



# Installation and Operation

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## **Load Sharing Module**

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Pulse Width Modulated Output, Caterpillar P/N 161-0797,  
Woodward Manual 02036 (Revision D)

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## WARNING—DANGER OF DEATH OR PERSONAL INJURY



### WARNING—FOLLOW INSTRUCTIONS

Read this entire manual and all other publications pertaining to the work to be performed before installing, operating, or servicing this equipment. Practice all plant and safety instructions and precautions. Failure to follow instructions can cause personal injury and/or property damage.



### WARNING—OVERSPEED PROTECTION

The engine, turbine, or other type of prime mover should be equipped with an overspeed shutdown device to protect against runaway or damage to the prime mover with possible personal injury, loss of life, or property damage.

The overspeed shutdown device must be totally independent of the prime mover control system. An overtemperature or overpressure shutdown device may also be needed for safety, as appropriate.



### WARNING—PROPER USE

Any unauthorized modifications to or use of this equipment outside its specified mechanical, electrical, or other operating limits may cause personal injury and/or property damage, including damage to the equipment. Any such unauthorized modifications: (i) constitute "misuse" and/or "negligence" within the meaning of the product warranty thereby excluding warranty coverage for any resulting damage, and (ii) invalidate product certifications or listings.

## CAUTION—POSSIBLE DAMAGE TO EQUIPMENT OR PROPERTY



### CAUTION—BATTERY CHARGING

To prevent damage to a control system that uses an alternator or battery-charging device, make sure the charging device is turned off before disconnecting the battery from the system.



### CAUTION—ELECTROSTATIC DISCHARGE

Electronic controls contain static-sensitive parts. Observe the following precautions to prevent damage to these parts.

- Discharge body static before handling the control (with power to the control turned off, contact a grounded surface and maintain contact while handling the control).
- Avoid all plastic, vinyl, and Styrofoam (except antistatic versions) around printed circuit boards.
- Do not touch the components or conductors on a printed circuit board with your hands or with conductive devices.

## IMPORTANT DEFINITIONS

- A **WARNING** indicates a potentially hazardous situation which, if not avoided, could result in death or serious injury.
- A **CAUTION** indicates a potentially hazardous situation which, if not avoided, could result in damage to equipment or property.
- A **NOTE** provides other helpful information that does not fall under the warning or caution categories.

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## Electrostatic Discharge Awareness

All electronic equipment is static-sensitive, some components more than others. To protect these components from static damage, you must take special precautions to minimize or eliminate electrostatic discharges.

Follow these precautions when working with or near the control.

1. Before doing maintenance on the electronic control, discharge the static electricity on your body to ground by touching and holding a grounded metal object (pipes, cabinets, equipment, etc.).
2. Avoid the build-up of static electricity on your body by not wearing clothing made of synthetic materials. Wear cotton or cotton-blend materials as much as possible because these do not store static electric charges as much as synthetics.
3. Keep plastic, vinyl, and Styrofoam materials (such as plastic or Styrofoam cups, cup holders, cigarette packages, cellophane wrappers, vinyl books or folders, plastic bottles, and plastic ash trays) away from the control, the modules, and the work area as much as possible.
4. Do not remove the printed circuit board (PCB) from the control cabinet unless absolutely necessary. If you must remove the PCB from the control cabinet, follow these precautions:
  - Do not touch any part of the PCB except the edges.
  - Do not touch the electrical conductors, the connectors, or the components with conductive devices or with your hands.
  - When replacing a PCB, keep the new PCB in the plastic antistatic protective bag it comes in until you are ready to install it. Immediately after removing the old PCB from the control cabinet, place it in the antistatic protective bag.



### **CAUTION—ELECTROSTATIC DISCHARGE**

To prevent damage to electronic components caused by improper handling, read and observe the precautions in Appendix B, *Guide for Handling and Protection of Electronic Controls, Printed Circuit Boards, and Modules*.



# Chapter 1.

## General Information

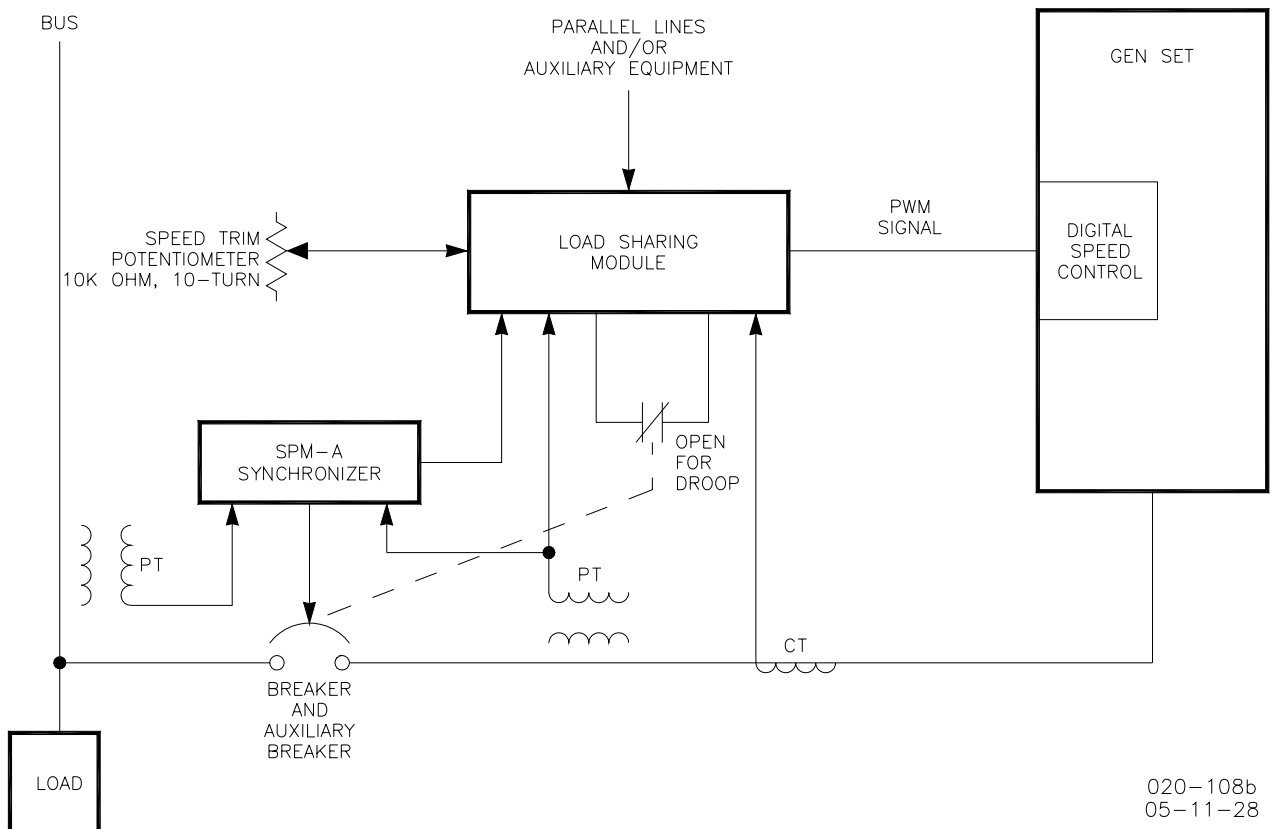
### Introduction

The Woodward Load Sharing Module is made for use with Caterpillar engines equipped with a Caterpillar digital speed control with a pulse width modulated (PWM) input. The Load Sharing Module allows use of Woodward power generation accessories and allows load sharing between the Caterpillar digital speed control equipped engines and engines controlled with Woodward electronic controls.

### Description

The Load Sharing Module provides isochronous and droop load-sharing capability for engines equipped with Caterpillar digital controls in generator set applications. Additional equipment in the control system can include the Woodward SPM-A Synchronizer, Paralleling Phase Switch, Import/Export Control, Precision Frequency Control, Automatic Generator Loading Control, and Automatic Power Transfer and Loading Control.

Figure 1-1 shows a typical system using a Load Sharing Module.



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Figure 1-1. Typical System Using a Load Sharing Module

