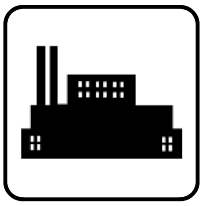
Protocol Operation

Modbus® Communications Protocol for Industrial Generator Sets



Models:

Decision-Maker™ 550 Generator Set Controller

ISO 9001
KOHLER GENERATORS
INTERNATIONALLY REGISTERED

KOHLER® POWER SYSTEMS

TP-6113 6/01

Table of Contents

IMPORTANT SAFETY INSTRUCTIONS. Electromechanical equipment, including generator sets, transfer switches, switchgear, and accessories, can cause bodily harm and pose life-threatening danger when improperly installed, operated, or maintained. To prevent accidents be aware of potential dangers and act safely. Read and follow all safety precautions and instructions. SAVE THESE INSTRUCTIONS.

This manual has several types of safety precautions and instructions: Danger, Warning, Caution, and Notice.

DANGER

Danger indicates the presence of a hazard that ***will cause severe personal injury, death***, or ***substantial property damage***.

WARNING

Warning indicates the presence of a hazard that ***can cause severe personal injury, death,*** or ***substantial property damage***.

CAUTION

Caution indicates the presence of a hazard that ***will*** or ***can cause minor personal injury*** or ***property damage***.

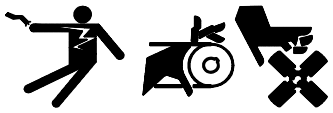
NOTICE

Notice communicates installation, operation, or maintenance information that is safety related but not hazard related.

Safety decals affixed to the equipment in prominent places alert the operator or service technician to potential hazards and explain how to act safely. The decals are shown throughout this publication to improve operator recognition. Replace missing or damaged decals.

Accidental Starting

WARNING



Accidental starting.
Can cause severe injury or death.

Disconnect the battery cables before working on the generator set. Remove the negative (-) lead first when disconnecting the battery. Reconnect the negative (-) lead last when reconnecting the battery.

Disabling the generator set. Accidental starting can cause severe injury or death. Before working on the generator set or connected equipment, disable the generator set as follows: (1) Move the generator set master switch to the OFF position. (2) Disconnect the power to the battery charger. (3) Remove the battery cables, negative (-) lead first. Reconnect the negative (-) lead last when reconnecting the battery. Follow these precautions to prevent starting of the generator set by an automatic transfer switch, remote start/stop switch, or engine start command from a remote computer.

Hazardous Voltage/ Electrical Shock

DANGER

Hazardous voltage.
Will cause severe injury or death.

Disconnect all power sources before opening the enclosure.

(over 600 volts)

WARNING

Hazardous voltage.
Can cause severe injury or death.

Disconnect all power sources before opening the enclosure.

(600 volts and under)

Grounding electrical equipment. Hazardous voltage can cause severe injury or death. Electrocution is possible whenever electricity is present. Open the main circuit breakers of all power sources before servicing the equipment. Configure the installation to electrically ground the generator set, transfer switch, and related equipment and electrical circuits to comply with applicable codes and standards. Never contact electrical leads or appliances when standing in water or on wet ground because these conditions increase the risk of electrocution.

Making line or auxiliary connections. Hazardous voltage can cause severe injury or death. To prevent electrical shock deenergize the normal power source before making any line or auxiliary connections.

⚠ DANGER

Hazardous voltage.
Will cause severe injury or death.

Disconnect all power sources before servicing. Install the barrier after adjustments, maintenance, or servicing.

(over 600 volts)

⚠ WARNING

Hazardous voltage.
Can cause severe injury or death.

Disconnect all power sources before servicing. Install the barrier after adjustments, maintenance, or servicing.

(600 volts and under)

Servicing the transfer switch. Hazardous voltage can cause severe injury or death. Deenergize all power sources before servicing. Open the main circuit breakers of all transfer switch power sources and disable all generator sets as follows: (1) Move all generator set master controller switches to the OFF position. (2) Disconnect power to all battery chargers. (3) Disconnect all battery cables, negative (-) leads first. Reconnect negative (-) leads last when reconnecting the battery cables after servicing. Follow these precautions to prevent the starting of generator sets by an automatic transfer switch, remote start/stop switch, or engine start command from a remote computer. Before servicing any components inside the enclosure: (1) Remove all jewelry. (2) Stand on a dry, approved electrically insulated mat. (3) Test circuits with a voltmeter to verify that they are deenergized.

Servicing the transfer switch controls and accessories within the enclosure. Hazardous voltage can cause severe injury or death. Disconnect the transfer switch controls at the inline connector to deenergize the circuit boards and logic circuitry but allow the transfer switch to continue to supply power to the load. Disconnect all power sources to accessories that are mounted within the enclosure but are not wired through the controls and deenergized by inline connector separation. Test circuits with a voltmeter to verify that they are deenergized before servicing.

