the creep speed can be adjusted by Function 2 of the Handset or a trimpot. The field control section allows the adjustment of the field weakening level in order to set the top speed of the motor. This top speed function (Minimum Field Current) is enabled when the armature current is less than the value set by Function 24 and the accelerator input voltage is less than 1 volt. Top Speed can be adjusted by Function 7 of the Handset or a trimpot.

The percent on-time has a range of approximately 0 to 100 percent. The SX controllers operate at a constant frequency and the percent on-time is controlled by the pulse width of the voltage / current applied to the motor circuits.

Section 2.1.1.b Creep Speed

With the accelerator at maximum ohms or volts (approximately 3.7 to 3.5 VDC), the creep speed can be adjusted by Function 2 of the Handset. At creep speed, the ON time can decrease to approximately 5%, with the OFF time at approximately 95%. At full transistor operation, this condition will be reversed (short OFF time, long ON time). This variation of ON and OFF time of the oscillator varies the voltage applied to the motor, thereby varying the speed of the motor for a given load.

Section 2.1.1.c Control Acceleration

This feature allows for adjustment of the rate of time it takes for the control to accelerate to 100% applied battery voltage to the motor on hard acceleration. C/A is adjusted by Function 3 from 0.1 to 22 seconds.

Section 2.1.2 Current Limit

This circuit monitors motor current by utilizing sensors in series with the armature and field windings. The information detected by the sensor is fed back to the card so that current may be limited to a pre-set value. If heavy load currents are detected, this circuit overrides the oscillator and limits the average current to a value set by Function 4 and Function 8 of the Handset. The C/L setting is based on the maximum thermal rating of the control. Because of the flyback current through 3REC, the motor current is usually greater than battery current, except at 100% ON time.

Section 2.1.3 Braking

Section 2.1.3.a Regenerative Braking to Zero Speed

Slow down is accomplished when reversing direction by providing a small amount of retarding torque for deceleration. If the vehicle is moving, and the directional lever is moved from one direction to the other, the regen signal is initiated. Once the regen signal has been initiated, the field current is increased. Armature current is regulated to the regen current limit as set by Function 9. As the vehicle slows down, the field current continues to increase, and transistor Q2 begins to chop. The field current will increase until it reaches a preset value set by Function 10, and transistor Q2 on-time will increase until it reaches 100% on-time. Once both of the above conditions have been met, and regen current limit can no longer be maintained, the braking function is canceled. The fields will then reverse, and the control reverts back to motoring.

Part of the energy produced by the motor during regen is returned to the battery, and part is dumped in the motor as heat.

Section 2.1.3.b Auto Braking

This feature is enabled by initiating a "neutral position" using either the directional switch or the accelerator switch.

Section 2.1.3.c Overspeed Regenerative Braking

Overspeed regenerative braking provides a means of controlling the speed of a vehicle in operation on an incline. The feature is enabled when the tachometer pulses seen by the control exceed the values set by Function 11 or 12. Once this occurs, the control will provide retarding torque to regulate the vehicle speed, as determined by Functions 11 and 12.

Section 2.1.4 Auxiliary Speed Control

Section 2.1.4.a Field Weakening

This function allows the adjustment of the field weakening level in order to set the top speed of the motor. The function is enabled when the armature current is less than the value set by Function 24 and the accelerator input voltage is less than 1 volt. It is important to note that this function is used to optimize motor and control performance, and this setting...
will be determined by GE and OEM engineers at the time of vehicle development. This setting must not be changed by field personnel without the permission of the OEM.

Section 2.1.4.b Speed Limits

This feature provides a means to control speed by re-scaling the maximum number of tachometer pulses to a set value at the maximum throttle to be regulated. These speeds are set by Functions 11 and 12. These speed limits are activated by a normally open switch to positive 12 volts.

Section 2.1.5 Ramp Start

This feature provides maximum control torque to restart a vehicle on an incline. The memory for this function is the directional switch. When stopping on an incline, the directional switch must be left in its original or neutral position to allow the control to initiate full power when restarted. The accelerator potentiometer input will modulate ramp start current.

Section 2.1.6 On-Board Coil Drivers & Internal Coil Suppression

Coil drivers for the LINE and SP or BYPASS contactors are on-board the control card. These contactors must have coils rated for the vehicle battery volts.

Section 2.2 System Protective Override

Section 2.2.1 Static Return to Off (SRO)

This inherent feature of the control is designed to require the driver to return the directional lever to the neutral position anytime he removes his foot from the foot switch.

Section 2.2.2 Accelerator Volts Hold Off

This feature checks the voltage level at the accelerator input whenever the key switch or seat switch is activated. If, at start up, the voltage is less than 3.0 volts, the control will not operate. This feature assures that the control is calling for low speed operation at start up.

Section 2.2.3 Pulse Monitor Trip (PMT)

The PMT design contains three features which shut down, or lock out, control operation if a fault conditions occurs that would cause a disruption of normal vehicle operation:

- Look ahead
- Look again
- Automatic look again and reset

The PMT circuit will not allow the control to start under the following conditions:

- The control monitors both armature and field FET's at start-up and during running.
- The control will not allow the line contactor to close at start-up, or will drop it out during running, if either the armature or field FET's are defective, so as to cause uncontrolled truck movement.

Section 2.2.4 Thermal Protector (TP)

This temperature sensitive device is internal to the power transistor (Q1) module. If the transistor's temperature begins to exceed the design limits, the thermal protector will lower the maximum current limit, and maintain the transistors within their temperature limits. As the control cools, the thermal protector will automatically reset, returning the control to full power.

Section 2.2.5 Low Voltage

Batteries under load, particularly if undersized or more than 80 percent discharged, will produce low voltages at the control terminals. The SX control is designed for use down to 50 percent of a nominal battery voltage of 36-84 volts, and 75 percent of a nominal battery voltage of 24 volts. Lower battery voltage may cause the control to operate improperly, however, the resulting PMT should open the Line contactor, in the event of a failure.

Section 2.3 Diagnostics

Section 2.3.1 Systems Diagnostics

The control detects the system's present operating status and can be displayed to either the Dash Display or the Handset. There are currently over 70 status codes that are available with SX systems using Traction and Pump controls and Truck Management Module (TMM). Along with the status code display from the TMM, the SX control is capable of reducing the current to the motor, alerting the operator of a critical fault condition.

Section 2.3.2 Status Codes

Section 2.3.2a Standard Status Codes

The SX traction control has over 30 Status Codes that assist the service technician and operator in trouble shooting the vehicle. If mis-operation of the vehicle occurs, a status code will be displayed on the Dash Display for vehicles so equipped, or be available by plugging the Handset into the “y” plug of the logic card.

With the status code number, follow the procedures outlined in DIAGNOSTIC STATUS CODES to determine the problem and a solution.
Note: The Status Code Instruction Sheets do not purport to cover all possible causes of a display of a “status code”. They do provide instructions for checking the most direct inputs that can cause status codes to appear.

Section 2.3.2.b Stored Status Codes

This feature records the last 16 “Stored Status Codes” that have caused a PMT controller shut down and/or disrupted normal vehicle operation. (PMT type faults are reset by cycling the key switch). These status codes, along with the corresponding BDI and hourmeter readings, can be accessed with the Handset, or by using the RS 232 communications port and dumping the information to a Personal Computer terminal.

Section 2.3.3 Hourmeter Readings

This feature will display the recorded hours of use of the traction and pump control to the Dash Display each time the key switch is turned off.

Section 2.3.4 Battery Discharge Indication (BDI)

The latest in microprocessor technology is used to provide accurate battery state of charge information and to supply passive and active warning signals to the vehicle operator. Features and functions:

- Displays 100 to 0 percent charge.
- Display blinks with 20% charge. Disables pump circuit with 10% charge. Auto ranging for 36/48 volt operation. Adjustable for use on 24 to 80 volts.

Section 2.3.4.a Internal Resistance Compensation

This feature is used when the Battery Discharge Indicator is present. Adjustment of this function will improve the accuracy of the BDI.

Section 2.3.5 Handset

This is a multi-functional tool used with the LX, ZX, and SX Series GE solid state controls. The Handset consists of a Light Emitting Diode (LED) display and a keyboard for data entry. Note, for ordering purposes, a separate Handset part is required for SX controls.

Features and functions:

- Monitor existing system status codes for both traction and pump controls. Monitor intermittent random status codes.
- Monitor battery state of charge, if available.
- Monitor hourmeter reading on traction and pump controls. Monitor or adjust the control functions.

Section 2.3.6 RS 232 Communication Port

This serial communication port can be used with Interactive Custom Dash Displays to allow changes to vehicle operating parameters by the operator. Or, it can be used by service personnel to dump control operating information and settings into a personal computer program.

Section 2.3.6.a Interactive Dash Display Modes

The Interactive Custom Dash Display allows the operator to select the best vehicle performance for changing factory (task) conditions. There are four (4) “operator interaction modes” that can be selected by depressing a push button on the dash display.

From the Dash Display, the operator may select any of four pre-set interactive modes consisting of (4) Controlled Acceleration levels, (4) Field Weakening levels and (4) Speed Limits.

These interactive modes are “pre-set” using the Handset (Functions 48-63) or a personal computer (Functions 97-112). This feature allows the operator to select the best vehicle performance for changing factory (task) conditions.

Section 2.3.7 Circuit Board Coil Driver Modules

Coil drivers are internal to the control card, and are the power devices that operate the Line, 1A and SP contactor coils. On command from the control card, these drivers initiate opening and closing the contactor coils. All driver modules are equipped with reverse battery protection, such that, if the battery is connected incorrectly, the contactors can not be closed electrically.
Section 3.0 ORDERING INFORMATION, ELEMENTARY AND OUTLINE DRAWINGS

Section 3.1 Ordering Information for Separately Excited Controls

Example:

<table>
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<tr>
<th>Part Number: IC3645</th>
<th>SE</th>
<th>4</th>
<th>D</th>
<th>33</th>
<th>2</th>
<th>C3</th>
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<td>Argument Number:</td>
<td>01</td>
<td>02</td>
<td>03</td>
<td>04</td>
<td>05</td>
<td>06</td>
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</table>

**Argument 01:**

Basic Electric Vehicle Control Number

**Argument 02:**

Control Type:
- SH = Separately Excited Control (Plugging)
- SR = Separately Excited Control (Regen to Zero)

**Argument 03:**

Operating Voltage:
- 1 = 120 volts
- 2 = 24 volts
- 3 = 36 volts
- 4 = 48 volts
- 5 = 36/48 volts
- 6 = 24/36 volts
- 7 = 72/80 volts

**Argument 04:**

Package Size:
- D = 6.86" X 6.67"
- R = 6.86" X 8.15"
- U = 8.66" X 8.13"
- W = 8.66" X 10.83"

**Argument 05:**

Armature Current
- 22 = 220 Amps
- 33 = 330 Amps
- 40 = 400 Amps
etc.

**Argument 06:**

Field Current
- 2 = 20 Amps
- 3 = 30 Amps
- 4 = 40 Amps
etc.