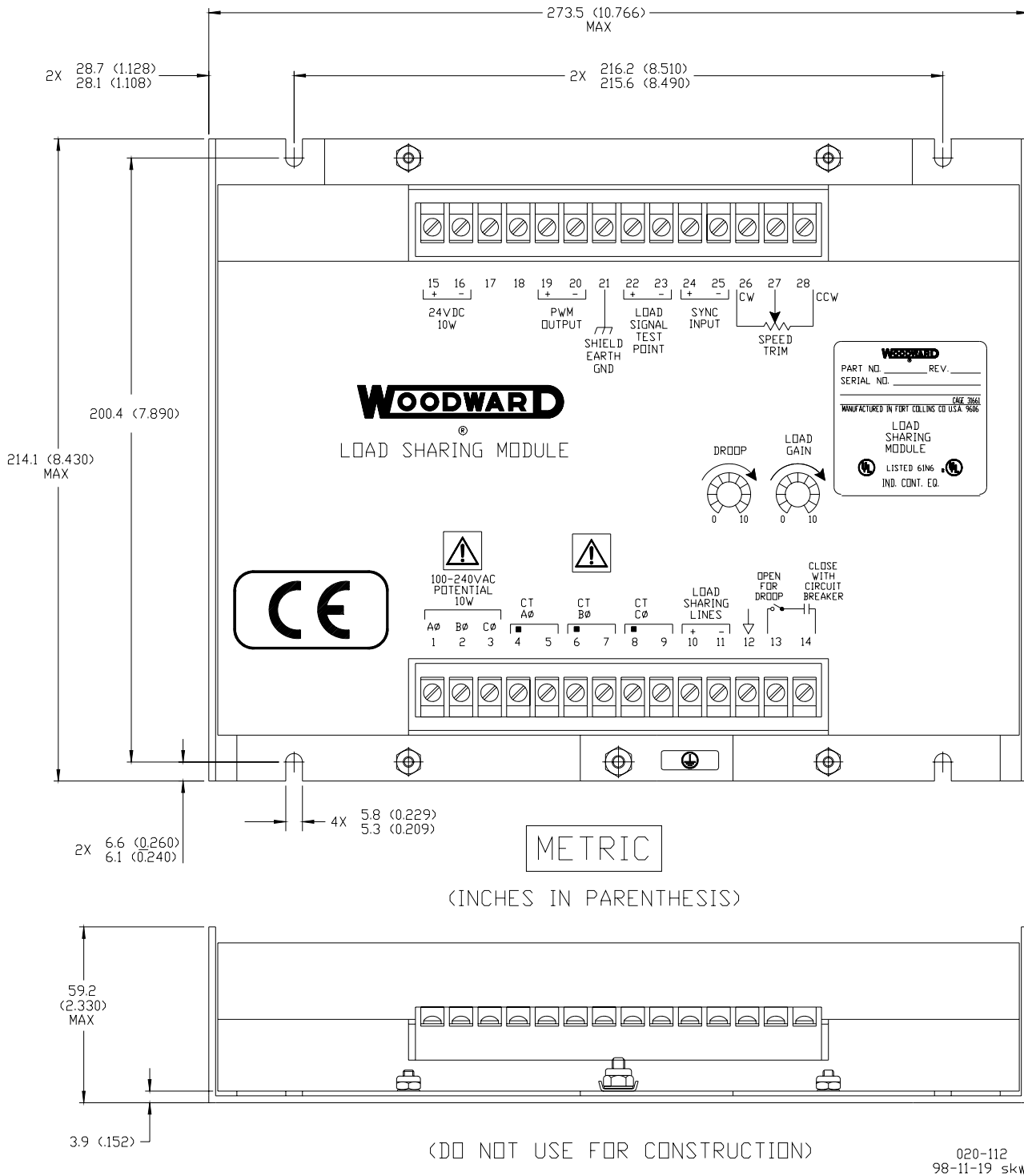


Figure 1-2. Outline Drawing of Load Sharing Module

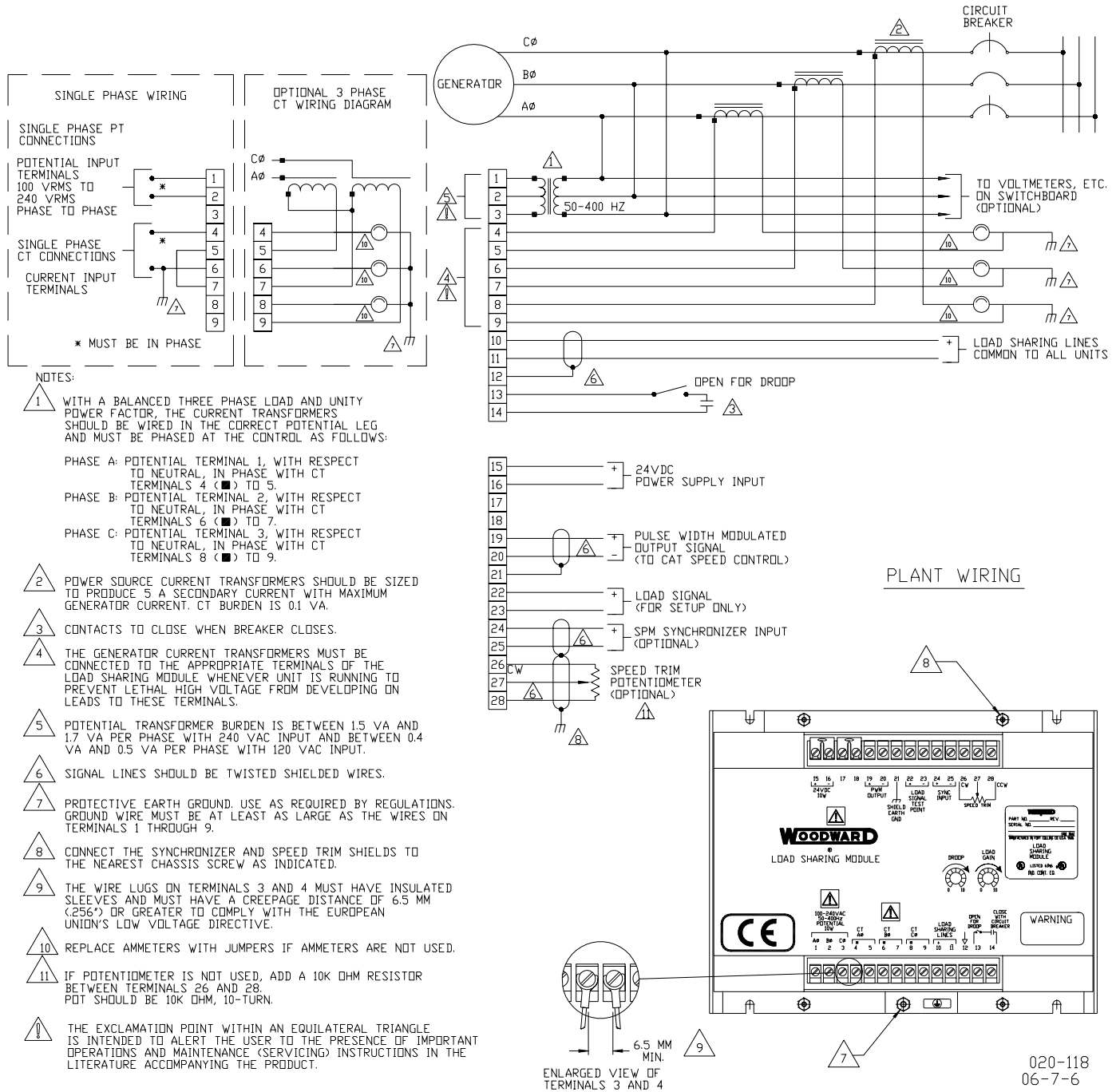


Figure 1-3. Plant Wiring Diagram of Load Sharing Module

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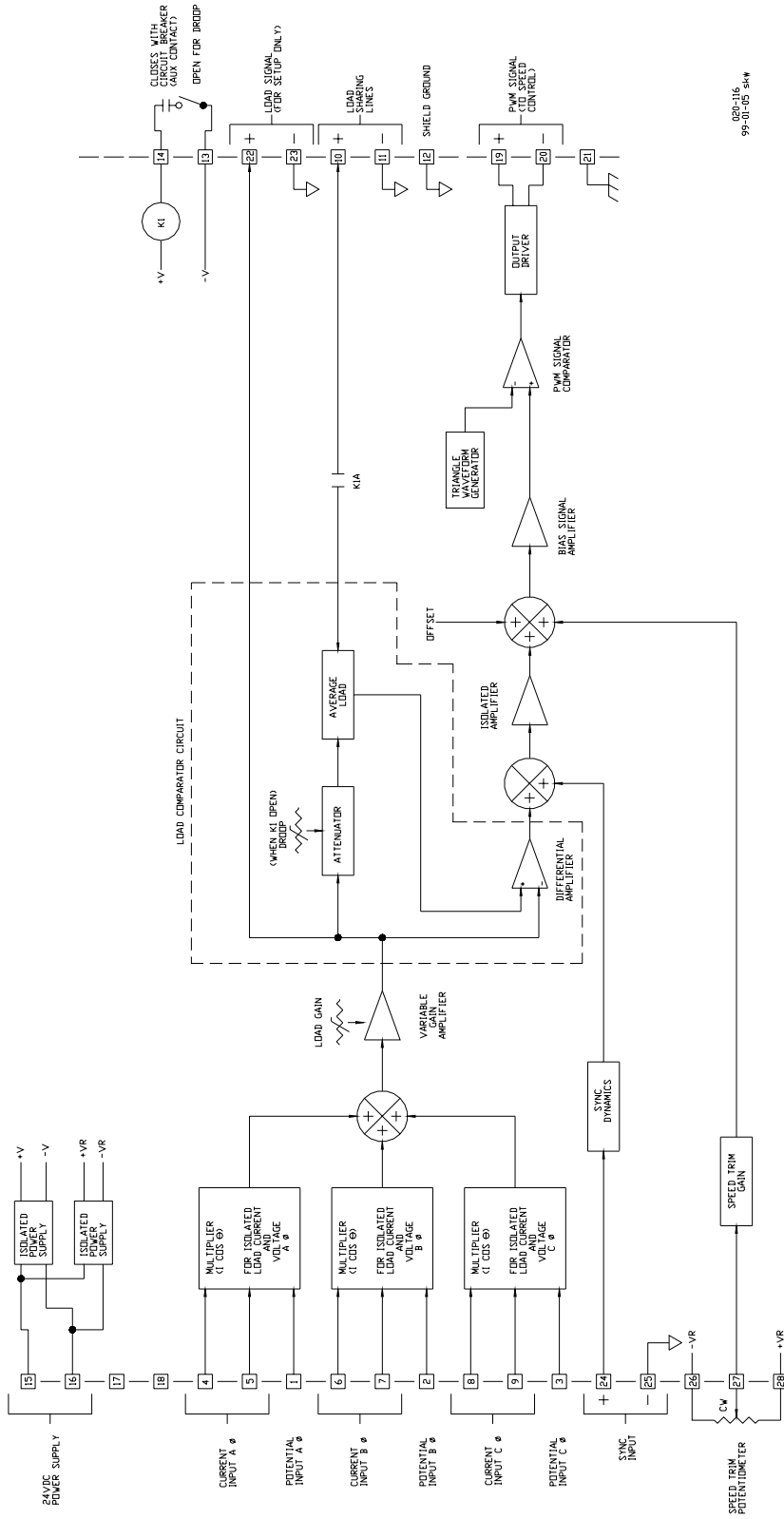


Figure 1-4. Block Diagram of Load Sharing Module

# Chapter 2. Installation

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## Introduction

This section contains general installation instructions for the Load Sharing Module. Environmental precautions and location considerations are included to determine the best location for the Load Sharing Module. Additional information includes unpacking instructions, electrical connections, and an installation check-out procedure.

## Unpacking

Before handling the Load Sharing Module, read page iii, Electrostatic Discharge Awareness. Be careful when unpacking the Load Sharing Module. Check the unit for signs of damage such as bent or dented panels, scratches, and loose or broken parts. Notify the shipper of any damage.

## Location Considerations

Consider these requirements when selecting the mounting location:

- Adequate ventilation for cooling
- Space for servicing and repair
- Protection from direct exposure to water or to a condensation-prone environment
- Protection from high-voltage or high-current devices, or devices which produce electromagnetic interference
- Protection from excessive vibration
- An ambient operating temperature range of  $-40$  to  $+70$  °C ( $-40$  to  $+158$  °F)
- All wiring to/from the Load Sharing Module should be limited to 30 m (98 ft) in length.

**Do not mount the Load Sharing Module on the engine.**

Figure 1-2 is an outline drawing of the Load Sharing Module. Install the unit near the electronic engine control. It may be installed in any position.

To maintain compliance with CE marking requirements, the European Union Low Voltage Directive requires that the Load Sharing Module (LSM) be mounted in an IP43 enclosure as defined in EN60529. Access to the Load Sharing Module must be restricted to qualified personnel.

## General Wiring Requirements



The circled ground symbol identifies the Protective Earth Terminal. This terminal must be connected directly to protective earth using a grounding conductor at least as large as those used on terminals 1 through 9. The insulation of the grounding conductor must be of green and yellow color.



This symbol identifies functional or EMC earth. This terminal is to be used for cable shield connections only. It is not to be used as a protective earth terminal.

External wiring connections and shielding requirements for a typical installation are shown in the plant wiring diagram, Figure 1-3. These wiring connections and shielding requirements are explained in more detail in this chapter.