Short circuits. Hazardous voltage/current can cause severe injury or death. Short circuits can cause bodily injury and/or equipment damage**.** Do not contact electrical connections with tools or jewelry while making adjustments or repairs. Remove all jewelry before servicing the equipment.

Opening the power monitor enclosure. Hazardous voltage can cause severe injury or death. Only trained and qualified personnel should open the power monitor enclosure.

Opening the power monitor enclosure. Hazardous voltage can cause severe injury or death. A transfer switch or generator set connected to the power monitor could automatically energize the power monitor or accessories. Disconnect all power sources before opening the enclosure. Move the generator set master switch on the controller to the OFF position and disconnect the battery negative (-) lead before proceeding.

Current transformer voltage. Hazardous voltage can cause severe injury or death. Disconnecting current transformer leads and reenergizing the power source could cause equipment damage and personal injury. If the situation requires reenergizing the power source, reconnect the current transformer leads or short the leads together first.

Unintended Operation

⚠ WARNING

Unintended operation when applying the communications protocol can cause severe injury, death, or equipment damage. Understand the following before designing the system: (1) the system application requirements, (2) the communications protocol, and (3) the equipment manufacturers' specifications and operating limits.

Ensure the accuracy of commands that update controller settings or affect generator management or transfer switch function.

Perform control system and software qualification tests to ensure that the system operates controlled equipment safely, reliably, and as intended.

Notice

NOTICE

When replacing hardware, do not substitute with inferior grade hardware. Screws and nuts are available in different hardness ratings. To indicate hardness, American Standard hardware uses a series of markings, and metric hardware uses a numeric system. Check the markings on the bolt heads and nuts for identification.

NOTICE

Electrostatic discharge damage. Electrostatic discharge (ESD) damages electronic circuit boards. Prevent electrostatic discharge damage by wearing an approved grounding wrist strap when handling electronic circuit boards or integrated circuits. An approved grounding wrist strap provides a high resistance (about 1 megohm), *not a direct short*, to ground.

This manual provides instructions for using the Modbus® RTU communication protocol with the Kohler® Decision-Maker™ 550 generator set controller.

Information in this publication represents data available at the time of print. Kohler Co. reserves the right to change this literature and the products represented without notice and without any obligation or liability whatsoever.

Read this manual and carefully follow all procedures and safety precautions to ensure proper equipment operation and to avoid bodily injury. Read and follow the Safety Precautions and Instructions section at the beginning of this manual. Keep this manual with the equipment for future reference.

The equipment service requirements are very important to safe and efficient operation. Inspect parts often and perform required service at the prescribed intervals. Obtain service from an authorized service distributor/ dealer to keep equipment in top condition.

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The system designer assumes responsibility for ensuring that the equipment is used only as intended by the manufacturer.

Modbus Protocol

The Modbus® protocol, initially developed by the Modicon Corporation, is a de facto industry communication standard used by a controller to communicate with other devices. A complete discussion of the protocol is beyond the scope of these instructions. See the applicable Modbus master application program documentation or other reliable technical information sources for Modbus® protocol details.

This manual contains:

- Modbus® connection information
- Controller setup instructions
- Modbus® register documentation

Related Materials

The protocol covered in this manual is part of a total control system. The controller operation manual, TP-6083, provides information about setting up the generator set controller to enable remote communications and programming. It also provides information about equipment operating limits, specifications, and functions.

Consult the specification sheets, accessory installation instructions, service bulletins, application notes, drawings, and other applicable literature for additional information on equipment operating limits and specifications. Contact your local distributor/dealer or the equipment manufacturer to obtain applicable literature. Related literature part numbers follow.

Literature Description	Document Part Number
Decision-Maker™ 550 Controller Spec Sheet	G6-46
Decision-Maker™ 550 Communications Spec Sheet	G6-50
Decision-Maker™ 550 Generator Set Controller Operation Manual	TP-6083
Controller Communication Kits Installation Instructions	TT-847

Modbus® is a registered trademark of Schneider Electric.

Service Assistance

Please contact a local authorized distributor/dealer for sales, service, or other information about Kohler Co. Generator Division products.