**Argument 07:**

Customer / Revision
- A1 = Customer A / Revision 1
- B1 = Customer B / Revision 1
etc.
Section 3.2 Outline: SX-2 Package Size
Section 3.3 Standard Dual Motor Proportioning Drive Elementary
### Section 3.4 Standard Dual Motor Proportioning Drive Input/Output List

Connections to Main Plug (23 Pin) and “Y” Plug (12 Pin)

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<th>PIN</th>
<th>STANDARD DUAL MOTOR PROPORTIONING MAIN PLUG INPUT/OUTPUT DESCRIPTION</th>
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<tbody>
<tr>
<td>1</td>
<td>BATTERY VOLTS FROM BATTERY</td>
</tr>
<tr>
<td>2</td>
<td>12 VOLTS FROM KEY</td>
</tr>
<tr>
<td>3</td>
<td>12 VOLTS FROM BOOM SWITCH</td>
</tr>
<tr>
<td>4</td>
<td>12 VOLTS FROM DIRECTIONAL SWITCH</td>
</tr>
<tr>
<td>5</td>
<td>12 VOLTS FROM TRAVEL ENABLE SWITCH</td>
</tr>
<tr>
<td>6</td>
<td>12 VOLTS FROM FOOT SWITCH</td>
</tr>
<tr>
<td>7</td>
<td>ACCELERATOR INPUT VOLTAGE SIGNAL</td>
</tr>
<tr>
<td>8</td>
<td>NEGATIVE</td>
</tr>
<tr>
<td>9</td>
<td>ACCELERATOR POT +5 VOLTS SUPPLY</td>
</tr>
<tr>
<td>10</td>
<td>BRAKE DRIVER SIGNAL</td>
</tr>
<tr>
<td>11</td>
<td>CROSS TALK SEND</td>
</tr>
<tr>
<td>12</td>
<td>TURN SWITCH</td>
</tr>
<tr>
<td>13</td>
<td>TILT SENSOR</td>
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<tr>
<td>14</td>
<td>TACHOMETER INPUT SIGNAL</td>
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<tr>
<td>15</td>
<td>TACHOMETER +12 VOLTS SUPPLY</td>
</tr>
<tr>
<td>16</td>
<td>MOTOR CURRENT COMPENSATION</td>
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<tr>
<td>17</td>
<td>LINE CONTACTOR DRIVER AND SUPPRESSION</td>
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<td>18</td>
<td>N/A</td>
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<tr>
<td>19</td>
<td>N/A</td>
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<td>20</td>
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<td>SERIAL RECEIVE</td>
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<table>
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<tr>
<th>PIN</th>
<th>MOTOR TRACTION “Y” PLUG INPUT/OUTPUT DESCRIPTION</th>
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<tbody>
<tr>
<td>1</td>
<td>CLOCK (OUT) (DASH DISPLAY-4)</td>
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<td>2</td>
<td>DATA (OUT) (DASH DISPLAY-3)</td>
</tr>
<tr>
<td>3</td>
<td>ENABLE (OUT) (DASH DISPLAY-1)</td>
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<tr>
<td>4</td>
<td>NEGATIVE (DASH DISPLAY-2)</td>
</tr>
<tr>
<td>5</td>
<td>+5V SUPPLY (DASH DISPLAY-5)</td>
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<tr>
<td>6</td>
<td>CONT/STORE (IN) (HANDSET)</td>
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<td>7</td>
<td>MOTOR CURRENT</td>
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<tr>
<td>8</td>
<td>VALUE (TMMA-9)</td>
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<tr>
<td>9</td>
<td>FUNCTION (TMMA-7)</td>
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<tr>
<td>10</td>
<td>+5V SUPPLY (TMMA-13)</td>
</tr>
<tr>
<td>11</td>
<td>SERIAL RECEIVE</td>
</tr>
<tr>
<td>12</td>
<td>SERIAL TRANSMIT</td>
</tr>
</tbody>
</table>

[Wire End View - Main Plug](#)

[Wire End View - "Y" Plug](#)
Section 4.0 TROUBLESHOOTING AND DIAGNOSTIC STATUS CODES

Section 4.1 General Maintenance Instructions

The transistor control, like all electrical apparatus, does have some thermal losses. The semiconductor junctions have finite temperature limits, above which these devices may be damaged. For these reasons, normal maintenance should guard against any action which will expose the components to excessive heat and/or those conditions which will reduce the heat dissipating ability of the control, such as restricting air flow.

The following Do's and Don't's should be observed:

Any controls that will be applied in ambient temperatures over 100° F (40° C) should be brought to the attention of the vehicle manufacturer.

All external components having inductive coils must be filtered. Refer to vehicle manufacturer for specifications.

The wiring should not be directly steam cleaned. In dusty areas, blow low-pressure air over the control to remove dust. In oily or greasy areas, a mild solution of detergent or denatured alcohol can be used to wash the control, and then low-pressure air should be used to completely dry the control.

For the control to be most effective, it must be mounted against the frame of the vehicle. The metal vehicle frame, acting as an additional heat sink, will give improved vehicle performance by keeping the control package cooler. Apply a thin layer of heat-transfer grease (such as Dow Corning 340) between the control heat sink and the vehicle frame.

Control wire plugs and other exposed transistor control parts should be kept free of dirt and paint that might change the effective resistance between points.

CAUTION: The vehicle should not be plugged when the vehicle is jacked up and the drive wheels are in a free wheeling position. The higher motor speeds can create excessive voltages that can be harmful to the control.

Do not hipot (or megger) the control. Refer to control manufacturer before hipotting.

Use a lead-acid battery with the voltage and ampere hour rating specified for the vehicle. Follow normal battery maintenance procedures, recharging before 80 percent discharged with periodic equalizing charges.

Visual inspection of GE contactors contained in the traction and pump systems is recommended to occur during every 160 hours of vehicle operation. Inspection is recommended to verify that the contactors are not binding and that the tips are intact and free of contaminants.

GE does not recommend that any type of welding be performed on the vehicle after the installation of the control(s) in the vehicle. GE will not honor control failures during the warranty period when such failures are attributed to welding while the control is installed in the vehicle.

Section 4.2 Cable Routing and Separation

Electrical noise from cabling of various voltage levels can interfere with a microprocessor-based control system. To reduce this interference, GE recommends specific cable separation and routing practices, consistent with industry standards.

Section 4.2.1 Application Responsibility

The customer and customer’s representative are responsible for the mechanical and environmental locations of cables. They are also responsible for applying the level rules and cabling practices defined in this section. To help ensure a lower cost, noise-free installation, GE recommends early planning of cable routing that complies with these level separation rules.

On new installations, sufficient space should be allowed to efficiently arrange mechanical and electrical equipment. On vehicle retrofits, level rules should be considered during the planning stages to help ensure correct application and a more trouble-free installation.

Section 4.2.2. Signal/Power Level Definitions

The signal/power carrying cables are categorized into four defining levels: low, high, medium power, and high power. Within those levels, signals can be further divided into classes.

Sections 4.2.2.a through 4.2.2.d define these levels and classes, with specific examples of each. Section 4.2.3 contains recommendations for separating the levels.

Section 4.2.2.a Low-Level Signals (Level L)

Low-level signals are designated as level L. These consist of:

- Analog signals 0 through ±15 V
- Digital signals whose logic levels are less than 15 V DC
- 4 – 20 mA current loops
- DC busses less than 15 V and 250 mA

The following are specific examples of level L signals used in drive equipment cabling:

- Control common tie
- DC busses feeding sensitive analog or digital hardware
• All wiring connected to components associated with sensitive analog hardware with less than 5V signals (for example, potentiometers and tachometers)
• Digital tachometers and resolvers
• Dash display cabling
• RS-232 cabling

Note: Signal inputs to analog and digital blocks should be run as shielded twisted-pair (for example, inputs from tachometers, potentiometers, and dash displays).

Section 4.2.2.b High-Level Signals (Level H)

High-level signals are designated as level H. These signals consist of:

• Analog and digital signals greater than 15 V DC and less than 250 mA

For example, switch inputs connected to battery volts are examples of level H signals used in drive equipment cabling.

Section 4.2.2.c Medium-Power Signals (Level MP)

Medium power signals are designated as level MP. These signals consist of:

• DC switching signals greater than 15 V
• Signals with currents greater than 250 mA and less than 10 A

The following are specific examples of level MP signals used in drive equipment cabling:

• DC busses less than 10 A
• Contactor coils less than 10 A
• Machine fields less than 10 A

Section 4.2.2.d High Power Signals (Level HP)

Power wiring is designated as level HP. This consists of DC buses and motor wiring with currents greater than 10 A. The following are specific examples of level HP signals used in drive equipment cabling:

• Motor armature loops
• DC outputs 10 A and above
• Motor field loops 10 A and above

Section 4.2.3. Cable Spacing Guidelines

Recommended spacing (or clearance) between cables (or wires) is dependent on the level of the wiring inside them. For correct level separation when installing cable, the customer must apply the general guidelines (section 4.2.3.a), outlined below.

Section 4.2.3.a General Cable Spacing

The following general practices should be used for all levels of cabling:

• All cables and wires of like signal levels and power levels must be grouped together.
• In general, different levels must run in separate wire bundles, as defined in the different classes, identified above. Intermixing cannot be allowed, unless noted by exception.
• Interconnecting wire runs should carry a level designation.
• If wires are the same level and same type signal, group those wires from one location to any other location together in multicore cables or bind them together with twine or zip-ties.
• When unlike signals must cross, cross them in 90° angles at a maximum spacing. Where it is not possible to maintain spacing, place a grounded steel barrier between unlike levels at the crossover point.

Section 4.2.4 Cabling for Vehicle Retrofits

Reducing electrical noise on vehicle retrofits requires careful planning. Lower and higher levels should never encircle each other or run parallel for long distances. It is practical to use existing wire runs or trays as long as the level spacing (see section 4.2.2) can be maintained for the full length of the run.

Existing cables are generally of high voltage potential and noise producing. Therefore, route levels L and H in a path separate from existing cables, whenever possible. For level L wiring, use barriers in existing wire runs to minimize noise potential.

Do not loop level L signal wires around level H, level MP, or HP wires.

Section 4.2.5 RF Interference

To prevent radio frequency (RF) interference, care should be taken in routing power cables in the vicinity of radio-controlled devices.

Section 4.2.6 Suppression

Unless specifically noted otherwise, suppression (for example, a snubber) is required on all inductive devices controlled by an output. This suppression minimizes noise and prevents damage caused by electrical surges.
Section 4.3 Recommended Lubrication of Pins and Sockets Prior to Installation

Beginning in January of 1999, GE will implement the addition of a lubricant to all connections using pins and sockets on EV100/EV200 and Gen II products. Any connection made by GE to the A, B, X, Y, or Z plugs will have the lubricant NYE 760G added to prevent fretting of these connections during vehicle operation.

Fretting occurs during microscopic movement at the contact points of the connection. This movement exposes the base metal of the connector pin which, when oxygen is present, allows oxidation to occur. Sufficient build up of the oxidation can cause intermittent contact and intermittent vehicle operation. This can occur at any similar type of connection, whether at the control or in any associated vehicle wiring, and the resultant intermittent contact can provide the same fault indication as actual component failure.