To maintain compliance with CE marking requirements, the Low Voltage Directive requires that the Load Sharing Module must only be connected to Class III equipment.

Wiring for the Load Sharing Module must be suitable for at least 90 °C (194 °F) and also be suitable for the maximum installed operating temperature.

The Load Sharing Module must be permanently connected and employ fuses or circuit breakers in each of the PT lines to limit current to the LSM PT inputs to no more than 5 A. In addition, a 2 A fast-acting fuse or circuit breaker must be provided in the 24 Vdc power supply line.

All terminal block screws must be tightened to 0.56 to 0.79 N·m (5.0 to 7.0 lb-in).

To maintain compliance with CE marking requirements, the EMC Directive requires that all shields be connected to the terminals provided per the plant wiring diagram, Figure 1-3.

Wiring for the Load Sharing Module should not exceed 30 m (98 ft) in length. If any signal run must exceed this limit, an isolator must be used within 30 m of the Load Sharing Module. The isolator must provide galvanic isolation via optical or magnetic means.

## Power Requirements

The Load Sharing Module is powered from a 24 Vdc source. The 24 Vdc source must be a minimum of 18 Vdc and a maximum of 32 Vdc continuous. If a battery is used for operating power, an alternator or other battery charging device is necessary to maintain a stable supply voltage.



### **CAUTION—BATTERY**

**To prevent possible serious damage to the Load Sharing Module, make sure the alternator or other battery charging device is turned off or disconnected before disconnecting the battery from the unit.**

## Shielded Wiring

All shielded cable must be twisted conductors with either a foil or braided shield. Do not attempt to tin (put solder on) the braided shield. All signal lines should be shielded to prevent picking up stray signals from adjacent equipment. Connect the shields to the terminals indicated in the plant wiring diagram. Wire exposed beyond the shield must be as short as possible.

The other end of the shields must be left open and insulated from any other conductor. Do not run shielded signal wires with other wires carrying large currents. See Appendix C, *EMI Control in Electronic Governing Systems*, for more information.

Where shielded cable is required, cut the cable to the desired length and prepare the cable as instructed below and shown in Figure 2-1.

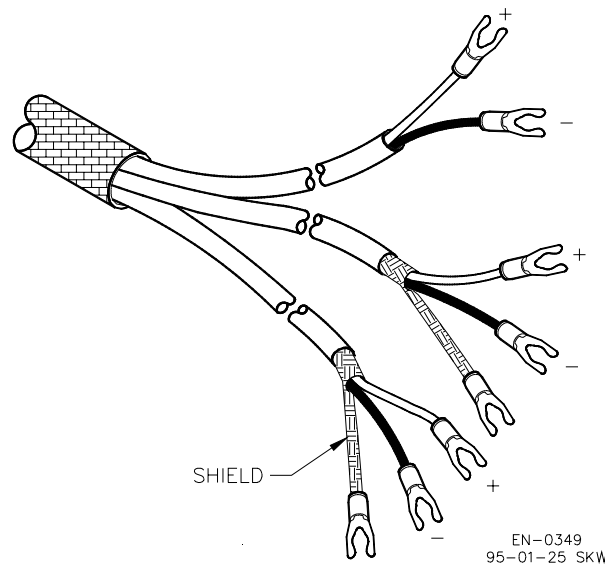


Figure 2-1. Preparation of Shielded Cables

1. Strip outer insulation from both ends, exposing the braided or spiral wrapped shield. Do not cut the shield on the end nearest to the Load Sharing Module. Cut off the shield on the end away from the unit.
2. Use a sharp, pointed tool to carefully spread the strands of the shield.
3. Pull the inner conductors out of the shield. Twist braided shields to prevent fraying. The breakout length of the shield braid should be 51 mm (2 inches) or less.
4. Connect lugs to the shield and to the control wires. Number 6 slotted or round crimp-on terminals are used for most installations. Connect the wires to the appropriate terminals on the module.

Installations with severe electromagnetic interference (EMI) may require shielded wire run in conduit, double shielded wire, or other precautions.

## Generator Connections

**NOTE**

Use 1 mm<sup>2</sup> (18 AWG) or larger wire for all PT and CT connections.

The spacing between the lugs on terminals 3 and 4 must be 6.5 mm (0.256 inch) or greater to comply with the European Union Low Voltage Directive (see Figure 1-3). The lugs must have insulated sleeves.

**IMPORTANT**

Connections from the potential transformers and current transformers must be made correctly in regard to the three phases for the Load Sharing Module to operate correctly. Sorting out the three phases at the module is tedious and requires numerous generator starts and stops. If at all possible, make sure that the wiring is correctly done at the time of installation and the phases correctly and permanently identified at the generator and at the module.

Connect the PT output from the A leg to terminal 1. Connect the PT output from the B leg to terminal 2. Connect the PT output from the C leg to terminal 3. Size the potential transformers to produce 100–240 Vac.

## Current Transformers

Power source current transformers should be sized to produce 5 A secondary current with maximum generator current (3–7 A secondary current at full load is acceptable). CT burden is 0.1 VA. To prevent lethal high voltage from developing on leads to the terminals, the Load Sharing Module contains internal burden which must be connected across the power source current transformers whenever the unit is running. Ammeters may be installed on the leads from the current transformers.

Connect phase “A” CT to terminals 4 and 5. Connect phase “B” CT to terminals 6 and 7. Connect Phase “C” CT to terminals 8 and 9. Observe correct phasing as shown in the plant wiring diagram, Figure 1-3.

## Load Sharing Lines, Droop, and Auxiliary Contacts

The droop contact for selecting droop or isochronous operation is wired in series with the circuit breaker auxiliary contact between terminals 13 and 14. When both the droop contact and circuit breaker auxiliary contact are closed, the Load Sharing Module is in the isochronous load sharing mode. In this mode the internal load-sharing-line relay is energized, the droop signal is disabled, and the load matching circuit is connected to the load-sharing lines, permitting isochronous load sharing.

The Load Sharing Module is in the droop mode when EITHER the droop contact or the circuit breaker auxiliary contact is open. If the droop contact is open, the Load Sharing Module remains in the droop mode even when the circuit breaker auxiliary contact is closed. If droop is not desired when the auxiliary contact is open, turn the droop potentiometer fully counterclockwise.

Use a single pole, single-throw switch with a 0.1 A minimum rating for the “open for droop” switch.

Use twisted 0.5 mm<sup>2</sup> (20 AWG) or larger shielded wire to connect the load sharing lines to the other Load Sharing Modules. Connect the (+) wire from the other Load Sharing Modules to terminal 10. Connect the (-) wire from the other Load Sharing Modules to terminal 11. Connect the shield of the load share wiring to terminal 12. The shield should always be connected only to terminal 12. No other shields should be connected to this terminal.

## Output to the Caterpillar Digital Electronic Control

Use twisted 0.5 mm<sup>2</sup> (20 AWG) or larger shielded wire to connect the pulse-width modulated output signal from terminals 19(+) and 20(-) to the Caterpillar control. Connect the shield to terminal 21 only. Do not connect the shield at the Caterpillar control end of the wiring.

## Synchronization Connections

If an SPM-A synchronizer is used, connect twisted-pair 0.5 mm<sup>2</sup> (20 AWG) or larger shielded wire from the synchronizer to terminals 24(+) and 25(-). Tie the shield to terminal 21. Do not connect the shield at the synchronizer end of the wiring.

## Speed Trim Potentiometer

If a speed-trim potentiometer is used, connect a 10 k $\Omega$  10-turn potentiometer to terminals 26 (CW), 27 (wiper), and 28 (CCW). Use 0.5 mm<sup>2</sup> (20 AWG) or larger shielded wire, and connect the shield to terminal 21. Do not connect the potentiometer end of the shield. The potentiometer is used to move the speed setting when manually synchronizing the generator or to change load demand in droop mode. If no potentiometer is used, add a 10 k $\Omega$  resistor between terminals 26 and 28.



### NOTE

Shielded output lines should be limited to 30 m (98 ft) maximum length.

## Chapter 3. Setup and Calibration

### Introduction

Use this calibration procedure after a Load Sharing Module is installed on a generator set, to obtain the needed operating characteristics during load sharing.

1. Check that the proper voltage is connected to terminals 15(+) and 16(-). Proper polarity must be maintained. See the plant wiring diagram, Figure 1-3.
2. Remove wires from load sharing line terminals 10 and 11, and from the SPM-A Synchronizer (if used) at terminals 24 and 25.
3. Select isochronous operation by shorting terminals 13 and 14.
4. If a speed setting potentiometer is used, set it to mid position (50%).



#### **WARNING—START-UP**

**Be prepared to make an emergency shutdown when starting the engine, turbine, or other type of prime mover, to protect against runaway or overspeed with possible personal injury, loss of life, or property damage.**

5. Start the engine according to the engine manufacturer's instructions. Adjust the engine for rated speed. Apply full load to the generator set.



#### **NOTE**

**The most accurate calibration is made at full load. However, if it is not possible to run the generator set at full load, run it at less than full load, and reduce the voltage readings given in this calibration procedure proportionally. For example: run a 200 kW generator set at 100 kW and divide all voltages given in this calibration procedure by 2. If you reduce the load in this manner, be sure to reduce it by the same amount throughout the calibration procedure.**

6. Set the LOAD GAIN potentiometer fully clockwise.
7. Check the load signal voltage between terminals 22 and 23. Adjust the LOAD GAIN potentiometer for 6.0 Vdc signal. If this voltage is not obtainable, set the load signal as close as possible to 6 Vdc.
8. Remove the load from the generator set.
9. Check the voltage between terminals 22 and 23. This voltage should be 0.0  $\pm$  0.25 Vdc. If this voltage is not correct, the Load Sharing Module unit is faulty or there may still be load on the generator.

## Phasing Check



### WARNING-HIGH VOLTAGE

A high voltage across open CTs (current transformers) can cause death or serious injury. Do not disconnect a CT from the Load Sharing Module while the engine is running. The CTs can develop dangerously high voltages and may explode if open circuited while the engine is running.

For this check, the generator set must be running isochronously, not paralleled, and with a power factor greater than 0.8.

10. Check that the potential connections are made as follows and correct them if they are not.
  - Phase A to terminal 1
  - Phase B to Terminal 2
  - Phase C to Terminal 3



### NOTE

The most accurate calibration is made at full load. However, if it is not possible to run the generator set at full load, run it at less than full load, and reduce the voltage readings given in this calibration procedure proportionally. For example: run a 200 kW generator set at 100 kW and divide all voltages given in this calibration procedure by 2. If you reduce the load in this manner, be sure to reduce it the same amount throughout this calibration procedure.