- Look on the product or in the information included with the product
- Consult the Yellow Pages under the heading Generators—Electric
- Visit the Kohler Co. Generator Division web site at www.kohlergenerators.com
- Inside the U.S.A. and Canada, call 1-800-544-2444
- Outside the U.S.A. and Canada, call the nearest regional office

Africa, Europe, Middle East
London Regional Office
Langley, Slough, England
Phone: (44) 1753-580-771
Fax: (44) 1753-580-036

Australia
Australia Regional Office
Queensland, Australia
Phone: (617) 3893-0061
Fax: (617) 3893-0072

China
China Regional Office
Shanghai, People's Republic of China
Phone: (86) 21-6482 1252
Fax: (86) 21-6482 1255

India, Bangladesh, Sri Lanka
India Regional Office
Bangalore, India
Phone: (91) 80-2284270
(91) 80-2284279
Fax: (91) 80-2284286

Japan
Japan Regional Office
Tokyo, Japan
Phone: (813) 3440-4515
Fax: (813) 3440-2727

Latin America
Latin America Regional Office
Lakeland, Florida, U.S.A.
Phone: (941) 619-7568
Fax: (941) 701-7131

South East Asia
Singapore Regional Office
Singapore, Republic of Singapore
Phone: (65) 264-6422
Fax: (65) 264-6455

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1.1 Specifications

The controller's Modbus® communication capability:

- Supports industry-standard Modbus® RTU protocol.
- Connects to a Modbus® master singly over an RS232-C line or over an RS-485 network.
- Operates as an RS-232 to RS-485 converter.
- Uses standard baud rates of 9600 or 19200.

1.2 Configurations

The controller can communicate directly to a Modbus® master or participate in a network of devices. It can also be used to interface a local master to a network of devices. See Figure 1-1 through Figure 1-4 for an overview of the possible configurations. The configuration chosen determines the required connections and the controller setup.

Note: Install communication conductors in raceways, cables, or conduit separate from AC power conductors.