The addition of the NYE 760G lubricant will prevent the oxidation process by eliminating the access of oxygen to the contact point. GE recommends the addition of this lubricant to the 12 pin and 23 pin plugs of all new Gen II controls at the time of their installation into a vehicle.

When servicing existing vehicles exhibiting symptoms of intermittent mis-operation or shutdown by the GE control, GE recommends the addition of this lubricant to all 12 and 23 pin plugs, after proper cleaning of the connectors, as a preventative measure to insure fretting is not an issue before GE control replacement.

Section 4.4 General Troubleshooting Instructions

Troubleshooting the SX family of controls should be quick and easy when following the instructions outlined in the following status code instruction sheets.

If mis-operation of the vehicle occurs, a status code will be displayed on the Dash Display (for vehicles equipped with a Dash Display) or made available by plugging a Handset into the plug "Y" location, and then reading the status code.

With the status code number, follow the procedures outlined in the status code instruction sheets to determine the problem.

Important Note: Due to the interaction of the logic card with all vehicle functions, almost any status code or control fault could be caused by the logic card. After all other status code procedures have been followed and no problem is found, the controller should then be replaced as the last option to correct the problem.

The same device designations have been maintained on different controls but the wire numbers may vary. Refer to the elementary and wiring diagrams for your specific control. The wire numbers shown on the elementary diagram will have identical numbers on the corresponding wiring diagrams for a specific vehicle, but these numbers may be different from the numbers referenced in this publication.

**WARNING:** Before trouble-shooting, jack up the drive wheels, disconnect the battery and discharge the capacitors. Reconnect the battery as needed for specific checks. Capacitors should be discharged by connecting a 200 ohm 2 watt resistor between the positive and negative terminals on the control panel.

Check resistance on R x 1000 scale from frame to power and control terminals. A resistance of less than 20,000 ohms can cause misleading symptoms. Resistance less than 1000 ohms should be corrected first.

Before proceeding, visually check for loose wiring, mis-aligned linkage to the accelerator switch, signs of overheating of components, etc.

Tools and test equipment required are: clip leads, volt-ohm meter (20,000 ohms per volt) and basic hand tools.
### Section 4.5 Traction Control Status Codes

<table>
<thead>
<tr>
<th>TRACTION STATUS CODE</th>
<th>DESCRIPTION OF STATUS</th>
<th>CAUSE OF STATUS INDICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>NONE</td>
<td>Segments do not illuminate on the Dash Display and/or the Handset.</td>
<td>No input voltage to the control card or the display unit.</td>
</tr>
<tr>
<td>MEMORY RECALL NO</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**CORRECTIVE ACTIONS**

**SYMPTOM**
Display screen on Dash Display and/or Handset is blank.

**POSSIBLE CAUSE**
Positive or negative control voltage is not present.
- Insure that the key switch is closed and voltage is present between P1 & battery negative (Power Terminal “NEG”). Also check for voltage between P2 and control negative.

- Open circuit between control card Plug Y & the Dash Display or Handset.
- Check for an open circuit or loose connection going from the “Y” plug and the Dash Display or Handset.
- Defective Dash Display or Handset.
- Replace Dash Display or Handset.

### TROUBLE-SHOOTING DIAGRAM

#### -01

**DESCRIPTION OF STATUS**
No foot switch or deadman switch input (no voltage to P6).

**CAUSE OF STATUS INDICATION**
This status code will be displayed when P6 is less than 12% battery volts.

---

**CORRECTIVE ACTIONS**

**SYMPTOM**
Control will not operate.

**POSSIBLE CAUSE**
Mis-adjusted or defective foot or deadman switch.
- Check to see that the foot switch closes properly.

- Open circuit between battery positive and P6.
- Check for loose connections or broken wires:
  - Between the foot switch and P6
  - Between the key switch and the battery positive side of the foot switch.
  - Between the foot switch and P2.

- On vehicles without a foot/deadman switch, check for a loose connection or broken wire from P2 and/or P6.
<table>
<thead>
<tr>
<th>TRACTION STATUS CODE</th>
<th>DESCRIPTION OF STATUS</th>
<th>CAUSE OF STATUS INDICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>-02</td>
<td>Directional switch is closed on initial power up.</td>
<td>This status code will be displayed when P4 is greater than 12% of battery voltage at initial key switch on.</td>
</tr>
</tbody>
</table>

**MEMORY RECALL NO**

**CORRECTIVE ACTIONS**

**SYMPTOM**

Control will not operate because of Static Return to Off (SRO) lock out.

**POSSIBLE CAUSE**

1. Forward directional switch is closed on initial start up (i.e. closure of battery, key switch or foot switch).
   - Return directional switch lever to neutral and then return lever to forward position.

2. Forward directional switch is welded closed or mis-adjusted to be held closed.
   - Replace or adjust directional switch to insure that it opens when the directional switch is returned to neutral.

   - Disconnect the wire from P4 and check for a short circuit between P3 and the wire that was connected to P4.

4. Defective control.
   - Replace the controller unit.

**TROUBLE-SHOOTING DIAGRAM**

---

<table>
<thead>
<tr>
<th>TRACTION STATUS CODE</th>
<th>DESCRIPTION OF STATUS</th>
<th>CAUSE OF STATUS INDICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>-03</td>
<td>Travel enable switch is closed on initial power up.</td>
<td>This status code will be displayed when P5 is greater than 12% of battery voltage at initial key switch on.</td>
</tr>
</tbody>
</table>

**MEMORY RECALL NO**

**CORRECTIVE ACTIONS**

**SYMPTOM**

Control will not operate because of Static Return to Off (SRO) lock out.

**POSSIBLE CAUSE**

1. Reverse directional switch is closed on initial start up (i.e. closure of battery, key switch or foot/deadman switch).
   - Return directional switch lever to neutral and then return lever to reverse position.

2. Reverse directional switch is welded closed or mis-adjusted to be held closed.
   - Replace or adjust directional switch to insure that it opens when the directional switch is returned to neutral.

3. Short circuit between P3 and P5.
   - Disconnect the wire from P5 and check for a short circuit between P3 and the wire that was connected to P5.

4. Defective control. Replace the controller unit.

**TROUBLE-SHOOTING DIAGRAM**

---

April 1999
## Traction Status Codes

### -05

**Description of Status:** Accelerator depressed without selecting travel enable switch.

**Cause of Status Indication:** This status code will be displayed when P4 and P5 are less than 12% of battery volts, and P7 is less than 2.5 volts.

**Corrective Actions:**

- **Symptom:** Control will not operate.
- **Possible Cause:**
  - Accelerator pedal is depressed before closing forward or reverse directional switch.
  - Status code will disappear when directional switch is closed or when accelerator pedal is released.
  - Defective directional switch
    - Check forward or reverse switch to insure closure when direction is selected.
  - Open circuit between directional switch(es) and battery positive or between directional switch(es) and P4 or P5.
    - Check all control wires and connections shown in Trouble Shooting Diagram.

### -07

**Description of Status:** Accelerator input voltage too high on power up after initial key switch closure.

**Cause of Status Indication:** This status code will be displayed when the accelerator input voltage at P7 is higher than 3.7 volts, and travel enable switch is selected.

**Corrective Actions:**

- **Symptom:** Control will not operate when accelerator pedal is depressed or status code -07 is displayed then disappears when the vehicle starts to accelerate.
- **Possible Cause:** Accelerator input mis-adjusted or defective.
  - Input voltage at P7 should be less than 3.7 volts. Adjust or replace accelerator unit to insure that the voltage at P7 will vary from 3.5 volts to less than .5 volts when the pedal is depressed.
  - Open circuit between battery negative and P7 in accelerator input circuit.
    - Check for broken wires or loose connections or open potentiometer / voltage supply.
  - Short circuit from battery positive to wiring in accelerator input circuit.
    - Disconnect wire from P7 and measure voltage at wire to negative. Should be zero volts for potentiometer type and less than 3.7 volts for solid state type accelerator input.
<table>
<thead>
<tr>
<th>TRACTION STATUS CODE</th>
<th>DESCRIPTION OF STATUS</th>
<th>CAUSE OF STATUS INDICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>-08</td>
<td>Accelerator input voltage too low on power up after initial key switch closure.</td>
<td>This status code will be displayed when the accelerator input voltage at P7 is less than 3.0 volts, and any of the following connections are opened and closed: battery plug or key switch.</td>
</tr>
</tbody>
</table>

**CORRECTIVE ACTIONS**

**SYMPTOM**
Control will not operate.

**POSSIBLE CAUSE**
Accelerator input mis-adjusted or defective.
- Input voltage at P7 should be more than 3.0 volts. Adjust or replace accelerator unit to insure that the voltage at P7 is more than 3.0 volts before depressing pedal.
- Short circuit between battery negative and TB1 in accelerator input circuit.
  - Disconnect wire from P7. Check for short circuit from wire to battery negative. Resistance should be greater than 4.7K ohms.
- Defective control.
  - Disconnect wire from P7. Measure voltage from TB1 to negative. Voltage should be greater than 4.5 volts, if not, replace control.

**TROUBLE-SHOOTING DIAGRAM**

---

<table>
<thead>
<tr>
<th>TRACTION STATUS CODE</th>
<th>DESCRIPTION OF STATUS</th>
<th>CAUSE OF STATUS INDICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>-09</td>
<td>The travel enable switch is open and the directional switch is closed.</td>
<td>This status code will be displayed when P5 is less than 12% of battery volts and P4 is greater than 12% of battery volts.</td>
</tr>
</tbody>
</table>

**CORRECTIVE ACTIONS**

**SYMPTOM**
Control will not operate.

**POSSIBLE CAUSE**
Forward or reverse directional switch welded closed or mis-adjusted to be held closed.
- Replace or adjust directional switches to insure that they open when directional switch is returned to neutral.
- Short circuit between battery positive and P4 and/or P5.
  - Disconnect wires from P4 and P5 and check wire for short circuit to positive side of directional switch.
- Defective Control
  - Disconnect wires and measure voltage at P4 and P5. Voltage should be less than 60% of battery volts.

**TROUBLE-SHOOTING DIAGRAM**

---

April 1999
### Traction Status Code -15

**Description of Status:**
Battery voltage is too low or control card is mis-adjusted.

**Cause of Status Indication:**
This status code will be displayed when the battery volts are less than 1.95 volts per cell at initial key switch on. See table below.

### Corrective Actions

**Symptom:**
Control will not operate.

**Possible Cause:**
- Discharged battery: Check battery for proper open circuit voltage as shown in “Trouble Shooting Diagram”, charge battery, if required.
- Defective battery: Check each battery cell for proper voltage (greater than 1.95 volts at cell). Replace or repair battery.
- Incorrect control card adjustment: Check Function 15 for proper adjustment for battery being used. See Handset instruction sheet for details. Adjust to proper settings.
- Check “minimum” battery volts at P1 and NEG.

### Troubleshooting Diagram

**Circuits valid for Traction Controller**

### Traction Status Code -16

**Description of Status:**
Battery voltage is too high or control card is mis-adjusted.

**Cause of Status Indication:**
This status code will be displayed when the battery volts are greater than 2.4 volts per cell at initial key switch on. See table below.