11. Start the engine and apply full load to the generator set.
12. Using a dc voltmeter, measure the load signal at terminals 22 and 23. Adjust the load gain potentiometer to give a 6 Vdc load signal. If 6 Vdc is not obtainable, set the load signal as close as possible to 6 Vdc. Record this voltage.
13. Shut down the generator set.



### WARNING-HIGH VOLTAGE

A high voltage across open CTs (current transformers) can cause death or serious injury. Do not disconnect a CT from the Load Sharing Module while the engine is running. The CTs can develop dangerously high voltages and may explode if open circuited while the engine is running.

14. Disconnect the wire from terminal 5 that comes from the phase "A" CT and connect both wires from this CT to terminal 4.
15. Start the generator set and apply full load.
16. Measure the load signal at terminals 22 and 23. If the phase "B" and "C" current transformers are connected correctly, this voltage will be 1/3 lower than the voltage recorded in step 13. For example: if the reading was 6 volts in step 13, the reading in this step should be approximately 4 volts.
17. Shut down the generator set.
18. Reconnect the phase "A" CT wire to terminal 5.
19. If the reading in step 16 was correct, proceed to Load Gain Adjustment later in this chapter. Otherwise, perform the following Phase Correction Procedure.

## Phase Correction Procedure

If this procedure is followed, the correct connection of the current transformers is assured; the correct CT will be connected to the correct input on the Load Sharing Module with the correct polarity. Use this procedure only if the Phasing Check indicates that the phasing is incorrect.

A CT for any phase (A, B, or C), will produce the most positive load signal voltage when it is connected, in the proper polarity, to the terminals on the Load Sharing Module which correspond to the same phase. Any other connections of this CT will produce a less positive load signal voltage. This procedure makes trial connections of the first CT to all three CT inputs on the Load Sharing Module, polarized both ways on each CT input. The load signal voltage is recorded for each connection, and the CT is then connected to the CT input terminals that produced the most positive load signal voltage and with the polarity that produced the most positive load signal voltage.

In a like manner, the second CT is tried on each of the two remaining CT input terminals in each polarity, then connected, in the correct polarity, to the terminals which produced the most positive load signal voltage.

The remaining CT is then connected to the remaining CT input and the load signal checked for each polarity. This CT is then connected to the CT input, polarized so that it produces the most positive load signal voltage.

When the procedure is completed, all three CTs are connected to the proper CT inputs on the Load Sharing Module, with the correct polarity, and are now labeled with their correct designations.

The procedure for correcting phase wiring requires that the generator set be shut down and the current transformers disconnected many times. For convenience during the phasing check, the temporary method of connecting the current transformers shown in Figure 3-1 is recommended. By connecting a burden resistor (a 0.5  $\Omega$ , 20 W resistor), across each current transformer, that current transformer can be disconnected from the Load Sharing Module after removing all load. The connections between the terminal strip and the Load Sharing Module can be changed with the generator set running; however, remove all load before any changes in connections are made. *Do not disconnect a wire from a current transformer with load on the system.* After completion of the procedure remove the terminal strip and the resistors.



### **WARNING—HIGH VOLTAGE**

**A high voltage across open CTs (current transformers) can cause death or serious injury. Do not disconnect a CT from the Load Sharing Module while the engine is running. The CTs can develop dangerously high voltages and may explode if open circuited while the engine is running.**

For this procedure, the generator set must be running isochronously, not paralleled, and with a power factor greater than 0.8.

1. Start with the generator shut down.
2. Label each CT wire with the phase and polarity that you think it should be. Even though this identification may prove to be wrong during this procedure, this step is necessary so that the individual wires may be identified during the description of the procedure.

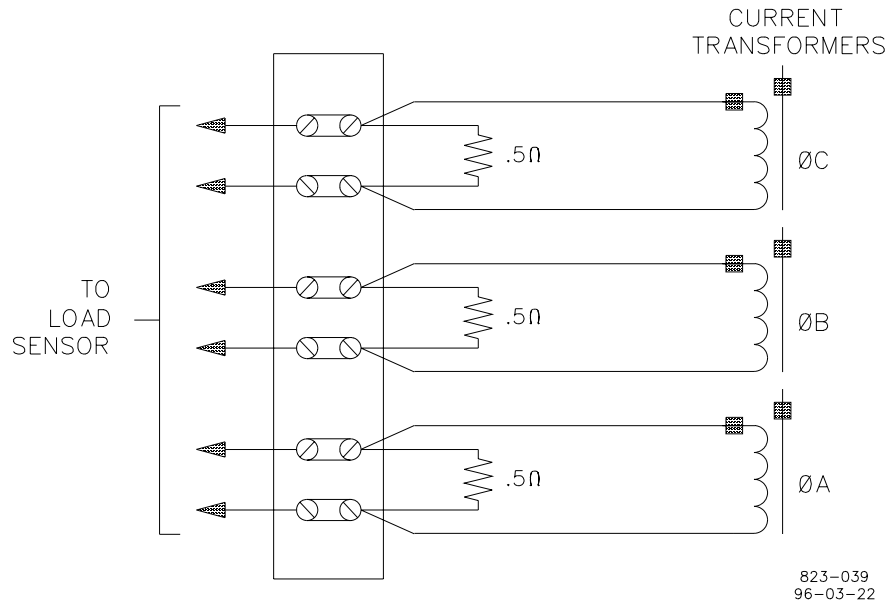


Figure 3-1. Temporary CT Connections

3. Disconnect the phase "B" CT wires from terminals 6 and 7 and connect these two wires together. Use a small screw and nut and tape the connection.
4. Disconnect the phase "C" CT wires from terminals 8 and 9 and connect these two wires together. Use a small screw and nut and tape the connection.
5. Connect the two wires from the phase "A" CT to phase "A" input terminals 4 and 5.

**WARNING—START-UP**

**Be prepared to make an emergency shutdown when starting the engine, turbine, or other type of prime mover, to protect against runaway or overspeed with possible personal injury, loss of life, or property damage.**

6. Start the engine and apply full load.
7. Measure the load signal voltage between terminals 22 and 23 and record this voltage.
8. Shut the generator set down and reverse the phase "A" wires on terminals 4 and 5.
9. Start the engine and apply full load.
10. Measure the load signal voltage between terminals 22 and 23 and record this voltage.
11. Shut the generator set down.
12. Remove the phase "A" CT wires from terminal 4 and 5 and connect the phase "A" CT wires to the phase "B" input terminals 6 and 7.

13. Start the engine and apply full load.
14. Measure the load signal voltage between terminals 22 and 23 and record this voltage.
15. Shut the generator set down and reverse the phase "A" CT wires on terminals 6 and 7.
16. Start the engine and apply full load.
17. Measure the load signal voltage between terminals 22 and 23 and record this voltage.
18. Shut down the generator set.
19. Remove the phase "A" CT wires from terminal 6 and 7 and connect the phase "A" CT wires to the phase "C" input terminals 8 and 9.
20. Start the engine and apply full load.
21. Measure the load signal voltage between terminals 22 and 23 and record this voltage.
22. Shut the generator set down and reverse the phase "A" wires on terminals 8 and 9.
23. Start the engine and apply full load.
24. Measure the load signal voltage between terminals 22 and 23 and record this voltage.
25. Shut down the generator set.
26. Remove the phase "A" CT wires from terminal 8 and 9 and connect the wires to the pair of terminals, in the same polarity, that produced the most positive load signal voltage.
27. Untape and disconnect the Phase "B" CT wires. Connect the phase "B" CT wires to one pair of the two remaining CT input terminals on the Load Sharing Module.
28. Start the generator set and apply full load.
29. Measure the load signal voltage at terminals 22 and 23 and record this voltage.
30. Shut the generator set down and reverse the phase "B" wires on the CT input terminals.
31. Start the engine and apply full load.
32. Measure the load signal voltage between terminals 22 and 23 and record this voltage.
33. Shut down the generator set.
34. Remove the phase "B" CT wires from the terminals they are connected to and connect them to the remaining pair of CT input terminals on the Load Sharing Module.

35. Start the generator set and apply full load.
36. Measure the load signal at terminals 22 and 23 and record this voltage.
37. Shut the generator set down and reverse the phase "B" wires on the CT input terminals.
38. Start the engine and apply full load.
39. Measure the load signal voltage between terminals 22 and 23 and record this voltage.
40. Shut down the generator set.
41. Remove the phase "B" CT wires from the CT input terminals and connect the wires to the pair of terminals, in the same polarity, that produced the most positive load signal voltage.
42. Untape and disconnect the Phase "C" CT wires. Connect the phase "C" CT wires to remaining pair of CT input terminals on the Load Sharing Module.
43. Start the generator set and apply full load.
44. Measure the load signal voltage at terminals 22 and 23 and record this voltage.
45. Shut the generator set down and reverse the phase "C" wires on the CT input terminals.
46. Start the engine and apply full load.
47. Measure the load signal voltage between terminals 22 and 23 and record this voltage.
48. Shut down the generator set.
49. Remove the phase "C" CT wires from the CT input terminals and connect the wires to the pair of terminals, in the same polarity that produced the most positive load signal voltage.
50. Label each wire with the designation of the terminal to which it is now connected. Be sure and remove the original designations to avoid future confusion.

## Load Gain Adjustment

For this procedure, the generator set must be running isochronously, not paralleled, and with a power factor greater than 0.8.

1. Start the generator set and run at full load.
2. Measure the load signal voltage and adjust the LOAD GAIN potentiometer for  $6 \pm 0.1$  Vdc.

If the load signal voltage cannot be raised to 6 volts, and the phasing has been checked and is correct, it will be necessary to use a lower load signal voltage. Set the full load signal voltages of all generator sets in the system to the same voltage.

When paralleled, adjustment of a generator set's LOAD GAIN potentiometer clockwise will cause that generator set to carry less load. If stability problems occur when paralleled at a particular load signal voltage, reduce the load signal voltage by adjusting the LOAD GAIN potentiometer counterclockwise and set the load signal voltage of all other generator sets in the system to the same voltage (NOTE—Adjust the LOAD GAIN with the generator running isochronously and not paralleled). When the load signal voltages of all generator sets in a system are reduced, the load sharing gain will be reduced. This may result in some loss of load-sharing sensitivity but will increase load sharing stability. It may be necessary to reduce the load signal voltage of each unit in the system to as low as three volts in cases of extremely poor system dynamics.