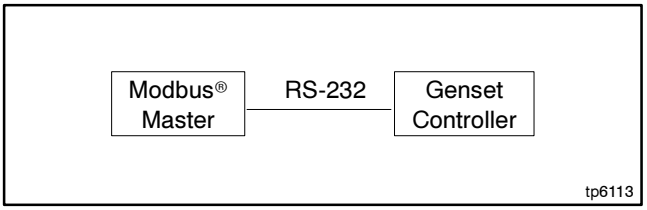

Figure 1-1 Single RS-232 Connection

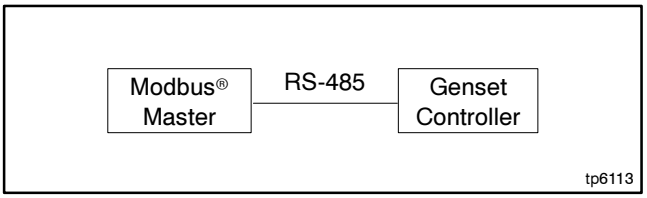

Figure 1-2 Single RS-485 Connection

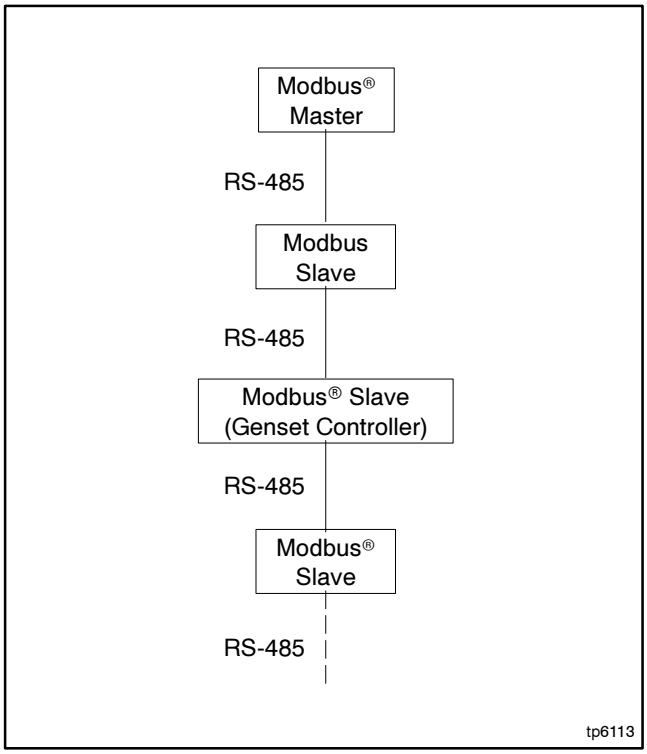

Figure 1-3 RS-485 Network

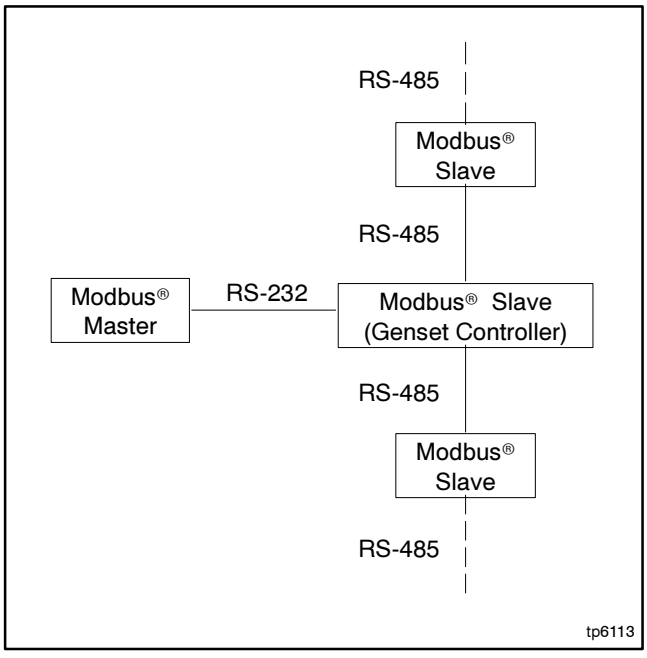

Figure 1-4 RS-485 Network with the 550 Controller used as a Convertor

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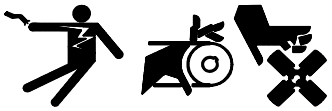
1.3 Hardware Connections

⚠ WARNING



Accidental starting.
Can cause severe injury or death.

Disconnect the battery cables before working on the generator set. Remove the negative (-) lead first when disconnecting the battery. Reconnect the negative (-) lead last when reconnecting the battery.

Disabling the generator set. Accidental starting can cause severe injury or death. Before working on the generator set or connected equipment, disable the generator set as follows: (1) Move the generator set master switch to the OFF position. (2) Disconnect the power to the battery charger. (3) Remove the battery cables, negative (-) lead first. Reconnect the negative (-) lead last when reconnecting the battery. Follow these precautions to prevent starting of the generator set by an automatic transfer switch, remote start/stop switch, or engine start command from a remote computer.

Plan the connections and refer to Figure 1-1 through Figure 1-4 to identify the cables needed. Use either an RS-232 cable or the supplied RS-485 connector with Belden #9841 or equivalent cable for a single connection. Use the RS-485 connector and Belden #9841 or equivalent cable to connect devices in a network. Attach the RS-485 connectors as shown in Figure 1-5. Use the termination resistor on the last device in the network.

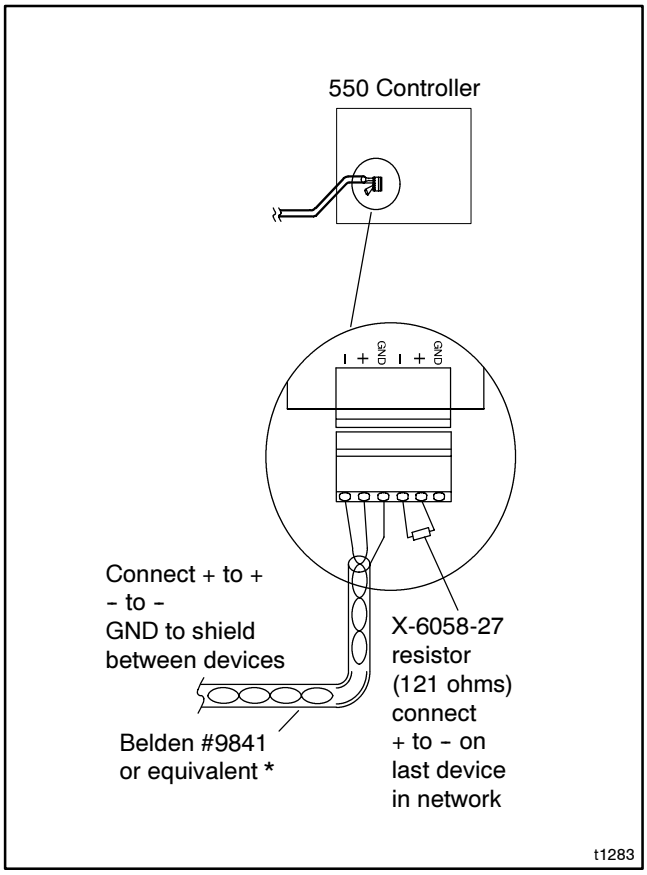


Figure 1-5 RS-485 Connector Details

Use the following procedure to connect the hardware. Observe the safety precautions.

Controller Connection Procedure

1. Place the generator set master switch in the OFF position.
2. Disconnect the power to the battery charger, if equipped.
3. Disconnect the generator set engine starting battery(ies), negative (-) lead first.