### Corrective Actions

**Symptom:**
Control will not operate.

**Possible Cause:**
- Incorrect control card adjustment: Check Function 15 for proper adjustment for battery being used. See Handset instructions for details. Adjust to proper setting.
- Battery over charged or incorrect battery used: Check battery for proper open circuit voltage per table at right. If voltage is excessive, check battery charger for proper output voltage.
- Check “maximum” battery volts at P1 and NEG.

### Troubleshooting Diagram

**Circuits valid for Traction Controller**

**Nominal Battery Voltage vs. Maximum Limit Volts at 2.40 VDC per Cell**

<table>
<thead>
<tr>
<th>Circuit Voltage</th>
<th>Nominal Battery Voltage</th>
<th>Maximum Limit Volts at 2.40 VDC per Cell</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td>23.4</td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>35.1</td>
<td></td>
</tr>
<tr>
<td>48</td>
<td>46.8</td>
<td></td>
</tr>
<tr>
<td>72</td>
<td>70.2</td>
<td></td>
</tr>
<tr>
<td>80</td>
<td>76.0</td>
<td></td>
</tr>
<tr>
<td>TRACTION STATUS CODE</td>
<td>DESCRIPTION OF STATUS</td>
<td>CAUSE OF STATUS INDICATION</td>
</tr>
<tr>
<td>----------------------</td>
<td>------------------------</td>
<td>---------------------------</td>
</tr>
<tr>
<td>-23</td>
<td>Motor field current is high on start up in the reverse direction.</td>
<td>This status code will be displayed when the current draw in the motor field is too high at start up in the reverse direction.</td>
</tr>
</tbody>
</table>

**MEMORY RECALL NO**

**CORRECTIVE ACTIONS**

- **SYMPTOM**
  Control will not operate.
- **POSSIBLE CAUSE**
  Defective control.
  - Replace controller unit.

**TROUBLE-SHOOTING DIAGRAM**

**NO GRAPHIC FOR THIS STATUS CODE**

---

<table>
<thead>
<tr>
<th>TRACTION STATUS CODE</th>
<th>DESCRIPTION OF STATUS</th>
<th>CAUSE OF STATUS INDICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>-24</td>
<td>Motor field current is high on start up in the forward direction.</td>
<td>This status code will be displayed when the current draw in the motor field is too high at start up in the forward direction.</td>
</tr>
</tbody>
</table>

**MEMORY RECALL NO**

**CORRECTIVE ACTIONS**

- **SYMPTOM**
  Control will not operate.
- **POSSIBLE CAUSE**
  Defective control.
  - Replace controller unit.

**TROUBLE-SHOOTING DIAGRAM**

**NO GRAPHIC FOR THIS STATUS CODE**
### Status Code -27

**Description of Status:** Power supply is less than 10 Volts DC.

**Cause of Status Indication:** This status code will be displayed when the power supply is less than 10 volts.

**Corrective Actions:**
- **Symptom:** Line contactor opens and closes, then can only be closed by opening and closing the key switch.
- **Possible Cause:**
  - Discharged Battery
  - Voltage may be dropping below 10 Volts DC under load.
  - Loose connection at P1.
  - Insure that the wire connection at P1 is tight.
  - Defective control.
  - Replace controller unit.

---

### Status Code -41

**Description of Status:** Open thermal protector (TP) or transistor over temperature.

**Cause of Status Indication:** This status code will be displayed when the voltage at the thermal protector is too high.

**Corrective Actions:**
- **Symptom:** Reduced or no power to traction motor in control range.
- **Possible Cause:**
  - Control is in thermal cut-back.
  - Allow control to cool, status code should disappear.
  - Defective control.
  - Replace controller unit.

**Trouble-Shooting Diagram:**

- [Diagram](#)

**Memory Recall:** Yes

**Circuits valid for Traction Controller:**

---

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<table>
<thead>
<tr>
<th>TRACTION STATUS CODE</th>
<th>DESCRIPTION OF STATUS</th>
<th>CAUSE OF STATUS INDICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>-42</td>
<td>Motor armature offset voltage is too high.</td>
<td>This status code will be displayed when the voltage at the current sensor input is greater than 2.6 volts with no current flowing in the motor circuit.</td>
</tr>
</tbody>
</table>

**MEMORY RECALL**

**NO**

**CORRECTIVE ACTIONS**

**SYMPTOM**
Control will not operate.

**POSSIBLE CAUSE**
Defective control.
- Replace controller unit.

**TROUBLE-SHOOTING DIAGRAM**

**NO GRAPHIC FOR THIS STATUS CODE**

<table>
<thead>
<tr>
<th>TRACTION STATUS CODE</th>
<th>DESCRIPTION OF STATUS</th>
<th>CAUSE OF STATUS INDICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>-43</td>
<td>Motor armature offset voltage is too low.</td>
<td>This status code will be displayed when the voltage at the current sensor input is less than 2.4 volts with no current flowing in the motor circuit.</td>
</tr>
</tbody>
</table>

**MEMORY RECALL**

**NO**

**CORRECTIVE ACTIONS**

**SYMPTOM**
Control will not operate.

**POSSIBLE CAUSE**
Defective control.
- Replace controller unit.

**TROUBLE-SHOOTING DIAGRAM**

**NO GRAPHIC FOR THIS STATUS CODE**
## Traction Status Codes
### SX Transistor Control

<table>
<thead>
<tr>
<th>Traction Status Code</th>
<th>Description of Status</th>
<th>Cause of Status Indication</th>
</tr>
</thead>
<tbody>
<tr>
<td>-44</td>
<td>Armature transistor did not turn off properly.</td>
<td>This status code will be displayed when, during control operation, the armature transistor fails to turn off. This will result in a PMT condition.</td>
</tr>
</tbody>
</table>

**Memory Recall:** Yes

**Symptom:**
- Line contactor opens and closes, then can only be closed by opening and closing the key switch.

**Possible Cause:**
- Defective control.
- Replace controller unit.

### TROUBLE-SHOOTING DIAGRAM

---

<table>
<thead>
<tr>
<th>Traction Status Code</th>
<th>Description of Status</th>
<th>Cause of Status Indication</th>
</tr>
</thead>
<tbody>
<tr>
<td>-45</td>
<td>Armature transistor did not turn on properly.</td>
<td>This status code will be displayed when, during control operation, the armature transistor fails to turn on properly. This will result in a PMT condition.</td>
</tr>
</tbody>
</table>

**Memory Recall:** Yes

**Symptom:**
- Line contactor open and closes, then can only be closed by opening and closing the key switch.

**Possible Cause:**
- Defective control.
- Replace controller unit.

### TROUBLE-SHOOTING DIAGRAM
### TRACTION STATUS CODE: -46

<table>
<thead>
<tr>
<th>DESCRIPTION OF STATUS</th>
<th>CAUSE OF STATUS INDICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Look Ahead” test for A2 volts less than 12% of battery volts.</td>
<td>This status code will be displayed when the voltage at A2 is less than 12% of battery volts.</td>
</tr>
</tbody>
</table>

#### CORRECTIVE ACTIONS

**SYMPTOM**
Line contactor will not pick up.

**POSSIBLE CAUSE**
- Check for short circuit from the motor armature to the frame of the vehicle.
- Defective control.
  - Replace controller unit.

#### TROUBLE-SHOOTING DIAGRAM

![Trouble-Shooting Diagram](image)

### TRACTION STATUS CODE: -47

<table>
<thead>
<tr>
<th>DESCRIPTION OF STATUS</th>
<th>CAUSE OF STATUS INDICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>The PMT enable signal from the opposite control dropped below 5V during motoring.</td>
<td>This status code will be displayed when the voltage at PL2-21 drops below 5V during motoring.</td>
</tr>
</tbody>
</table>

#### CORRECTIVE ACTIONS

**SYMPTOM**
Control will not operate.

**POSSIBLE CAUSE**
- Auxiliary control shut down.
  - Check auxiliary control for stored faults.
- Verify the connection between the master control P21 and the auxiliary/slave control P11.
### Traction Status Code -49

**Description of Status:** Motor field current is too low during the run mode.

**Cause of Status Indication:** This status code will be displayed when the current draw in the motor field is too low during the run mode.

**Corrective Actions:**
- **Symptom:** Control will not operate.
- **Possible Cause:**
  - Defective control.
  - Replace controller unit.

**Trouble-Shooting Diagram:**

**Circuits Valid for Traction Controller:**

**NO Graphic for This Status Code**

### Traction Status Code -51

**Description of Status:** Capacitor volts are low before the line contactor closes.

**Cause of Status Indication:** This status code will be displayed during “key on” when the capacitor volts is less than 85% of battery volts at initial key switch on.

**Corrective Actions:**
- **Symptom:** Line contactor does not close when capacitor does not precharge.
- **Possible Cause:**
  - Defective control fuse.
  - Check control fuse for open circuit. Replace fuse, if necessary.
  - Defective control.
  - Replace controller unit.

**Trouble-Shooting Diagram:**

**Circuits Valid for Traction Controller:**

**NO Graphic for This Status Code**
<table>
<thead>
<tr>
<th>Traction Status Code</th>
<th>Description of Status</th>
<th>Cause of Status Indication</th>
</tr>
</thead>
<tbody>
<tr>
<td>-57</td>
<td>Controller “motor current sensor” input too low during running.</td>
<td>This status code will be displayed when the voltage input from the current sensor is too low during running.</td>
</tr>
</tbody>
</table>

**Memory Recall:** Yes

**Corrective Actions**

**Symptom:** Control will not operate.

**Possible Cause:**
- Defective control.
- Replace controller unit.

**Trouble-Shooting Diagram**

---

<table>
<thead>
<tr>
<th>Traction Status Code</th>
<th>Description of Status</th>
<th>Cause of Status Indication</th>
</tr>
</thead>
<tbody>
<tr>
<td>-68</td>
<td>The PMT enable signal from the opposite control (from the one displaying the -68 fault code) drops below 5V.</td>
<td>This status code will be displayed when the voltage at PL21 drops below 5V.</td>
</tr>
</tbody>
</table>

**Memory Recall:** Yes

**Corrective Actions**

**Symptom:** Control will not operate.

**Possible Cause:**
- Auxiliary control shut down. Check Auxiliary control for stored faults.
- Verify the connection between the master control P21 and the auxiliary/slave control P11.

**Trouble-Shooting Diagram**
<table>
<thead>
<tr>
<th>TRACTION STATUS CODE</th>
<th>DESCRIPTION OF STATUS</th>
<th>CAUSE OF STATUS INDICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>-76</td>
<td>Capacitor (1C) voltage too high.</td>
<td>This status code will be displayed when the voltage on the capacitor goes above limit voltage* during the regenerative braking cycle.</td>
</tr>
</tbody>
</table>

**MEMORY RECALL**

NO |

**CORRECTIVE ACTIONS**

**SYMPTOM**

Line contactor opens and closes, then opens and can only close by opening and closing the key switch.

**POSSIBLE CAUSE**

- Unplugging the battery connector during regenerative braking.
- Line contactor bouncing open during regen.
- Main power fuse opening during regen.
- Intermittent battery plug connection.