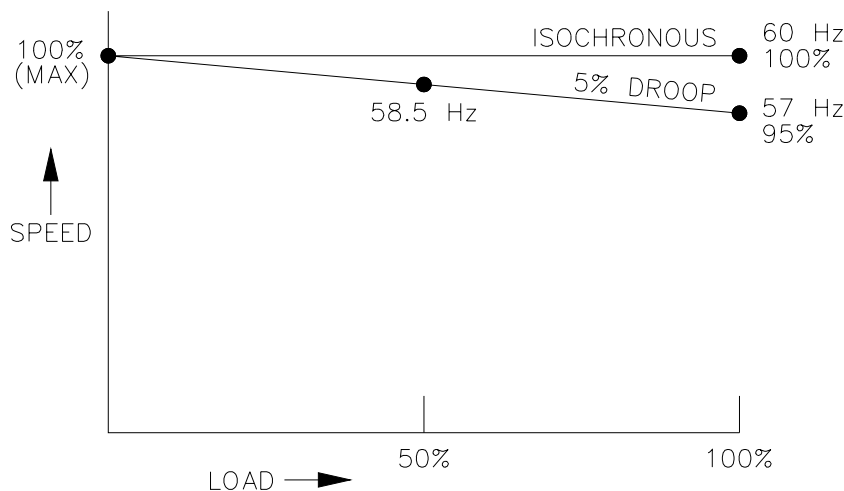
## Droop Adjustment

Droop is usually expressed as a percentage. Droop percentage is calculated by dividing the difference between the no load speed and the full load speed by the rated speed.

The DROOP potentiometer only needs to be adjusted when the generator set is to be operated in droop mode. The method of setting droop depends on whether the load on the generator set is an isolated load or an infinite bus. Once adjusted, the droop potentiometer will not have to be readjusted unless a different droop percentage is desired.

### Setting Droop for an Isolated Load

1. Open the OPEN FOR DROOP switch (or disconnect the wires from terminals 13 and 14).
2. Start the engine and adjust the speed for rated with no load.
3. Apply full load.
4. Adjust the DROOP potentiometer to give the desired speed.  
Example: Operating at 60 Hz, 57 Hz at full load indicates 5 percent droop. If only 50 percent loading is possible, 58.5 Hz would indicate 5 percent droop (see Figure 3-2).



823-038

Figure 3-2. Droop Adjustment

## Setting Droop for an Infinite Bus

1. With the generator not paralleled, adjust the speed above rated frequency by the percent droop required (set engine at 63 Hz for 5 percent droop on a 60 Hz system).
2. Mark the speed setting potentiometer position or measure dc voltage on TB27(+) and TB26(-), and re-adjust the engine speed for rated frequency.
3. Turn the DROOP potentiometer fully clockwise for maximum droop.
4. Synchronize the generator with the bus and parallel it with the bus.
5. Increase the speed setting potentiometer to the position marked in step 2, increasing load.
6. Slowly adjust the DROOP potentiometer counterclockwise, decreasing droop, until 100 percent load is obtained.

If it is necessary to set the droop without pulling 100 percent load, set the engine speed accordingly for the desired percent of droop at the load to be pulled. For example: Five percent droop at 50 percent load will require a no load rated speed of 61.5 Hz, not 63 Hz, on a 60 Hz system.

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## Chapter 4. Theory of Operation

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### Introduction

This chapter describes the operation of the Load Sharing Module and its internal circuits. Figure 1-4 is a block diagram of the circuits in the module.

The Load Sharing Module senses the power output of a generator and provides a pulse-width modulated signal to the Caterpillar digital speed control to adjust the power output of the engine-generator set to match the reference power level. The Load Sharing Module can also produce a droop condition (instead of isochronous load-sharing) for the engine with Caterpillar digital speed control, making it possible to connect the generator set in parallel with either a generator set which is running isochronously, or with an infinite bus.

### Power Supply

The internal power supply generates a regulated dc voltage for the operation of the circuits in the Load Sharing Module. The power supply gets its power from the engine 24 Vdc power source. To prevent damage to the Load Sharing Module that uses an alternator or battery charging device, make sure the charging device is turned off before disconnecting or connecting the 24 Vdc supply to the unit.

### Power Sensor

Generator load is measured by the power-sensor circuit of the Load Sharing Module. The power-sensor circuit senses current amplitude, and produces a load signal proportional to the current amplitude times the power factor. The potential input comes from potential transformers (PTs) and the current input comes from the current transformers (CTs). The circuit uses these two inputs to generate a load signal which is then filtered and sent to the controller circuit. The load signal voltage of each generator set will be proportional to the percentage of rated load on the generator set.

Ammeters and voltmeters may be driven with the same PT and CT wires.

### Load Comparator Circuit

In the load comparator circuit, the load signal voltage is balanced with the other generator sets in the system via the load sharing lines. The comparator circuit of each Load Sharing Module includes a load gain potentiometer to adjust each generator set's load signal so that the load signal voltage of each is the same at full load. This compensates for varying CT ratios or different generator set sizes. The load sharing voltage will be one-half the measured voltage of the load signal test point.

## Speed Trim Circuit

A 10 k $\Omega$ , 10-turn speed-trim potentiometer can be added to the Load Sharing Module to permit remote adjustment of the load or frequency of the generator. The speed trim is normally used for manual synchronization of a generator set with an existing bus or to change the load demand when in droop mode. If no speed trim is needed, add a 10 k $\Omega$  resistor between terminals 26 and 28.

## Isochronous Load Sharing

Each comparator circuit compares the load signal voltage for its generator set to two times the voltage on the load sharing lines and produces an error voltage proportional to the difference. This error voltage is used to generate a pulse width modulated signal which is output to the Caterpillar speed control. This output biases the speed loop of the Caterpillar control until the load signal voltage is equal to that of other generators on the load sharing lines.

## Droop Operation

In droop operation, a portion of the load signal voltage is fed to the controller circuit. This voltage is used by the comparator circuit to reduce the control output by a percentage determined by the DROOP potentiometer. The output is reduced, and the Caterpillar digital speed control reduces engine power according to the desired droop percentage.

When a generator set using the Load Sharing Module is paralleled in droop with other generator sets, the common load signal on the paralleling lines is not used. The frequency of the generator set will therefore vary with load, so it must be determined by a different means. In an isolated system with two or more generator sets paralleled, if isochronous speed control is required, one of the generator sets must be running in the isochronous (constant speed) mode. This generator set maintains the frequency of the system. If a generator set is in droop and is paralleled with an infinite bus, the bus determines and maintains the frequency. The DROOP percentage and the speed setting on the Caterpillar digital speed control determine the amount of the load that is carried by the generator, when running in droop.

## Auxiliary Equipment

The Woodward SPM-A synchronizer functions by biasing the output of the Load Sharing Module. All other Woodward auxiliary generating control equipment functions by biasing the voltage on the load-sharing lines.

## Pulse Width Modulation

The Load Sharing Module output to the Caterpillar digital speed control engine is a frequency of  $500 \pm 100$  Hz. The duty cycle ranges from a low of 10 percent for maximum decrease in load or speed to a high of 90 percent for maximum increase in speed or load. The duty cycle varies according to the magnitude of difference between the reference load and the actual power generation.

## Chapter 5. Troubleshooting

The following trouble-shooting guide is an aid in isolating trouble to the Load Sharing Module, engine control, plant wiring, or elsewhere. The guide assumes that the system wiring, soldered connections, switch and relay contacts, and input and output connections are correct and in good working order. Make the checks in the order indicated.



### CAUTION—SERVICING

To prevent possible serious damage to the Load Sharing Module, do not attempt to service the unit beyond that described in the operating instructions. All other servicing should be referred to qualified service personnel.

SYMPTOMS	CAUSE	TEST/REMEDY
Undesirable speed decrease with load increase.	Droop mode switch is open or auxiliary contact is open. Load Sharing Module is in droop mode.	Jumper Load Sharing Module terminals 13 and 14. If this corrects the problem, replace wiring or switch as required. The module will not go into droop with the terminals connected.
	Improper engine operation. Operate the engine and observe speed while applying load.	If droop occurs near the full load point only, it is possible the engine is not producing the horsepower called for or is being overloaded.
	Faulty engine control. Disconnect the Load Sharing Module and load the engine as a single, isolated unit.	If speed continues to decrease with load, engine operation may be faulty.
Erratic Load Sharing Module operation.	Open or intermittent wire.	Check all wiring for continuity and tight connections. Repair if necessary.
	EMI (Electromagnetic Interference).	Remove ground loops. Shield all wiring (load sharing lines, output to the speed control, speed trim pot, and SPM-A synchronizer input. Route wiring away from noise sources.
	Unstable system.	Check system for proper operation.
	Unstable voltage regulator.	Consult voltage regulator manufacturer's manual for proper adjustment.
	Poor system stability.	Reduce the load signal voltage of each unit in the system to three volts.
Load Signal voltage is low. Adjusting LOAD Gain won't raise it.	Incorrect phasing of CT and PT wiring.	Perform phasing check. If phasing check indicates need, perform procedure for correct phase wiring.
	Insufficient CT output.	Check for 5 amp CT output at full load. Change to a lower primary current CT if necessary.

SYMPTOMS	CAUSE	TEST/REMEDY
Load Signal voltage is too high. Adjusting LOAD GAIN will not lower it.	CT output too high.	Check for 5 amp CT output at full load. (CT output must be between 3 and 7 amps at full load.) Change to a higher primary current CT if necessary.
Engine does not properly share load with other units.	Engine not responding to signal from Load Sharing Module.	Check for maximum voltage from terminals 22 to 23. If possible check the voltage from terminal 19 to 20. If the Load Sharing Module is putting out a maximum signal, the problem is either in the wiring to the engine control, the engine control, or the engine.
	Unequal speed settings.	Be sure the speed settings of all off-line units at no load are identical. Adjust as necessary. Resynchronize.
	Unequal load gain voltages.	Check that load gain settings of all load sharing units are correct. See load gain adjustment in Chapter 3. Adjust as necessary.
	Improper load sensing phasing.	Perform the transformer phasing check in Chapter 3. Correct as necessary.
Engine does not properly share load with other units.	Circulating currents between generators. (Noted by unequal power factors between generators.)	Properly adjust the generator voltage regulators.
Engine does not properly share load with other units.	Terminals 13 and 14 not shorted. Load sharing module is in droop.	Jumper Load Sharing Module terminals 13 and 14. Observe engine operation. Replace wiring or switch as required.