4. Turn off and disconnect the power to all devices in the system.

5. Open the enclosure and locate the connection ports as shown in Figure 1-6 and Figure 1-7.

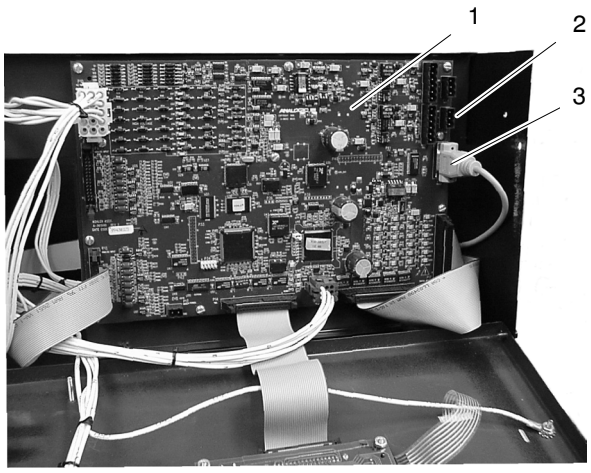
6. Make connections to the desired controller port(s). For RS-232 connections, use connector P18. For RS-485 connections, use the Modbus® RS-485 connector, P20. (Connectors P19 and P21 are used for other applications.)

7. Close the controller enclosure.

8. Check that the generator set master switch is in the OFF position.

9. Reconnect the generator set engine starting battery, negative (–) lead last.

10. Reconnect power to the battery charger, if equipped.



1. Main logic board
2. Modbus® RS-485 port (P20)
3. RS-232-C port (P18), connects with standard DB-9 RS-232 cable

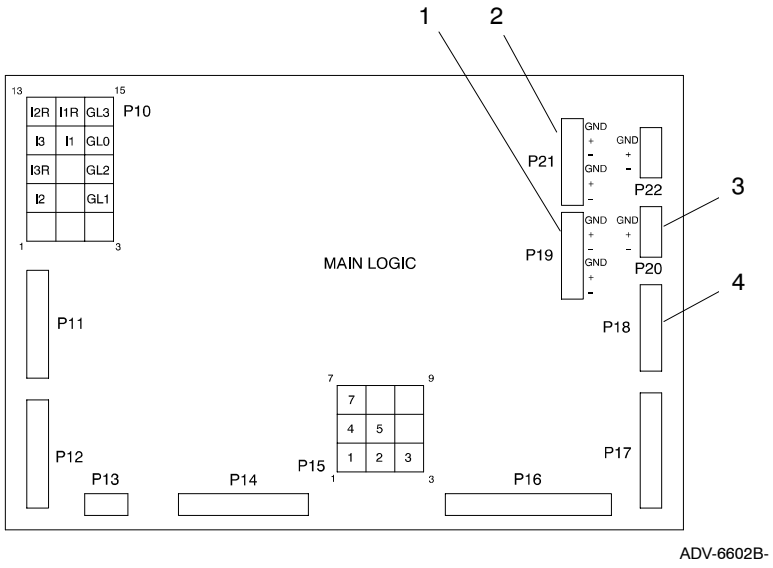
Figure 1-6 Communication Port Locations for the Decision-Maker 550 Generator Set Controller

MAIN LOGIC BOARD

P18 RS232 CONNECTIONS
P18–1 CD
P18–2 RX
P18–3 TX
P18–4 DTR
P18–5 GROUND
P18–6 DSR
P18–7 RTS
P18–8 CTS
P18–9 RI

P20 RS485 NON–ISOLATED CONNECTIONS
P20–1 GND
P20–2 +
P20–3 –

P21 RS485A ISOLATED CONNECTIONS
P21–1 GND
P21–2 +
P21–3 –
P21–4 GND
P21–5 +
P21–6 –



1. P19 spare connector for factory use
2. P21 RS-485 KBUS isolated connections
3. P20 RS-485 Modbus® non-isolated connections
4. P18 RS-232 connections

Figure 1-7 Communication Connections Pin Identification

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1.4 Controller Setup

After connecting the hardware, set up the controller. Enter the communication settings shown in the procedure below. Refer to the controller operation manual for detailed instructions on how to enter settings through the controller keypad.

Note: Changing the programming mode requires entering the generator set controller access code. Refer to the controller operation manual for more information.

Controller Setup Procedure

1. Go to Menu 14—Programming Mode using the controller keypad. Enter the local programming mode to allow changes to the controller communication settings.
2. Enter the controller access code when prompted by the controller.
3. Go to Menu 13—Communications.
4. Use the MENU arrow buttons to move to the Protocol Modbus® heading.
5. Enter Yes at the Modbus® Online Y/N display.
6. Choose the connection type. Choose Converter and proceed to step 8 if the controller is converting RS-232 to RS-485. Otherwise, choose Single and proceed to step 7.