* Limit Voltage:

<table>
<thead>
<tr>
<th>Limit</th>
<th>Battery Voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td>50V</td>
<td>36V</td>
</tr>
<tr>
<td>70V</td>
<td>48V</td>
</tr>
<tr>
<td>96V</td>
<td>72/80V</td>
</tr>
</tbody>
</table>

**TROUBLE-SHOOTING DIAGRAM**

---

<table>
<thead>
<tr>
<th>TRACTION STATUS CODE</th>
<th>DESCRIPTION OF STATUS</th>
<th>CAUSE OF STATUS INDICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>-77</td>
<td>Motor current is detected during regenerative braking.</td>
<td>This status code will be displayed when motoring current is detected during the regen braking cycle.</td>
</tr>
</tbody>
</table>

**MEMORY RECALL**

YES |

**CORRECTIVE ACTIONS**

**SYMPTOM**

Line contactor opens and closes, then opens and can only close by opening and closing the key switch.

**POSSIBLE CAUSE**

- Defective control.
  - Replace controller unit

**TROUBLE-SHOOTING DIAGRAM**

---

April 1999
<table>
<thead>
<tr>
<th>TRACTION STATUS CODE</th>
<th>DESCRIPTION OF STATUS</th>
<th>CAUSE OF STATUS INDICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>-81</td>
<td>The input from the tach sensor has been lost or the motor has stalled.</td>
<td>This status code will be displayed when the control is not seeing any tach pulses.</td>
</tr>
</tbody>
</table>

**MEMORY RECALL YES**

**CORRECTIVE ACTIONS**

**SYMPTOM**
Control will not operate.

**POSSIBLE CAUSE**
Bad tachometer
- Replace tachometer
Lost wire from tachometer.
- Verify tach connections.
Motor has stalled.
Defective control.
- Replace controller unit

**TROUBLE-SHOOTING DIAGRAM**

![Traction Controller Diagram](attachment:image_url)

**KEY SWITCH**

- L
- P1 P17 P2 P6
- FOOT SW.
- P181A OR SP DVR
- LEFT CONTROL (MASTER)
- P12
- LEFT TURN SW.
- P10
- 312
- FU3
- DRIVER BLOCK
- FU1
- LINE
- + 12V
- P21 P11
- RIGHT CONTROL (SLAVE)
- POWER CONNECTIONS
  - LEFT CONTROL
    - POS A1 F1
    - NEG A2 F2
  - FIELD ARMATURE
    - +
    - -
  - 48V

April 1999
Section 5.0 SX FAMILY GE HANDSET INSTRUCTIONS

Section 5.1 General Features

The GE Handset is a multi-functional tool to be used with the LX, ZX, and SX Series GE solid-state controls. The Handset consists of a Light Emitting Diode (LED) display and a keyboard for data entry. Note: A different handset cord is required for use with SX controls than that used with LX and ZX controls.

Section 5.2 Purpose / Setup Functions

The purpose of the Handset is to allow authorized personnel to perform the following functions of the SX family of Controls:

- Monitor existing system fault codes
- Monitor intermittent random fault codes
- Monitor battery state of charge on systems with BDI
- Monitor hourmeter reading
- Monitor or adjust the following control functions:
  - Creep speed
  - Armature Controlled Acceleration and 1A Time
  - Regenerative Braking Current Limit and Disable
  - Armature and Field Current Limit
  - Plugging Distance (Current)
  - Pedal Position Plug Range or Disable
  - 1A Drop Out Current or Disable
  - Speed Limit Points
  - Truck Management Fault Speed Limit
  - Internal Resistance Compensation for Battery State of Charge Indication
  - Battery Voltage (36/48 volts is auto ranging)
  - Selection of Card Operation Type.

Warning: Before making any adjustments to the control, you must consult the operating and maintenance instructions supplied by the vehicle manufacturer. Failure to follow proper set up instructions could result in mis-operation or damage to the control system.

<table>
<thead>
<tr>
<th>START-UP DISPLAY SEQUENCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Key Switch On</td>
</tr>
<tr>
<td>Verify Each LED Segment 8 8 8 8</td>
</tr>
<tr>
<td>If Maintenance Code Is Active</td>
</tr>
<tr>
<td>Display Code &quot;-99&quot; For Four Seconds and Activate Speed Limit (if selected)</td>
</tr>
<tr>
<td>BDI Display or Blank Display (no BDI used)</td>
</tr>
<tr>
<td>Diagnostics Override With Fault</td>
</tr>
<tr>
<td>Run Mode</td>
</tr>
<tr>
<td>BDI Display or Blank Display (no BDI used)</td>
</tr>
<tr>
<td>Diagnostics Override With Fault</td>
</tr>
<tr>
<td>Key Switch Off</td>
</tr>
<tr>
<td>Display Traction Hourmeter For Four Seconds</td>
</tr>
<tr>
<td>Display Pump Hourmeter For Four Seconds</td>
</tr>
</tbody>
</table>

Warning: Before connecting or disconnecting the Handset tool, turn off the key switch, unplug the battery and jack up the drive wheels of the vehicle.

At the transistor control traction card, unplug the "Y plug" if the dash display is in use, and plug in the Handset to the plug location "Y" on the control card. After installing the Handset tool, plug the battery in and turn the key switch on. The chart at the right details the start-up display sequence that will occur.

Note: The dash display must be disconnected when the Handset is plugged in, or the control power supply will be overloaded.
### Section 5.3 Setup Function Procedures

With the Handset connected, hold down the CONT key and turn on the key switch. This will place you in the setup mode, ready to monitor or adjust control function settings.

**NOTE:** The term “Push” means to depress key for approximately one second.

### Section 5.3.1 Setup Mode

**SET-UP MODE**

<table>
<thead>
<tr>
<th>ACTION</th>
<th>DISPLAY SHOWS</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hold Down CONT And Turn On Key</td>
<td>8 8 8 8</td>
<td>Segment Check Displayed</td>
</tr>
<tr>
<td>Push Function Number</td>
<td>U 0 0 5</td>
<td>Selected Function No. Is Displayed</td>
</tr>
<tr>
<td>After One Second Time Delay</td>
<td>0 8 5</td>
<td>Stored Value For The Function Is Displayed</td>
</tr>
<tr>
<td>Push CONT</td>
<td>0 8 5</td>
<td>Display Value Will Blink</td>
</tr>
<tr>
<td>Change Value with Adjustment Knob</td>
<td>125</td>
<td>Value Changes While Blinking</td>
</tr>
<tr>
<td>Push STORE</td>
<td>125</td>
<td>New Value Stored And Blinking Stops</td>
</tr>
<tr>
<td>Push ESC</td>
<td>8 8 8</td>
<td>Segment Check Displayed</td>
</tr>
</tbody>
</table>

At this point, another function can be monitored/changed by pushing another function number, or the vehicle can be placed in the run mode by holding the ESC key down for one second or longer. The display will return to either the diagnostics mode, the BDI display, or a blank display (if BDI is not used and there are no fault codes). The vehicle can now be operated with the Handset connected or the Handset can be disconnected before operation.

**NOTE:** You can return to the segment check mode at any time, by holding down the ESC key until 8888 appears in the display.

### Section 5.3.2 Status Code Scrolling

The SX family of controllers furnishes a function register that contains the last 16 “stored status codes” that shut down vehicle operation (a PMT type fault that is reset by cycling the key switch) and the battery state of charge reading at the time the fault occurred. The first of the 16 status codes will be overwritten each time a new status code occurs. This stored status code register can be cleared from memory by using the Handset.

**ACCESSING STORED STATUS CODES WITH GE HANDSET**

- Key Switch Off
- Push ESC and CONT At The Same Time
- Release ESC and CONT Key
- Status Code Displayed
- Push CONT Key
- Displays Battery State-Of-Charge When Fault Occurred
- Push CONT Key
- Display Hourmeter Reading When Fault Occurred
- Push CONT Key

---

Handset Cable Part Number - 328A1550ATP1 (12 pin plug)
Handset Part Number - IC3645LXHS1EC2 (12 pin plug)
(includes handset, cable and case)

April 1999
Section 5.4 Setup Functions for Traction Controller

**FUNCTION 1  TACHOMETER SAMPLE RATE**

This function allows for the adjustment of the rate at which the tachometer output is sampled by the control.

- **Range**: 0 to 1.275 seconds
- **Set**: 0 to 255
- **Resolution**: .005 seconds per set unit
- **Example**: Setting of 20 = 0.1 second

**FUNCTION 2  CREEP SPEED**  
(Push 2)

This function allows for the adjustment of the creep speed of the vehicle. Creep speed can be adjusted when an accelerator input voltage between 3.9 and 3.3 volts or an accelerator ohm input between 6.0 K and 4.0K ohms is provided.

- **Range**: 2% to 15% on time
- **Set**: 0 to 255
- **Resolution**: 0.05% per set unit
- **Example**: Setting of 20 = 3% on time

**FUNCTION 3  ARMATURE CONTROLLED ACCELERATION IN HIGH SPEED MODE**  
(Push 3)

This function allows for the adjustment of the rate of time it takes for the control to accelerate to 100% applied battery voltage to the motor on hard acceleration in high speed mode.

- **Range**: 0.1 to 25.5 seconds
- **Set**: 1 to 255
- **Resolution**: 0.1 seconds per set unit
- **Example**: Setting of 20 = 2.0 seconds
- \( \text{C/A} = 2.2 \text{ seconds} \)

**FUNCTION 4  ARMATURE CURRENT LIMIT**  
(Push 4)

This function allows for the adjustment of the armature current limit of the control. The rating of the control will determine the range of adjustment for this function. Please refer to the operating instructions and current limit curves for the control used in specific vehicle.

- **Range**: See control C/L curves
- **Set**: 0 to 255
- **Example**: 0 = min. current, 255 = max. current

**FUNCTION 5  PLUGGING CURRENT LIMIT**  
(Push 5)

This function allows for the adjustment of the plugging distance of the vehicle. The larger the current setting, the shorter the stopping distance.

<table>
<thead>
<tr>
<th>M in</th>
<th>M ax</th>
<th>Set</th>
<th>Resolution Per unit value</th>
<th>Example If set at 20</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
<td>226</td>
<td>0 to 255</td>
<td>0.78 amps</td>
<td>41.6 amps</td>
</tr>
<tr>
<td>55</td>
<td>455</td>
<td>0 to 255</td>
<td>1.57 amps</td>
<td>86.4 amps</td>
</tr>
<tr>
<td>55</td>
<td>655</td>
<td>0 to 255</td>
<td>2.35 amps</td>
<td>102 amps</td>
</tr>
</tbody>
</table>

Important Note: The function is used to optimize motor and control performance and this setting will be determined by GE and OEM engineers at the time of vehicle development. This setting must not be changed by field personnel without the permission of the OEM.

GE and OEM engineers at the time of vehicle development. This setting must not be changed by field personnel without the permission of the OEM.
**FUNCTION 6**  
**ARMATURE CONTROLLED ACCELERATION IN LOW SPEED MODE**  
*(Push 6)*  

This function allows for the adjustment of the rate of time it takes for the control to accelerate to 100% applied battery voltage to the motor on hard acceleration in low speed mode.