# Appendix A.

## LSM Control Specifications

<b>POWER SUPPLY</b>	18–32 Vdc, approximately 5 W. Protected against undervoltage, overvoltage to +80 Vdc, reverse voltage to –32 Vdc.
<b>INPUTS</b>	
3-phase PT Inputs	100–240 Vac line-to-line, 50–400 Hz. PT input burden is between 1.5 VA and 1.7 VA per phase at 240 Vac, and between 0.4 VA and 0.5 VA per phase at 120 Vac.
3-phase CT Inputs	3–7 Arms at full load, CT input burden at full load is 0.1 VA per phase.
Load Sharing Input	0–3 Vdc into 25 k $\Omega$ impedance in isochronous mode, open circuit in droop mode.
Sync Input	Compatible with optional Woodward SPM-A Synchronizer, 0.38% speed change* per volt input.
Speed Trim	$\pm 10\%$ minimum speed change* with an external 10 k $\Omega$ potentiometer.
Droop Switch	The external droop switch is to be wired in series with the auxiliary circuit breaker contact between terminals 13 and 14. Droop mode is selected when either the droop switch or the auxiliary circuit breaker is open.
<b>OUTPUTS</b>	
Load Signal	DC signal proportional to total real current measured by the Load Sharing Module. Load Gain adjustable over minimum range of 0.86 to 2.0 Vdc/Arms.
PWM Output	Pulse width modulated square wave, 500 $\pm$ 100 Hz. Zero error output duty cycle = 69.8 $\pm$ 2.0%. Minimum V(hi) = 10.0 Vdc, maximum V(lo) = 0.5 Vdc when driving external 5.1K load to 13.0 Vdc external pull-up.
<b>ADJUSTMENTS</b>	
Droop	Provides 0 to 9% speed reduction* between no load and full load conditions.
Load Gain	Provides adjustment of the load on an individual generator when two or more generators are paralleled. Adjusts specified full load condition from 3 to 7 Arms.

**ENVIRONMENTAL**

Operating Temperature	–40 to +70 °C (–40 to +158 °F).
Salt Fog	Tested at 5% NaCl, 35 °C, 48 hrs wet, 48 hrs dry.
Humidity	Tested at 95% RH, 65 °C, non-condensing, 5 cycles at 24 hr/cycle.
Vibration	Swept sine: 4 G, 5 mm, 5–2000 Hz, 3 hr min/axis, including four 30-minute dwells at resonant frequencies.
Shock	40 G, 11 ms sawtooth pulse.
Installation Overvoltage Category	Category III.
Air Quality	Pollution Degree 2.

**DIMENSIONS**

Linear (maximum)	Length: 273.6 mm (10.77 in) Width: 214.1 mm (8.43 in) Height: 59.2 mm (2.33 in)
Weight	1397 g (49.3 oz) approximate

**SAFETY AND EMC STANDARDS COMPLIANCE**

Conforms to EMC Directive 89/336/EEC. Conformity established by testing.

Conforms to Low Voltage Directive 73/23/EEC when used in accordance with instructions. Conformity established by testing.

Listed to UL and cUL Industrial Control Equipment (UL508).

**\*—When used with a speed control having a gain of 0.382% speed change per 1% duty cycle change.**

# Appendix B. Guide for Handling and Protection of Electronic Controls, Printed Circuit Boards, & Modules

## Introduction

[Appendix B reproduces Woodward manual 82715.]

All electronic equipment contains components that can be damaged, or suffer reduced reliability, from improper handling or incorrect wiring. This manual describes methods of handling electronic equipment and techniques for connecting and checking system wiring. These methods and techniques, if used, will substantially reduce handling damage and in-service failures. Although some types of electronic equipment are more easily damaged by mishandling or incorrect wiring than other types, regular use of these methods and techniques will result in fewer damaged components and increased reliability for all types of electronic equipment.

Improper handling (installation, removal, storage, etc.) can cause two types of component failure: immediate failure or eventual failure (decreased reliability). Both of these types of failure, in turn, can be caused by electrostatic discharge, physical damage, or electrical damage.

An electrostatic discharge across a device which is sensitive to static electricity usually punctures an insulating layer, causing the device to fail immediately. However, an electrostatic discharge can also weaken an insulating layer without puncturing it, causing eventual premature failure with no immediate malfunction or sign of damage.

Rough handling or improper protection during installation, removal, shipping, or storage can cause physical damage to a module, a printed circuit board (PCB), or a complete control. Again, the damage may not be apparent immediately, but may cause eventual premature failure.

Incorrect system wiring or improper test procedures can electrically damage a control or can cause temporary incorrect operation without actual damage.

In order to prevent these types of unnecessary damage to a control, module, or PCB, the following instructions must be followed.

## Preventing Electrostatic Damage

To effectively reduce damage from electrostatic discharge, all four of the following precautions must be taken:

- Reduce the generation of static electricity
- Dissipate safely any charges that have built up
- Handle equipment correctly
- Use protective devices

The first of these four is the most important because, if no static electricity were generated, the other three precautions would not be necessary. However, since the generation of static electricity is impossible to completely eliminate, all four precautions must be taken to prevent damage from electrostatic discharge.

## Reduce Static Generation

- Do not wear clothing that readily generates static electricity (synthetic materials generate large amounts of static electricity). Cotton or cotton blend fabrics, for example, are good because they are not as likely to store electrostatic charges.
- Keep all plastic items away from any area where electronic devices are handled. Any plastic item is a potential static generator. This includes candy-wrappers, foam cups, synthetic carpet, foam cushions, etc.
- Avoid activities that produce static such as wiping feet or putting on smocks, when in the vicinity of static-sensitive devices.
- Maintain as high a humidity as is comfortable and practical.

## Dissipate Built-Up Charges

- Always discharge any static charge your body might have built up before touching any electronic module, PCB, or control. To do this, touch and hold a grounded metal object for a minimum of two seconds.
- When connecting a cable to a control, discharge any charge the cable may have. Touch the cable connector to the receptacle before removing the protective cover from the receptacle. Then, remove the protective cover from the receptacle and connect the cable.

## Handle Equipment Correctly

- Do not touch components, solder runs, or connectors on a PCB. Hold PCBs only by the edge and modules only by the handle (if provided) or by the front panel.
- When disconnecting a module from a cardcage-type control during testing or service, do not remove the module completely from the control. Pull it out only about 10–15 mm (about 1/2 inch) to disconnect it.

## Protective Devices

- Controls are sent from the factory with protective covers on cable receptacles. Leave the cover on any receptacle that has no cable connected to it. Always install covers on all receptacles when a control is in storage.
- Install a Conductive PCB Shunt Bar on any PCB or module that is not installed in a control. Install PCB Shunt Bars on all modules as soon as the module is removed from the control and keep the shunt bars on the modules during storage or shipment.
- When a module or PCB is removed from a control, insert it into an Antistatic Protective Bag.

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## Preventing Physical Damage

- Do not force a module when installing it into a control. If a module does not go into a control easily, check that the module is in the correct slot (each type of module is keyed to fit only into the correct slot), and that it is not upside down. Be sure that the module is being inserted straight, and that there are no bent pins or obstructions. Insert the module all the way in by hand before tightening the locking screws.
- Do not force a cable connector into its receptacle. Use only your hands, not pliers or other tools. If a connector doesn't easily go into its receptacle, check for bent pins or obstructions.

## Preventing Electrical Damage

### Installation

- When installing a control, double-check to be sure that all system wiring is correct. Do not connect the control until all wiring is correct.
- Do not use the control to check the system wiring; make sure that the wiring is correct before connecting it to the control.
- Do not make any connections with the power on. Doing so may damage the control and/or cause injury to personnel.

### Testing and Servicing

- Do not make connections with power on.
- Double-check all test equipment connections before applying power.
- Use battery-operated test equipment whenever possible.
- Make sure that all test equipment is isolated from ground.
- Do not remove or install modules or PCBs with power on.

## Shipping

- Unless otherwise stated in a product manual, preparing a device for shipment should be as follows:
- When a module or PCB is shipped separately, use a conductive PCB Shunt Bar on it (if applicable) and put it into an Antistatic Protective Bag.
- Pack each module that is not installed in a control individually, each with a Conductive PCB Shunt Bar (if applicable) and each in its own Antistatic Protective Bag.
- Use a non-abrasive material to protect all surfaces of the unit.
- Pack a complete control, a module, or a PCB so that it has at least 100 mm (four inches) of tightly packed, industry approved shock-absorbing material on all sides.
- Pack a complete control in a double-walled carton made of minimum 1500 N (340 pound) test material.
- Pack each module to be shipped in its own heavy cardboard box. Do not ship modules or PCBs in padded envelopes.

## Storage

- Leave all controls, modules, and PCBs that are to be stored, in their shipping boxes, with all protective devices in place.
- Store electronic equipment in a cool, dry place.
- Long-term stored units may require operational power prior to installation and setup. Apply power to controls as described in the manual or unit wiring diagram. Modules either can be installed in an operating control, or in a special powered storage rack available from Woodward. This will ensure that the stored unit is functional.

# Appendix C. EMI Control in Electronic Governing Systems

## Introduction

[Appendix C reproduces Woodward application note 50532.]

Electronic governing systems are required to operate in proximity to other electrical and electronic devices. Many of these devices emit electromagnetic energy. The emissions may be incidental to the operation of the device, such as from rectifiers (SCRs), motors, generators, relays, and switching power supplies. The emissions may be deliberate, such as from communication transmitters, radar, and navigation aids. When these emissions adversely affect another device, it is called electromagnetic interference (EMI).

This application note covers some of the ways EMI occurs and some ways in which interference can be prevented. Only the practical aspects of EMI in the typical prime mover wiring installation are covered.

## Interference Paths

These are two basic ways an interfering signal (noise) can be introduced into an electronic device:

- When two or more devices share a common ground, current drawn by one device creates a ground voltage seen by the other devices.
- Wires running through a noisy environment can pick up noise and conduct it into the electronic circuits.

## Methods of Noise Reduction

There are two primary ways of reducing interference:

- Grounding
- Shielding

The application of these techniques will prevent EMI in almost all systems employing electronic governors.

## Grounding

There are two important reasons for grounding:

- To prevent a high voltage shock hazard from lightning or component failure.
- To provide a common reference to the system. The ground system can also provide effective protection against EMI if properly designed.

## Ground

Ground is defined as an equipotential point or plane used for the system reference. Ground can be at earth potential, as required for safety grounds, or floating with respect to earth. The important point of this definition is equipotential. In the real world, all conductors have some impedance. When carrying current, no two points on the conductor are at the same potential. A good ground, then, is one in which the ground potentials and their effects are minimized.

## Ground Systems

The objectives of a good ground system are:

- To prevent ground potential noise coupling caused by currents from two or more circuits flowing through a common ground impedance.
- To avoid ground loops which are affected by magnetic fields and differences in ground potentials.

The first step in proper grounding is to establish a separate signal ground for the system electronics. A typical system will have a minimum of three separate grounds:

- **Hardware Ground**—This is for connecting enclosures, chassis, equipment racks, etc. In ac power systems, this is where the green safety wires are connected.
- **Power Ground**—This is the return for noisy equipment such as motors, relays, and SCRs.
- **Signal Ground**—This serves as the reference for the electronic devices in the system. Signal ground may be connected to the other grounds at a single point near the primary ground point.

Figure C-1 illustrates why a separate signal ground is important.