   Note: The controller automatically selects RS-232 for the primary port if Converter is chosen for the connection type.

7. Choose RS-232 or RS-485 for the primary port, which is the port connected to the Modbus® master.
8. Enter the network address of the unit. Enter 1 (one) for a single connection.

   Note: Use a unique network address for each unit. Use numbers between 1 and 247. Do not use 0 (zero).

9. Select the baud rate. Choose the same baud rate for the Modbus® master and connected devices .
10. Go to Menu 14—Programming Mode again. Choose either remote programming mode, local programming mode, or programming mode off as described below:

    a. To allow the Modbus® master to read and write to the controller, choose Remote; *or*

    b. To allow only monitoring through the Modbus® connections but local programming through the controller keypad, choose Local; *or*

    c. To turn the programming mode off, allowing no controller programming from either the Modbus® master or the local keypad, choose Off.

11. Enter the controller access code when prompted by the controller.

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2.1 Introduction

This section describes supported Modbus® functions and exception codes and lists Modbus® registers and message codes.

2.2 Modbus Functions

The controller supports the Modbus® functions listed in Figure 2-1.

2.3 Exception Codes

The controller sends exception codes to the Modbus® master to indicate errors. Figure 2-2 lists the exception codes and possible causes.

⚠ WARNING

Unintended operation when applying the communications protocol can cause severe injury, death, or equipment damage. Understand the following before designing the system: (1) the system application requirements, (2) the communications protocol, and (3) the equipment manufacturers' specifications and operating limits.

Ensure the accuracy of commands that update controller settings or affect generator management or transfer switch function.

Perform control system and software qualification tests to ensure that the system operates controlled equipment safely, reliably, and as intended.

Modbus® Function	Function Name	Description
03	Read Holding Registers	Reads a single register or a range of registers.
06	Preset Single Register	Sets the value of a single register. Use this function to set all data occupying a single register.
16	Preset Multiple Registers	Sets the value of a sequence of registers. Use this function to set all data occupying multiple registers. The maximum number of registers is 16.

Figure 2-1 Supported Modbus® Functions

Exception Code	Message	Possible Causes
01	Illegal Function	The request violates the register access type. The request attempts to write registers when the controller programming mode is not set to remote. The request attempts to write too many registers using Preset Multiple Registers. The maximum number of registers is 16. The requested function is not supported.
02	Illegal Data Address	The request attempts to read too many registers. The maximum is 50. The request attempts to access a nonexistent register.
03	Illegal Data Value	The request attempts to set a register to a value outside of the allowable limits. The request attempts to set system parameters while the generator set is not in OFF or AUTO. The request specifies an incorrect number of registers while attempting to read or write data occupying a sequence of registers. The request attempts to modify digital input while the input is high. The request attempts to modify analog input while the input is out of range. The request attempts to modify preset input that cannot be changed. The request attempts to read outside a restricted block. The request attempts to define an invalid common fault. The request attempts to activate an RDO that is not software-controlled. The request attempts to start the engine while the timed run is active.

Figure 2-2 Supported Modbus® Exception Codes

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2.4 Modbus Protocol Tables

The tables in this section document the controller information available using the Modbus® protocol.

In the following tables all word (16-bit) expressions are integers unless otherwise noted and are shown in decimal notation unless otherwise noted. Hexadecimal expressions begin with 0x. Characters are in the standard 8-bit ASCII character set. Unspecified bytes are undefined, such as the high (most significant) byte of holding registers that contain byte data in the low (least significant) byte.

The tables include the following items.

Address. Modbus® registers are 16-bit registers and are numbered consecutively. Request no more than 50 registers at one time. Do not read registers past the end of the block where noted in the tables.

Parameter. The Parameter column describes the information located at the address.

Access. The Access column shows the type of access allowed to the register. RO is read only, WO is write only, and RW is read and write.

Type/Size. The Type/Size column indicates whether the parameter is a WORD, SWORD, or LONG. A WORD is a 16-bit unsigned register. If multiple registers are used, the Type/Size column shows the number of WORDS used, and the Type/Range/Units/Scale column provides a breakdown of the information available within the parameter. An SWORD is a 16-bit register that should be interpreted as a signed (two's complement) value. A LONG is a 32-bit unsigned value, and the least significant word (LSW) is first (at the lowest address).

Type/Range/Units/Scale. This column lists additional information about the register type when applicable. For example, if multiple WORDs are used, this column describes the information stored in each WORD. It also lists the units for measurements which have them, the range for valid input or output when applicable, and the the scale factor for some parameters. Bit 0 is the least significant bit and bit 15 is the most significant.