- **Range:** 0.1 to 25.5 seconds  
- **Set:** 1 to 255  
- **Resolution:** 0.1 seconds per set unit  
- **Example:** Setting of 20 = 2.0 seconds  
  
  C/A = 2.2 seconds

**FUNCTION 7**  
**MIN. FIELD CURRENT**  
*(Push 7)*  

This function allows the adjustment of the field weakening level in order to set the top speed of the motor.

<table>
<thead>
<tr>
<th>Min</th>
<th>Max</th>
<th>Set</th>
<th>Resolution Per unit value</th>
<th>Example if set at 71</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>20</td>
<td>51 to 176</td>
<td>0.16 amps</td>
<td>3.2 amps</td>
</tr>
<tr>
<td>0</td>
<td>30</td>
<td>51 to 255</td>
<td>0.16 amps</td>
<td>3.2 amps</td>
</tr>
<tr>
<td>0</td>
<td>40</td>
<td>51 to 255</td>
<td>0.185 amps</td>
<td>3.7 amps</td>
</tr>
<tr>
<td>0</td>
<td>50</td>
<td>51 to 210</td>
<td>0.314 amps</td>
<td>6.28 amps</td>
</tr>
<tr>
<td>0</td>
<td>60</td>
<td>51 to 255</td>
<td>0.314 amps</td>
<td>6.28 amps</td>
</tr>
</tbody>
</table>

Important Note: The function is used to optimize motor and control performance and this setting will be determined by GE and OEM engineers at the time of vehicle development. This setting must not be changed by field personnel without the permission of the OEM.

**FUNCTION 8**  
**MAX FIELD CURRENT**  
*(Push 8)*  

This function allows for the adjustment of the maximum field current in order to obtain the maximum torque of the motor.

<table>
<thead>
<tr>
<th>Min</th>
<th>Max</th>
<th>Set</th>
<th>Resolution Per unit value</th>
<th>Example if set at 71</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>20</td>
<td>51 to 176</td>
<td>0.16 amps</td>
<td>3.2 amps</td>
</tr>
<tr>
<td>0</td>
<td>30</td>
<td>51 to 255</td>
<td>0.16 amps</td>
<td>3.2 amps</td>
</tr>
<tr>
<td>0</td>
<td>40</td>
<td>51 to 255</td>
<td>0.185 amps</td>
<td>3.7 amps</td>
</tr>
<tr>
<td>0</td>
<td>50</td>
<td>51 to 210</td>
<td>0.314 amps</td>
<td>6.28 amps</td>
</tr>
<tr>
<td>0</td>
<td>60</td>
<td>51 to 255</td>
<td>0.314 amps</td>
<td>6.28 amps</td>
</tr>
</tbody>
</table>

Important Note: The function is used to optimize motor and control performance and this setting will be determined by GE and OEM engineers at the time of vehicle development. This setting must not be changed by field personnel without the permission of the OEM.

**FUNCTION 9**  
**REGEN BRAKING CURRENT LIMIT**  
*(Push 9)*  

This function allows for the adjustment of the regen braking current limit.

<table>
<thead>
<tr>
<th>Min</th>
<th>Max</th>
<th>Set</th>
<th>Resolution Per unit value</th>
<th>Example if set at 20</th>
</tr>
</thead>
<tbody>
<tr>
<td>32</td>
<td>240</td>
<td>0 to 255</td>
<td>0.93 amps</td>
<td>50.6 amps</td>
</tr>
<tr>
<td>52</td>
<td>468</td>
<td>0 to 255</td>
<td>1.63 amps</td>
<td>84.6 amps</td>
</tr>
<tr>
<td>184</td>
<td>600</td>
<td>0 to 255</td>
<td>1.63 amps</td>
<td>216.6 amps</td>
</tr>
</tbody>
</table>

**FUNCTION 10**  
**MAX FIELD CURRENT FOR REGEN**  
*(Push 10)*  

This function allows for the adjustment of the maximum field current to be used during the regen braking mode.

<table>
<thead>
<tr>
<th>Min</th>
<th>Max</th>
<th>Set</th>
<th>Resolution Per unit value</th>
<th>Example if set at 71</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>20</td>
<td>51 to 176</td>
<td>0.16 amps</td>
<td>3.2 amps</td>
</tr>
<tr>
<td>0</td>
<td>30</td>
<td>51 to 255</td>
<td>0.16 amps</td>
<td>3.2 amps</td>
</tr>
<tr>
<td>0</td>
<td>40</td>
<td>51 to 255</td>
<td>0.185 amps</td>
<td>3.7 amps</td>
</tr>
<tr>
<td>0</td>
<td>50</td>
<td>51 to 210</td>
<td>0.314 amps</td>
<td>6.28 amps</td>
</tr>
<tr>
<td>0</td>
<td>60</td>
<td>51 to 255</td>
<td>0.314 amps</td>
<td>6.28 amps</td>
</tr>
</tbody>
</table>

Important Note: The function is used to optimize motor and control performance and this setting will be determined by GE and OEM engineers at the time of vehicle development. This setting must not be changed by field personnel without the permission of the OEM.

**FUNCTION 11**  
**“LOW SPEED” SPEED LIMIT**  
*(Push 11)*  

This function allows for the adjustment of the speed limit when the jack rabbit is not selected or the boom is raised.

- **Range:** 0 to 20  
- **Set:** 0 to 20  
- **Resolution:** 1 pulse per sample  
- **Example:** Setting of 5 = 5 pulses per sample rate

**FUNCTION 12**  
**“HIGH SPEED” SPEED LIMIT**  
*(Push 12)*  

This function operates in the same way as Function 11, except that it is activated when the jack rabbit is selected or the boom is lowered.
**FUNCTION 13**  FIELD RAMP UP RATE WHILE IN REGENERATIVE BRAKING MODE  
(Push 13)

Important Note: This function is used to optimize motor and control performance and this setting will be determined by GE and OEM engineers at the time of vehicle development. This setting must not be changed by field personnel without the permission of the OEM.

**FUNCTION 14** INTERNAL RESISTANCE COMPENSATION  
(Push 14)

This function is used when the Battery Discharge Indicator is present. Adjustment of this function will improve the accuracy of the BDI. In order to determine this setting, the voltage drop of the battery under load must first be calculated by the following method:

1. Record open circuit voltage ($V_o$) by measuring the voltage at the control positive and negative power terminals.
2. Load the traction motor to 100 amps in 1A and record the voltage ($V_i$) at the control positive and negative power terminals.
3. Calculate voltage drop ($V_{drop}$) as follows:
   $$V_{drop} = V_o - V_i$$
4. Use the table below to determine the appropriate setting using the calculated $V_{drop}$ as a reference.

**INTERNAL RESISTANCE COMPENSATION TABLE**

<table>
<thead>
<tr>
<th>Setting</th>
<th>$V_{drop}$</th>
<th>Setting</th>
<th>$V_{drop}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>11.44</td>
<td>17</td>
<td>1.34</td>
</tr>
<tr>
<td>3</td>
<td>7.60</td>
<td>18</td>
<td>1.27</td>
</tr>
<tr>
<td>4</td>
<td>5.72</td>
<td>19</td>
<td>1.20</td>
</tr>
<tr>
<td>5</td>
<td>4.57</td>
<td>20</td>
<td>1.14</td>
</tr>
<tr>
<td>6</td>
<td>3.81</td>
<td>21</td>
<td>1.09</td>
</tr>
<tr>
<td>7</td>
<td>3.27</td>
<td>22</td>
<td>1.04</td>
</tr>
<tr>
<td>8</td>
<td>2.86</td>
<td>23</td>
<td>0.99</td>
</tr>
<tr>
<td>9</td>
<td>2.54</td>
<td>24</td>
<td>0.95</td>
</tr>
<tr>
<td>10</td>
<td>2.28</td>
<td>25</td>
<td>0.91</td>
</tr>
<tr>
<td>11</td>
<td>2.08</td>
<td>26</td>
<td>0.88</td>
</tr>
<tr>
<td>12</td>
<td>1.90</td>
<td>27</td>
<td>0.85</td>
</tr>
<tr>
<td>13</td>
<td>1.76</td>
<td>28</td>
<td>0.82</td>
</tr>
<tr>
<td>14</td>
<td>1.63</td>
<td>29</td>
<td>0.79</td>
</tr>
<tr>
<td>15</td>
<td>1.52</td>
<td>30</td>
<td>0.76</td>
</tr>
<tr>
<td>16</td>
<td>1.43</td>
<td>31</td>
<td>0.74</td>
</tr>
</tbody>
</table>

**FUNCTION 15** BATTERY VOLTS  
(Push 15)

This function allows for the adjustment of voltage range for controls equipped with the Battery Discharge Indication function. In order for the BDI to operate properly, the setting as shown in the table must be entered:

<table>
<thead>
<tr>
<th>Battery Volts</th>
<th>Set Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>24 volts</td>
<td>Between 0 and 31</td>
</tr>
<tr>
<td>36 volts</td>
<td>Between 32 and 44</td>
</tr>
<tr>
<td>48 volts</td>
<td>Between 45 and 69</td>
</tr>
<tr>
<td>36/48 volts</td>
<td>Between 184 and 250</td>
</tr>
<tr>
<td>No BDI</td>
<td>Between 251 and 255</td>
</tr>
</tbody>
</table>

**FUNCTION 16** FIELD RAMP DOWN RATE WHILE IN REGENERATIVE BRAKING MODE  
(Push CONT 1)

Important Note: This function is used to optimize motor and control performance and this setting will be determined by GE and OEM engineers at the time of vehicle development. This setting must not be changed by field personnel without the permission of the OEM.

**FUNCTION 17** JOYSTICK TIMER  
(Push CONT 2)

This function allows for the adjustment of the delay time from the point at which a direction is selected to actual vehicle movement.

- **Range**: 1.0 to 25.5 seconds
- **Setting**: Between 0 and 255
- **Resolution**: 0.1 seconds per set unit
- **Example**: Setting of 2 = 0.2 seconds

**FUNCTION 18** ARMATURE CURRENT RAMP UP RATE WHILE IN REGENERATIVE BRAKING MODE  
(Push CONT 3)

Important Note: This function is used to optimize motor and control performance and this setting will be determined by GE and OEM engineers at the time of vehicle development. This setting must not be changed by field personnel without the permission of the OEM.

**FUNCTION 19** NOT APPLICABLE

This function is not applicable to this type of control and should not be adjusted.

**FUNCTION 20** NOT APPLICABLE

This function is not applicable to this type of control and should not be adjusted.
**FUNCTION 21** NOT APPLICABLE

This function is not applicable to this type of control and should not be adjusted.

**FUNCTION 22** NOT APPLICABLE

This function is not applicable to this type of control and should not be adjusted.

**FUNCTION 23** ERROR COMPENSATION (Push CONT 8)

This function is used to reduce the ripple in the field current due to the interaction between the motor field design and the digital field current regulation circuit. The value for this function will be defined to the vehicle manufacturer by the GE application engineer.