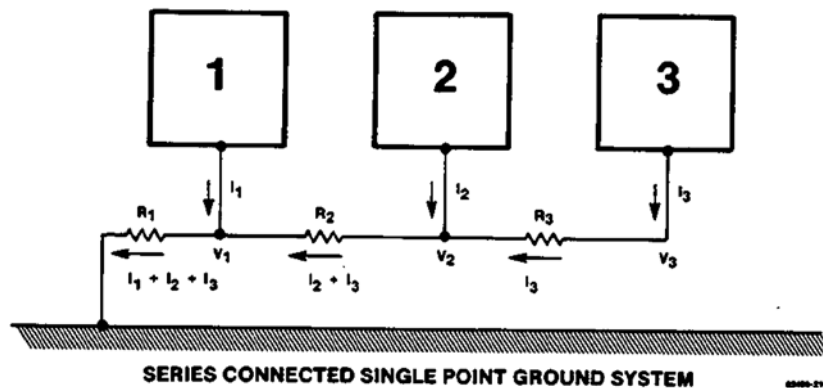


Figure C-1. Series Connected Single Point Ground System

The resistors shown represent the impedances of the ground conductors. Currents from circuits 2 and 3 combine with the current from circuit 1 to develop the ground potential

$$V_1 = R_1 (I_1 + I_2 + I_3)$$

The potential at 2 is

$$V_2 = R_1 (I_1 + I_2 + I_3) + R_2 (I_2 + I_3)$$

and likewise

$$V_3 = R_1 (I_1 + I_2 + I_3) + R_2 (I_2 + I_3) + R_3 I_3$$

This is a commonly used ground system due to simplicity and low cost. It is also the least desirable system from a noise standpoint. If this system must be used, locate the electronics nearest to the primary ground point as the ground potential will be lowest there.

Figure C-2 illustrates a properly designed ground system for low frequency noise. Separate returns are provided for hardware, power, and signal grounds. Each circuit sees only the ground potential generated by its own ground impedance and current.

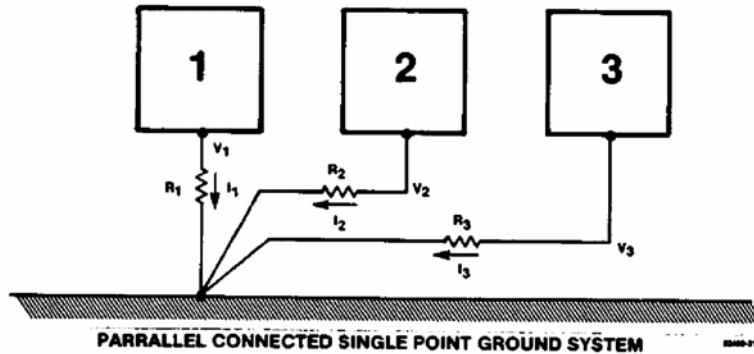


Figure C-2. Parallel Connected Single Point Ground System

### High Frequency Grounding

The above ground system is useful at frequencies below about 10 MHz. Occasionally, prime mover systems may be located near high frequency transmitters. In this case, a single point ground may not be appropriate due to the excessive length of the ground conductors. For instance, 1 meter of 5 mm<sup>2</sup> (#10 AWG) wire has an impedance of 0.0033  $\Omega$  at 60 Hz and 225  $\Omega$  at 27 MHz.

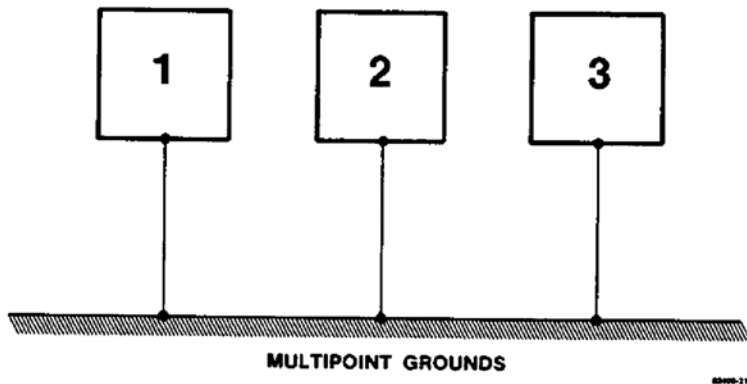


Figure C-3. Multipoint Ground System for High Frequency Grounding

For high frequency noise rejection, a multipoint ground system may be better. Connect all common terminals to the chassis grounds directly. All chassis then should be bonded together with heavy copper strapping. Enclosures should then be strapped to a ground rod located as close as possible. It is still a good idea to separate signal and power grounds by providing a non chassis return for power distribution.

## Ground Loops

Ground loops can occur from two sources of noise:

- Ground potentials
- Electromagnetic fields

The previous section covered how ground potentials occur. Figure C-4 illustrates how a ground potential can cause interference to an electronic control system.

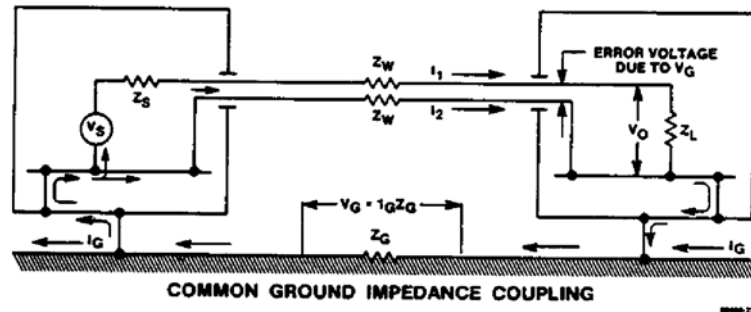


Figure C-4. Common Ground Impedance Coupling

Ground current,  $I_G$ , creates the ground potential,  $V_G$ , through the common ground impedance,  $Z_G$ . This potential drives current through the loop formed by the source and load wiring. This current creates an error voltage across the load impedance.

In a load sharing system, load imbalance is a result of dc ground potentials. Load sharing instability or slow system response are a result of ac ground potentials. Provide separate ground returns for electronic devices.

Electromagnetic fields also can induce current into a loop. Figure C-5 shows a ground loop formed by signal leads and circuit common. The field flux cuts through the loop and induces current flow. (This is the same principle that applies to generators.) The resulting voltage across the load causes an error in the measurement.

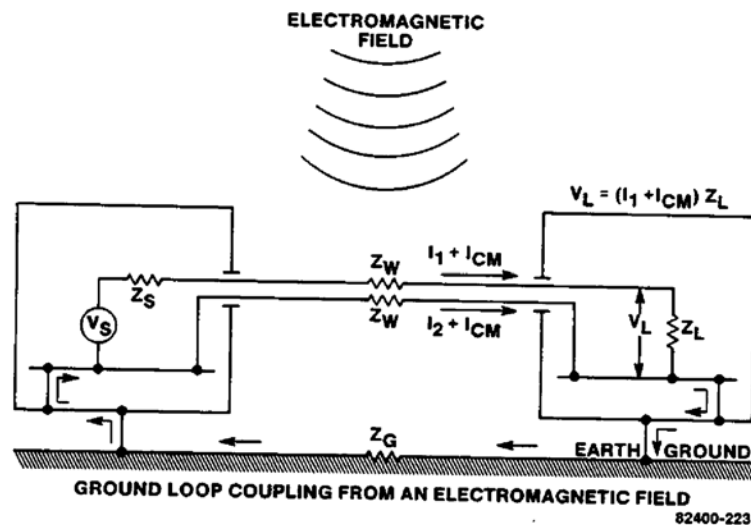


Figure C-5. Ground Loop Coupling from an Electromagnetic Field

The current induced into a loop is proportional to the field strength and area of the loop. Reducing field strength and loop area are both effective reduction methods. Loop area can be reduced by locating the electronics closer together and routing interconnecting wires near signal ground. Field strength can be reduced by routing wires as far from field sources as possible and orienting wiring at right angles to field sources. Shielding can be placed between the field source and wires to reduce the flux reaching the loop. This will be covered in the shielding section.

The most effective (and most expensive) solution to interference from ground loops is to open them. Figure C-6 shows the source floating with respect to ground, so no loop is formed as in Figures C-4 and C-5.

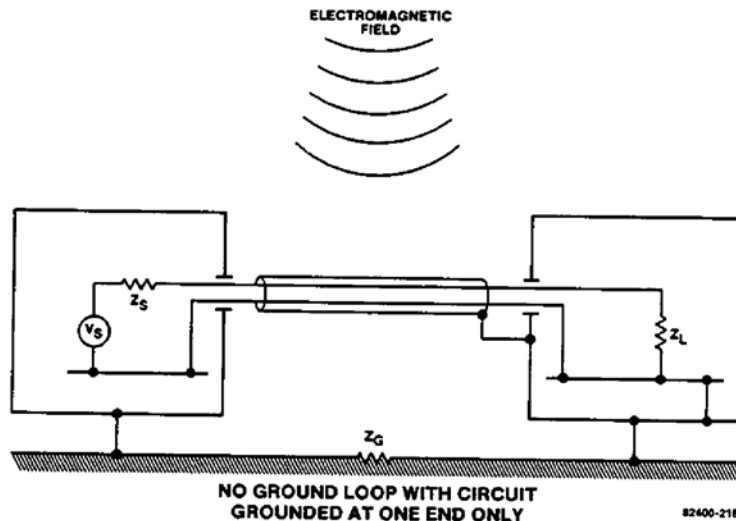


Figure C-6. No Ground Loop with Circuit Grounded at One End Only

Ground loops may be broken with isolated power supplies on the source or receiving circuits. For process signals such as 4–20 mA or 1–5 V, loop isolators are available. Take care in such wiring to prevent grounding of isolated circuits, usually via shields, which defeats the ground loop isolation.

Though not related to grounding, electromagnetic fields can also induce current into loops formed by signal lines as in Figure C-7.

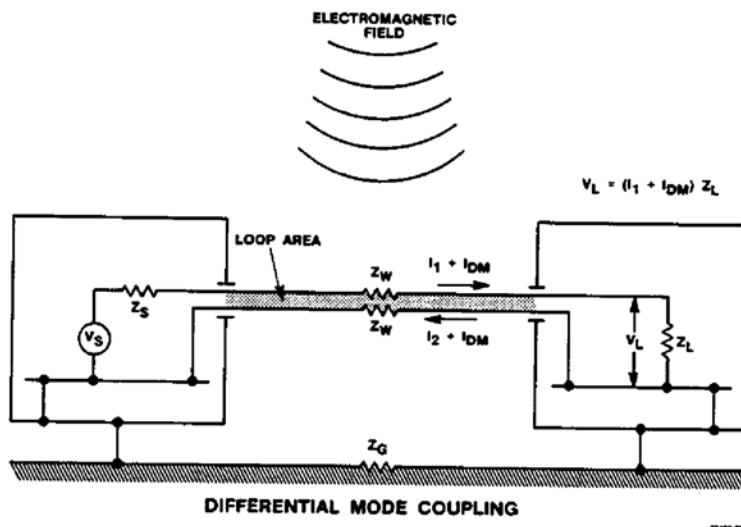


Figure C-7. Differential Mode Coupling into Loop Formed by Signal Lead Pair

Loop area and field strength reduction are again effective methods of reducing interference. Loop area is reduced by using twisted pairs and minimizing the area at terminations. Twisted pairs also offer a cancellation effect on low frequency noise.