Metric or English Units. The controller display setting determines whether the units are returned or interpreted as metric or English. Read or alter this setting in register 40139.

Pipe (|). A pipe symbol (|) indicates the breakdown of data within a word, with the most significant byte first. For example, Min. | Sec means that the most significant byte contains minutes and the least significant byte contains seconds.

Example: Refer to address 40113 in the table in Section 2.4.1. The table shows that the current date starts at register 40113 and that the date requires two words, or two registers. Register 40113 contains day|month, and register 40114 contains year (two-digits)|day of the week.

Using the Read Holding Registers function to read two registers gives the following hexadecimal data:

Register 40113: 190C
Register 40114: 0102

The most significant byte of 40113 is 19 hexadecimal, which equals 25. This is the day. The least significant byte of 40113 is 0C hexadecimal, which equals 12. This is the month, December.

The most significant byte of 40114 is 01 hexadecimal, which equals 1. This gives the year, 2001. The least significant byte of 40114 is 02 hexadecimal, which equals 2. This gives the day of the week, Tuesday(0= Sunday.)

The date is December 25, 2001, a Tuesday.

Setpoints. Setpoints are non-zero values only for analog inputs. The setpoint values for the analog inputs are:

1=Low Warning
2=High Warning
3=Low Shutdown
4=High Shutdown

All other setpoint values are zero (0=none).

Strings. Strings are character data represented in standard ASCII code. Strings are written as they appear on the controller display, with spaces used to pad to the right. The first character in a string is located in the most significant byte in the first register. The last character is located in the least significant byte of the last word.

Ranges and Bits. Some registers list a range of items with a bit set for each item. Interpret the first number in the range as corresponding to Bit 0 and the last number in the range as corresponding to Bit 15.

ECM only. This notation indicates that the item is available only for generator sets equipped with engine control modules (ECMs).

2.4.1 Modbus Registers

Address	Parameter	Access	Type/Size	Type/Range/Units/Scale
40001	L1 - L2 Voltage	RO	WORD	Volts AC
40002	L2 - L3 Voltage	RO	WORD	Volts AC
40003	L3 - L1 Voltage	RO	WORD	Volts AC
40004	L1 - L0 Voltage	RO	WORD	Volts AC
40005	L2 - L0 Voltage	RO	WORD	Volts AC
40006	L3 - L0 Voltage	RO	WORD	Volts AC
40007	L1 Current	RO	WORD	Amps AC
40008	L2 Current	RO	WORD	Amps AC
40009	L3 Current	RO	WORD	Amps AC
40010	Frequency	RO	WORD	Hz x 100
40011	Total kW	RO	WORD	kW
40012	Percent Of Rated kW	RO	WORD	% Rated kW
40013	Total Power Factor	RO	SWORD	PF x 100
40014	L1 kW	RO	WORD	kW
40015	L1 Power Factor	RO	SWORD	PF x 100
40016	L2 kW	RO	WORD	kW
40017	L2 Power Factor	RO	SWORD	PF x 100
40018	L3 kW	RO	WORD	kW
40019	L3 Power Factor	RO	SWORD	PF x 100
40020	Total kVAR	RO	SWORD	kVAR
40021	L1 kVAR	RO	SWORD	kVAR
40022	L2 kVAR	RO	SWORD	kVAR
40023	L3 kVAR	RO	SWORD	kVAR
40024	Total kVA	RO	WORD	kVA
40025	L1 kVA	RO	WORD	kVA
40026	L2 kVA	RO	WORD	kVA
40027	L3 kVA	RO	WORD	kVA
40028	*Reserved for Future Use*	RO	WORD	
40029	*Reserved for Future Use*	RO	WORD	
40030	*Reserved for Future Use*	RO	WORD	
40031	*Reserved for Future Use*	RO	WORD	
40032	*Reserved for Future Use*	RO	WORD	
40033	Oil Pressure*	RO	WORD	kPa/psi
40034	Coolant Temp*	RO	SWORD	°C/° F
40035	Engine Speed*	RO	WORD	rpm
40036	Local Battery Voltage*	RO	WORD	Volts DC x 10
40037	Fuel Pressure*	RO	WORD	kPa/psi (ECM only)
40038	Fuel Temp*	RO	SWORD	°C/°F (ECM only)
40039	Fuel Rate*	RO	WORD	Liters/Hour x 100/Gallons/Hour x 100 (ECM only)
40040	Used Last Run*	RO	WORD	Liters/Gallons (ECM only)
40041	Coolant Pressure*	RO	WORD	kPa/psi (ECM only)
40042	Coolant Level*	RO	WORD	% x 10 (ECM only)
40043	Oil Temp*	RO	SWORD	°C/°F (ECM only)
40044	Oil Level*	RO	WORD	% x 10 (ECM only)
40045	Crankcase Pressure*	RO	WORD	kPa/psi (ECM only)
40046	Ambient Temp*	RO	SWORD	°C/°F (ECM only)
40047	ECM Battery Voltage*	RO	WORD	Volts DC x 10 (ECM only)
40048	ECM Status	RO	WORD	0 = ECM-Equipped, 1 = Non-ECM
*0x7FD6= data unavailable. 0x7FFF=data is out of range.				