Important Note: The function is used to optimize motor and control performance and this setting will be determined by GE and OEM engineers at the time of vehicle development. This setting must not be changed by field personnel without the permission of the OEM.

**FUNCTION 24** FIELD WEAKENING START (Push CONT 9)

This function allows for setting the armature current at which minimum field current will be achieved.

| Range     | 0 to 414 amps       |
| Setting   | 0 to 255            |
| Resolution| 1.625 per set unit  |
| Example   | Setting of 20 = 32.5 amps |

**FUNCTION 25** MONITOR (Push CONT 10)

This function allows the monitoring of certain control functions by looking directly at the RAM of the microprocessor. Because absolute memory locations need to be known, this function should not be used without detailed instructions from the GE application engineer.

To ensure optimum operation of the control, this function must be left with zero stored in this register.

**FUNCTION 26** RATIO (Push CONT 11)

This function sets the ratio between armature and field current when transitioning from minimum field to maximum field current. The setting represents the quantity of field current changed for each 1 amp of armature current changed.

<table>
<thead>
<tr>
<th>Max Fld Ref</th>
<th>Max Change</th>
<th>Set</th>
<th>Resolution Per unit value</th>
<th>Example If set at 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>.24</td>
<td>0 to 10</td>
<td>0.024 amps</td>
<td>0.12 amps</td>
</tr>
<tr>
<td>30</td>
<td>.24</td>
<td>0 to 10</td>
<td>0.024 amps</td>
<td>0.12 amps</td>
</tr>
<tr>
<td>40</td>
<td>.27</td>
<td>0 to 10</td>
<td>0.027 amps</td>
<td>0.135 amps</td>
</tr>
<tr>
<td>50</td>
<td>.48</td>
<td>0 to 10</td>
<td>0.048 amps</td>
<td>0.24 amps</td>
</tr>
<tr>
<td>60</td>
<td>.48</td>
<td>0 to 10</td>
<td>0.048 amps</td>
<td>0.24 amps</td>
</tr>
</tbody>
</table>

**FUNCTION 27** NOT APPLICABLE

This function is not applicable to this type of control and should not be adjusted.

**FUNCTION 28** STORED STATUS CODE COUNT POINTER (Push CONT 13)

This register contains the location of the last stored status code recorded of the 16 stored status codes. These stored status codes have caused a PMT controller shutdown and/or disruption of normal vehicle operation.

To determine which stored status code was the last one recorded, read the number stored in Function 28. Using the Memory Map for your logic card, match the "stored status code pointer number" (the number shown in bold italics) in the HS (Handset) number column on the memory map, with the number obtained from Function 28. This will be the last stored status code recorded.

Note: When scrolling through the stored status code register, the register always starts at status code 1 and scrolls to status code 16. Instructions for scrolling the register are in section 5.3.2 of this instruction booklet.

**FUNCTION 48** NOT APPLICABLE

This function is not applicable to this type of control and should not be adjusted.

**FUNCTION 49** NOT APPLICABLE

This function is not applicable to this type of control and should not be adjusted.

---

Note: The following functions have function numbers larger than the numbers on the Handset keyboard. To access these functions, push the CONT key and the number shown in the following instructions at the same time. The seat switch must be closed.
FUNCTION 50 NOT APPLICABLE
This function is not applicable to this type of control and should not be adjusted.

FUNCTION 51 NOT APPLICABLE
This function is not applicable to this type of control and should not be adjusted.

FUNCTION 52 NOT APPLICABLE
This function is not applicable to this type of control and should not be adjusted.

FUNCTION 53 NOT APPLICABLE
This function is not applicable to this type of control and should not be adjusted.

FUNCTION 54 NOT APPLICABLE
This function is not applicable to this type of control and should not be adjusted.

FUNCTION 55 NOT APPLICABLE
This function is not applicable to this type of control and should not be adjusted.

FUNCTION 56 NOT APPLICABLE
This function is not applicable to this type of control and should not be adjusted.

FUNCTION 57 NOT APPLICABLE
This function is not applicable to this type of control and should not be adjusted.

FUNCTION 58 NOT APPLICABLE
This function is not applicable to this type of control and should not be adjusted.

FUNCTION 59 NOT APPLICABLE
This function is not applicable to this type of control and should not be adjusted.

FUNCTION 60 NOT APPLICABLE
This function is not applicable to this type of control and should not be adjusted.

FUNCTION 61 NOT APPLICABLE
This function is not applicable to this type of control and should not be adjusted.

FUNCTION 62 NOT APPLICABLE
This function is not applicable to this type of control and should not be adjusted.

FUNCTION 63 NOT APPLICABLE
This function is not applicable to this type of control and should not be adjusted.
Section 5.5 Summary of Current Limit Adjustments

The "minimum field current" setting is adjusted by Function 7. This function sets the top speed of the motor.

The "maximum field current" setting is adjusted by Function 8. This function, along with the "maximum armature current" (Function 4), sets the maximum torque of the motor.

The "ratio" setting is adjusted by Function 26. This function sets the ratio between armature and field current when transitioning from minimum field to maximum field current. Setting is the value of field current changed for each 100 amps of armature current changed.

The "error compensation" setting is adjusted by Function 23. This function is used to reduce the ripple in field current due to the interaction between motor field design and the digital field current regulation circuit. The value for this function will be defined by the GE application engineer.

The "field weakening start" setting is adjusted by Function 24. This function sets the armature current at which minimum field current will achieved.

The "full load transition point" is calculated by the control. This function sets the maximum field current transition point at approximately 80% of the maximum armature current.

The "maximum armature current" setting is adjusted by Function 4. The function along with the "maximum field current" (Function 8) sets the maximum torque of the motor.
Section 6.0 DASH DISPLAYS

Section 6.1 Application

The SX family Standard and Interactive Dash Displays allow the operator and maintenance personnel easy access to truck operation information and real-time system diagnostics of the controller, motor and various accessories. Hourmeter readings, battery discharge information, maintenance information and system status codes are clearly displayed during startup and running modes. Shielded cable connections are made to the Dash Display by means of five (5) 22-gage wires to the “Y” Plug of the traction and hydraulic pump controls.

Section 6.2 Standard Dash Displays

The GE Standard Dash Display is a four segment Light Emitting Diode (LED) instrument that displays the GE LX, ZX, and SX Status Codes, Hourmeter Readings, Battery Discharge Indication, and Maintenance Required Code. The four LED’s above the symbols indicate the active readout mode.

Section 6.3 Interactive Custom Dash Displays

The Interactive Custom Dash Display allows the operator to select the best vehicle performance for changing factory (task) conditions. There are four (4) “operator interaction modes” that can be selected by depressing a push-button on the dash display.

From the Dash Display, the operator may select any of four pre-set interactive modes consisting of (4) Controlled Acceleration levels, (4) Field Weakening Pick Up levels and (4) Speed Limit levels.

These interactive modes are “pre-set” using the Handset (Functions 48 - 63) or a personal computer (Functions 97 - 112). This feature allows the operator to select the best vehicle performance for changing factory (task) conditions.

The table below outlines the normal logic flow for pre-setting the four interactive modes:

<table>
<thead>
<tr>
<th>Value Logic Table</th>
<th>Mode 1</th>
<th>Mode 2</th>
<th>Mode 3</th>
<th>Mode 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>C/A Settings</td>
<td>=&gt; M2</td>
<td>&lt;= M3</td>
<td>=&gt; M4</td>
<td>&lt;= M3</td>
</tr>
<tr>
<td>FW Start Settings</td>
<td>&lt;= M2</td>
<td>&lt;= M3</td>
<td>&lt;= M2</td>
<td>=&gt; M3</td>
</tr>
<tr>
<td>Min. Fld Setting</td>
<td>=&gt; M2</td>
<td>&lt;= M3</td>
<td>&lt;= M2</td>
<td>=&gt; M3</td>
</tr>
<tr>
<td>M/C Setting</td>
<td>=&gt; M2</td>
<td>&lt;= M3</td>
<td>&lt;= M2</td>
<td>=&gt; M3</td>
</tr>
</tbody>
</table>

The Custom Dash Display incorporates all the features and functions of the Standard Dash Display, in addition to the following customer options:

- LED graphics to display Battery Discharge Indication status.
- Various LED indicators for Maintenance Required Status Codes. These can include options for traction, pump and power steer motors, hourmeter, over-temperature, seat belt, brake and other safety sensors.
- A push-button associated with the four segment LED that displays Status Codes can be used to scroll the last 16 “Stored Status Codes” that shut down vehicle operation with a PMT fault.

Section 6.3.1 Connections

Connections are made to the Dash Display with five (5) 22-gage wires to Plug “Y” of each control. Shielded cable is required to eliminate signal interference.

Section 6.3.2 Part Number

For Custom Dash Displays, contact your vehicle OEM.
Section 6.3.3 Connector Reference Numbers

- AMP#102241-3  Dash Display mating plug
- AMP#1-87195-8  Dash Display mating pin
- 44A723596-G09  Dash Display plug kit
- AMP#175965-2  "Y" Plug
- AMP#175180-1  "Y" Plug receptacle

Section 6.4 Start-Up Display Sequence

**START-UP DISPLAY SEQUENCE**

- Key Switch On
- Verify Each LED Segment
  - 8 8 8 8
- **If Maintenance Code Is Active**
- **If Maintenance Code Is Not Active**
- Display Code ",-99" For Four Seconds and Activate Speed Limit (if selected)
- BDI Display or Blank Display (no BDI used)
- Diagnostics Override With Fault
- Run Mode
- BDI Display or Blank Display (no BDI used)
- Diagnostics Override With Fault
- Key Switch Off
- Display Traction Hourmeter For Four Seconds
- Display Pump Hourmeter For Four Seconds

Section 6.5 Outline Drawings

For the standard GE traction dash display:

- Wiring connections to "Y" plugs of Traction & Pump controls.
Section 6.6  Suggested Wiring Configuration for Use of GE Standard Traction/Pump Dash Display with Dual Motor Traction System

NOTE: USE SHIELDED CABLE FOR DASH DISPLAY CONNECTIONS, WITH THE BARE WIRE CONNECTED TO PY4 (BATTERY NEGATIVE)
### Section 7.0 Memory Maps