## Summary

A properly designed ground system is the most effective EMI control method at low frequencies. The design should consider using:

- Signal ground for electronics separate from power and safety ground to prevent ground potentials.
- Minimum loop areas to reduce electromagnetic field coupling.
- Electronic wiring located as far as possible from sources of fields.
- Elimination of ground loops by single point grounds and isolation from ground.

## Shielding

Shielding is the second primary method of reducing noise. Shielding techniques depend on the frequency of the noise and if the field component is magnetic or electric. The major field component is usually electric if the noise source is separated from the susceptible circuits. Magnetic fields decrease proportional to the cube of the distance, where the electric field decreases directly proportional to the distance. High current alternating signals are good magnetic field sources, and high voltage, low current circuits are electric field sources.

## Electric Field Shielding

Electric fields are relatively easy to protect against. Two basic rules apply:

- Minimize the exposed wire beyond the shield.
- Provide a good ground for the shield.

Wire extending beyond the shield should be limited to 50 mm (2") or less. Avoid unnecessary breakouts. A terminal block in a cable run exposes a considerable length of wire.

For low frequency electric fields, a single point ground connection is preferred to prevent ground loops. Where this single ground connection is made is important. In most cases, the shield must be grounded at the receiver end of the wires. In a properly designed ground system, this is signal ground, not chassis or safety ground. Figure C-8 shows a shield terminated to chassis ground when a separate signal ground is provided. Due to impedances around the loop, noise currents cause a common mode voltage between the shield and wires. This noise voltage can couple capacitively into the circuits. The results can be worse than no shield at all.

In a circuit that is floating, the shields must be connected to circuit common. If the shield is connected to chassis ground, it has no meaning.

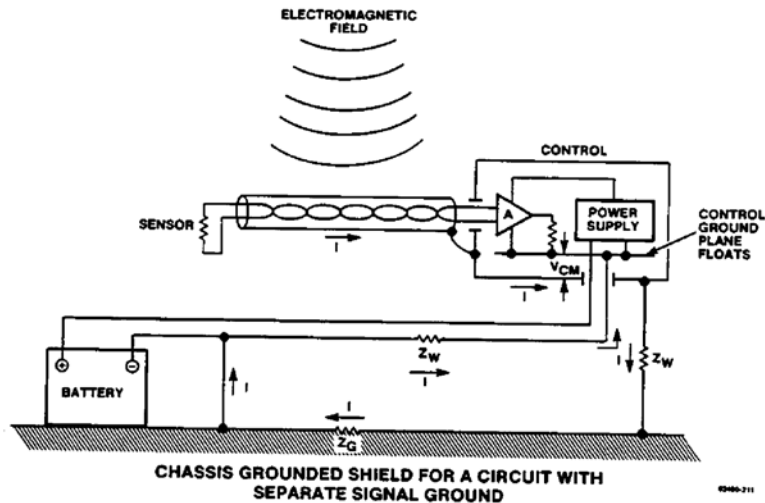


Figure C-8. Chassis Grounded Shield for a Circuit with Separate Signal Ground

Occasionally there are exceptions to grounding shields at the receiving end of the circuit. When grounded thermocouples with a floating amplifier are used, the shield should be grounded at the thermocouple end. Load sharing lines are another exception. Both ends of the lines are transmitters and receivers of signals. For controls with non-isolated circuits, the shields should be broken near the middle of the circuit. For controls with isolated power supplies, the shields may be connected at both ends to circuit common—providing there are no other connections between the controls to create a ground loop.

Shielding for high frequencies is different than for low frequencies. When the shield length exceeds approximately one-twentieth of a wave length of the noise, the shield on twisted pair wires is no longer effective. At 60 Hz, the wave length is about 5000 km (over 3000 miles). At the 27 MHz band, the wave length is 11 m (37 ft). A shield over 60 cm (2 ft) is electrically long at 27 MHz. Single point grounding of shielded twisted pair wires is effective at low frequencies only. Grounding the shields every 60 cm (2 ft) can be cumbersome and can also create ground loops. To effectively shield at high frequencies, solid conduit, continuously grounded, should be used. Fortunately, high frequency noise in great enough amplitude to cause interference is not common. Equipment cabinets typically shield the electronics sufficiently to prevent problems.

## Magnetic Field Shielding

Shielding against magnetic fields is more difficult than for electric fields. Magnetic fields induce current into loops. To shield a loop effectively, the entire loop must be shielded. Figure C-9 shows a ground loop area and induced current. Note that the shielded cable does not affect the ground loop. Electric field shielding is not effective for magnetic fields.

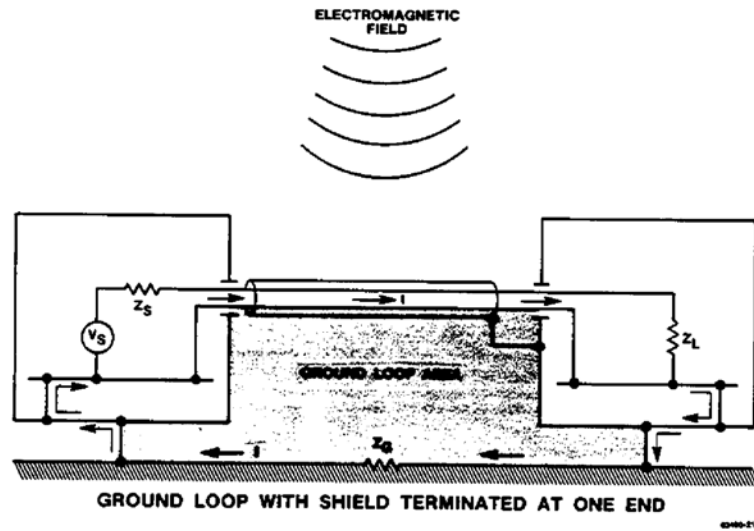


Figure C-9. Ground Loop with Shield Terminated at One End—No Shielding of Magnetic Field Occurs

Grounding the shield at both ends as in Figure C-10 will remove the ground loop from the signal wires. However, the large ground loop current in the shield circuit will induce noise into the wires anyway.

The most effective ways of shielding against magnetic fields is to decrease the loop area, reduce field strength, and isolate power supplies to eliminate the loops.

Since grounding shields at both ends does reduce magnetic field strength, place the shield around the field source. Use a magnetic material such as steel to enclose magnetic field sources completely. The induced ground currents can be quite high, so cabinets and doors should be well grounded to prevent arcing. Sensitive electronics and wiring should not be placed in these cabinets.

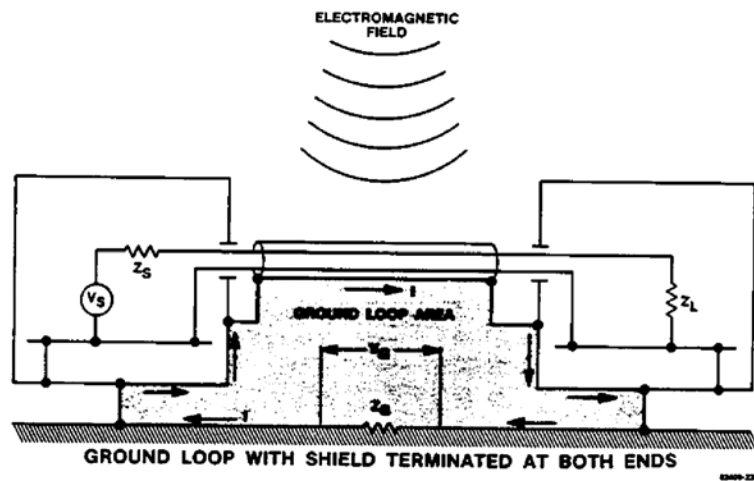


Figure C-10. Ground Loop with Shield Terminated at Both Ends

## Summary

Electric fields are easy to guard against:

- Single point grounds for low frequencies
- Minimum exposed wires at shield ends

Magnetic field shielding involves:

- Reducing or eliminating loop areas
- Shield magnetic fields at their source

## Economics of EMI Control

Noise suppression should be considered at the system design stage. Proper attention to grounding and shielding will prevent almost all EMI problems. When EMI occurs during system test, the problems can be very difficult and expensive to solve. For example, by separating sensitive wiring from noisy wiring, many problems can be prevented at almost no cost. Rewiring a system to fix it can entail considerable expense and production delays.

The elimination of noise at the source should always be given priority. An unsuppressed relay coil can generate noise that can interfere with several other devices in the system.

Effective design requires minimizing noise generation and preventing the remainder from reaching sensitive electronics.

**DECLARATION OF CONFORMITY**

According to EN 45014

**Manufacturer's Name:** WOODWARD GOVERNOR COMPANY (WGC)  
Industrial Controls Group

**Manufacturer's Address:** 1000 E. Drake Rd.  
Fort Collins, CO, USA, 80525

**Model Name(s)/Number(s):** Load Sharing Module - 115/230 VAC, Analog Output/9907-173;  
115/230 VAC, PWM Output/9907-174; 24 VDC, PWM Output/9907-  
175; 24 VDC Analog Output/9907-252.

**Conformance to Directive(s):** 89/336/EEC COUNCIL DIRECTIVE of 03 May 1989 on the  
approximation of the laws of the Member States relating to  
electromagnetic compatibility

73/23/EEC COUNCIL DIRECTIVE of 19 February 1973 on the  
harmonization of the laws of the Member States relating to electrical  
equipment designed for use within certain voltage limits

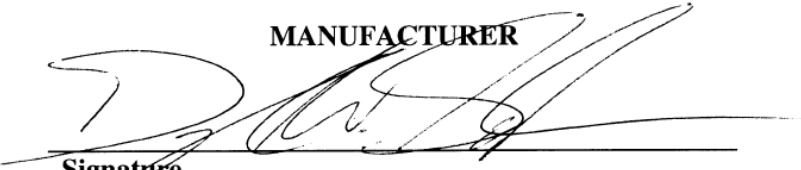
**Applicable Standards:** EN61000-6-2, 2001: EMC Part 6-2: Generic Standards - Immunity  
for Industrial Environments  
EN61000-6-4, 2001: EMC Part 6-4: Generic Standards - Emissions  
for Industrial Environments

EN50178, 1997: Electronic Equipment for Use in Power Installations

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**We, the undersigned, hereby declare that the equipment specified above conforms to the above  
Directive(s).**

**MANUFACTURER**



**Signature**

Douglas W. Salter

**Full Name**

Engineering Manager

**Position**

WIC, Fort Collins, CO, USA

**Place**

03-01-31

**Date**