#### Section 7.1 Typical Memory Map for Dual Motor Proportioning Controls

<table>
<thead>
<tr>
<th>E²</th>
<th>Func No.</th>
<th>HS No.</th>
<th>Traction Control Function</th>
<th>Access By</th>
<th>Restrictions</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
<td>Tachometer Sample Rate</td>
<td>HS or PC</td>
<td>None</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>2</td>
<td>Creep Speed</td>
<td>HS or PC</td>
<td>None</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>3</td>
<td>Armature Controlled Acceleration - H.S.</td>
<td>HS or PC</td>
<td>None</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>4</td>
<td>Armature Current Limit</td>
<td>HS or PC</td>
<td>None</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>5</td>
<td>Plugging Current Limit</td>
<td>HS or PC</td>
<td>None</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
<td>6</td>
<td>Armature Controlled Acceleration - L.S.</td>
<td>HS or PC</td>
<td>None</td>
</tr>
<tr>
<td>6</td>
<td>7</td>
<td>7</td>
<td>Minimum Field Current</td>
<td>HS or PC</td>
<td>None</td>
</tr>
<tr>
<td>7</td>
<td>8</td>
<td>8</td>
<td>Maximum Field Current</td>
<td>HS or PC</td>
<td>None</td>
</tr>
<tr>
<td>8</td>
<td>9</td>
<td>9</td>
<td>Regen Braking Current Limit</td>
<td>HS or PC</td>
<td>None</td>
</tr>
<tr>
<td>9</td>
<td>10</td>
<td>10</td>
<td>Maximum Field Current for Regen</td>
<td>HS or PC</td>
<td>None</td>
</tr>
<tr>
<td>10</td>
<td>11</td>
<td>11</td>
<td>“Low Speed” Speed Limit</td>
<td>HS or PC</td>
<td>None</td>
</tr>
<tr>
<td>11</td>
<td>12</td>
<td>12</td>
<td>“High Speed” Speed Limit</td>
<td>HS or PC</td>
<td>None</td>
</tr>
<tr>
<td>12</td>
<td>13</td>
<td>13</td>
<td>Field Ramp Up Rate in Regen</td>
<td>HS or PC</td>
<td>None</td>
</tr>
<tr>
<td>13</td>
<td>14</td>
<td>14</td>
<td>Internal Resistance Compensation</td>
<td>HS or PC</td>
<td>None</td>
</tr>
<tr>
<td>14</td>
<td>15</td>
<td>15</td>
<td>Battery Volts Select</td>
<td>HS or PC</td>
<td>None</td>
</tr>
<tr>
<td>15</td>
<td>16</td>
<td>16</td>
<td>Field Ramp Down Rate in Regen</td>
<td>HS or PC</td>
<td>None</td>
</tr>
<tr>
<td>16</td>
<td>17</td>
<td>17</td>
<td>Joystick Timer</td>
<td>HS or PC</td>
<td>None</td>
</tr>
<tr>
<td>17</td>
<td>18</td>
<td>18</td>
<td>Armature Current Ramp Up Rate in Regen</td>
<td>HS or PC</td>
<td>None</td>
</tr>
<tr>
<td>18</td>
<td>19</td>
<td>19</td>
<td>Not Used</td>
<td>HS or PC</td>
<td>None</td>
</tr>
<tr>
<td>19</td>
<td>20</td>
<td>20</td>
<td>Not Used</td>
<td>HS or PC</td>
<td>None</td>
</tr>
<tr>
<td>20</td>
<td>21</td>
<td>21</td>
<td>Not Used</td>
<td>HS or PC</td>
<td>None</td>
</tr>
<tr>
<td>21</td>
<td>22</td>
<td>22</td>
<td>Not Used</td>
<td>HS or PC</td>
<td>For DD on power up</td>
</tr>
<tr>
<td>22</td>
<td>23</td>
<td>23</td>
<td>Error Compensation</td>
<td>HS or PC</td>
<td>None</td>
</tr>
<tr>
<td>23</td>
<td>24</td>
<td>24</td>
<td>FW Start</td>
<td>HS or PC</td>
<td>None</td>
</tr>
<tr>
<td>24</td>
<td>25</td>
<td>25</td>
<td>Monitor</td>
<td>HS or PC</td>
<td>GE Temporary Storage</td>
</tr>
<tr>
<td>25</td>
<td>26</td>
<td>26</td>
<td>Ratio</td>
<td>HS or PC</td>
<td>GE Temporary Storage</td>
</tr>
<tr>
<td>26</td>
<td>27</td>
<td>27</td>
<td>Not Used</td>
<td>HS or PC</td>
<td>GE Temporary Storage</td>
</tr>
<tr>
<td>27</td>
<td>28</td>
<td>28</td>
<td>Stored Status Code Count Pointer</td>
<td>HS or PC</td>
<td>None</td>
</tr>
<tr>
<td>28</td>
<td>29</td>
<td>29</td>
<td>Not Used</td>
<td>HS or PC</td>
<td>None</td>
</tr>
<tr>
<td>29</td>
<td>30</td>
<td>30</td>
<td>Not Used</td>
<td>HS or PC</td>
<td>None</td>
</tr>
<tr>
<td>30</td>
<td>31</td>
<td>31</td>
<td>Aux HM (Tens/Ones)</td>
<td>PC Only</td>
<td>None</td>
</tr>
<tr>
<td>31</td>
<td>32</td>
<td>32</td>
<td>Aux HM (Thou/Hun)</td>
<td>PC Only</td>
<td>None</td>
</tr>
<tr>
<td>32</td>
<td>33</td>
<td>(18)</td>
<td>Stored Status Code #1</td>
<td>PC Only</td>
<td>Reset to Zero Only</td>
</tr>
<tr>
<td>33</td>
<td>34</td>
<td>34</td>
<td>BDI 1</td>
<td>PC Only</td>
<td>Reset to Zero Only</td>
</tr>
<tr>
<td>34</td>
<td>35</td>
<td>35</td>
<td>Hours (Tens/Ones) 1</td>
<td>PC Only</td>
<td>Reset to Zero Only</td>
</tr>
<tr>
<td>35</td>
<td>36</td>
<td>36</td>
<td>Hours (Thou/Hun) 1</td>
<td>PC Only</td>
<td>Reset to Zero Only</td>
</tr>
<tr>
<td>36</td>
<td>37</td>
<td>(20)</td>
<td>Stored Status Code #2</td>
<td>PC Only</td>
<td>Reset to Zero Only</td>
</tr>
<tr>
<td>37</td>
<td>38</td>
<td>38</td>
<td>BDI 2</td>
<td>PC Only</td>
<td>Reset to Zero Only</td>
</tr>
<tr>
<td>38</td>
<td>39</td>
<td>39</td>
<td>Hours (Tens/Ones) 2</td>
<td>PC Only</td>
<td>Reset to Zero Only</td>
</tr>
<tr>
<td>39</td>
<td>40</td>
<td>40</td>
<td>Hours (Thou/Hun) 2</td>
<td>PC Only</td>
<td>Reset to Zero Only</td>
</tr>
<tr>
<td>40</td>
<td>41</td>
<td>(22)</td>
<td>Stored Status Code #3</td>
<td>PC Only</td>
<td>Reset to Zero Only</td>
</tr>
<tr>
<td>41</td>
<td>42</td>
<td>42</td>
<td>BDI 3</td>
<td>PC Only</td>
<td>Reset to Zero Only</td>
</tr>
<tr>
<td>42</td>
<td>43</td>
<td>43</td>
<td>Hours (Tens/Ones) 3</td>
<td>PC Only</td>
<td>Reset to Zero Only</td>
</tr>
<tr>
<td>43</td>
<td>44</td>
<td>44</td>
<td>Hours (Thou/Hun) 3</td>
<td>PC Only</td>
<td>Reset to Zero Only</td>
</tr>
<tr>
<td>E²</td>
<td>Func No.</td>
<td>HS No.</td>
<td>Traction Control Function</td>
<td>Access By</td>
<td>Restrictions</td>
</tr>
<tr>
<td>----</td>
<td>----------</td>
<td>--------</td>
<td>---------------------------</td>
<td>-----------</td>
<td>--------------</td>
</tr>
<tr>
<td>45</td>
<td>46</td>
<td>BDI 4</td>
<td></td>
<td>PC Only</td>
<td>Reset to Zero Only</td>
</tr>
<tr>
<td>46</td>
<td>47</td>
<td>Hours (Tens/Ones) 4</td>
<td>PC Only</td>
<td>Reset to Zero Only</td>
<td></td>
</tr>
<tr>
<td>47</td>
<td>48</td>
<td>Hours (Thou/Hun) 4</td>
<td>PC Only</td>
<td>Reset to Zero Only</td>
<td></td>
</tr>
<tr>
<td>48</td>
<td>49 (26)</td>
<td>Stored Status Code #5</td>
<td>PC Only</td>
<td>Reset to Zero Only</td>
<td></td>
</tr>
<tr>
<td>49</td>
<td>50</td>
<td>BDI 5</td>
<td></td>
<td>PC Only</td>
<td>Reset to Zero Only</td>
</tr>
<tr>
<td>50</td>
<td>51</td>
<td>Hours (Tens/Ones) 5</td>
<td>PC Only</td>
<td>Reset to Zero Only</td>
<td></td>
</tr>
<tr>
<td>51</td>
<td>52</td>
<td>Hours (Thou/Hun) 5</td>
<td>PC Only</td>
<td>Reset to Zero Only</td>
<td></td>
</tr>
<tr>
<td>52</td>
<td>53 (28)</td>
<td>Stored Status Code #6</td>
<td>PC Only</td>
<td>Reset to Zero Only</td>
<td></td>
</tr>
<tr>
<td>53</td>
<td>54</td>
<td>BDI 6</td>
<td></td>
<td>PC Only</td>
<td>Reset to Zero Only</td>
</tr>
<tr>
<td>54</td>
<td>55</td>
<td>Hours (Tens/Ones) 6</td>
<td>PC Only</td>
<td>Reset to Zero Only</td>
<td></td>
</tr>
<tr>
<td>55</td>
<td>56</td>
<td>Hours (Thou/Hun) 6</td>
<td>PC Only</td>
<td>Reset to Zero Only</td>
<td></td>
</tr>
<tr>
<td>56</td>
<td>57 (30)</td>
<td>Stored Status Code #7</td>
<td>PC Only</td>
<td>Reset to Zero Only</td>
<td></td>
</tr>
<tr>
<td>57</td>
<td>58</td>
<td>BDI 7</td>
<td></td>
<td>PC Only</td>
<td>Reset to Zero Only</td>
</tr>
<tr>
<td>58</td>
<td>59</td>
<td>Hours (Tens/Ones) 7</td>
<td>PC Only</td>
<td>Reset to Zero Only</td>
<td></td>
</tr>
<tr>
<td>59</td>
<td>60</td>
<td>Hours (Thou/Hun) 7</td>
<td>PC Only</td>
<td>Reset to Zero Only</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>61 (32)</td>
<td>Stored Status Code #8</td>
<td>PC Only</td>
<td>Reset to Zero Only</td>
<td></td>
</tr>
<tr>
<td>61</td>
<td>62</td>
<td>BDI 8</td>
<td></td>
<td>PC Only</td>
<td>Reset to Zero Only</td>
</tr>
<tr>
<td>62</td>
<td>63</td>
<td>Hours (Tens/Ones) 8</td>
<td>PC Only</td>
<td>Reset to Zero Only</td>
<td></td>
</tr>
<tr>
<td>63</td>
<td>64</td>
<td>Hours (Thou/Hun) 8</td>
<td>PC Only</td>
<td>Reset to Zero Only</td>
<td></td>
</tr>
<tr>
<td>64</td>
<td>65 (34)</td>
<td>Stored Status Code #9</td>
<td>PC Only</td>
<td>Reset to Zero Only</td>
<td></td>
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### RS-232 MEMORY MAP TABLES

**SX TRANSISTOR CONTROL**

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Numbers in **(bold italics)** are Stored Status Code pointers.