Modbus® is a registered trademark of Schneider Electric.

Modbus Registers, continued

Address	Parameter	Access	Type/Size	Type/Range/Units/Scale
40049	*Reserved for Future Use*	RO	WORD	
40050	*Reserved for Future Use*	RO	WORD	
40051	*Reserved for Future Use*	RO	WORD	
40052	*Reserved for Future Use*	RO	WORD	
40053	*Reserved for Future Use*	RO	WORD	
40054	System Event Stack	RO	7 WORDS	Word #1: System Events 0-15 Word #2: System Events 16-31 Word #3: System Events 32-47 Word #4: System Events 48-63 Word #5: System Events 64-79 Word #6: System Events 80-95 Word #7: System Events 96-99 (bits 4-15 unused) Event exists if individual bit is set. Refer to Section 2.4.8 for message codes and descriptions.
40061	Analog Input 00(Battery voltage)*	RO	WORD	Volts DC
40062	Analog Input 01*	RO	WORD	User-Defined
40063	Analog Input 02*	RO	WORD	User-Defined
40064	Analog Input 03*	RO	WORD	User-Defined
40065	Analog Input 04*	RO	WORD	User-Defined
40066	Analog Input 05*	RO	WORD	User-Defined
40067	Analog Input 06*	RO	WORD	User-Defined
40068	Analog Input 07*	RO	WORD	User-Defined
40069	*Reserved for Additional Input*	RO	WORD	
40070	*Reserved for Additional Input*	RO	WORD	
40071	*Reserved for Additional Input*	RO	WORD	
40072	*Reserved for Additional Input*	RO	WORD	
40073	*Reserved for Additional Input*	RO	WORD	
40074	*Reserved for Additional Input*	RO	WORD	
40075	*Reserved for Additional Input*	RO	WORD	
40076	*Reserved for Additional Input*	RO	WORD	
40077	Digital Input Status	RO	2 WORDS	Word #1: Digital Inputs 0-15 Word #2: Digital Inputs 16-23 (bits 8-15 unused) Input is high if individual bit is set
40079	*Reserved for Future Use*	RO	WORD	
40080	*Reserved for Future Use*	RO	WORD	
40081	*Reserved for Future Use*	RO	WORD	
40082	*Reserved for Future Use*	RO	WORD	
40083	*Reserved for Future Use*	RO	WORD	
40084	Total Number Of Starts	RO	WORD	Starts
40085	Total Run Time Hours	RO	LONG	Hrs. x 10 (LSW First)
40087	Total Run Time Loaded Hours	RO	LONG	Hrs. x 10 (LSW First)
40089	Total Run Time Unloaded Hours	RO	LONG	Hrs. x 10 (LSW First)
40091	Total Run Time kW Hours	RO	LONG	kW Hrs. (LSW First)
40093	RTSM (Run Time Since Maintenance) Total Hours	RO	LONG	Hrs. x 10 (LSW First)
40095	RTSM Loaded Hours	RO	LONG	Hrs. x 10 (LSW First)
40097	RTSM Unloaded Hours	RO	LONG	Hrs. x 10 (LSW First)
40099	RTSM Kw Hours	RO	LONG	kW Hrs. (LSW First)
40101	Last Maintenance Date	RO	2 WORDS	Day| Month, Year
40103	Operating Days Since Maint.	RO	WORD	Days
*0x7FD6= data unavailable. 0x7FFF=data is out of range.				

Modbus Registers, continued

Address	Parameter	Access	Type/Size	Type/Range/Units/Scale
40104	Number Of Starts Since Maint.	RO	WORD	Starts
40105	Last Start Date	RO	2 WORDS	Day| Month, Year
40107	Last Start Time	RO	WORD	Hr. |Min.
40108	Last Run Length	RO	WORD	Hrs. x 10
40109	Last Run Loaded	RO	WORD	0=Unloaded, 1=Loaded
40110	Timed Run Time	RW	WORD	Hr. | Min.
40111	Timed Run Remaining	RO	WORD	Hr. | Min.
40112	Is Timed Run Active	RO	WORD	1=True, 0=False
40113	Current Date	RW	2 WORDS	Day| Month, 2 Digit Year | Day Of Week (0 = Sunday)
40115	Current Time (24 Hr. Clock)	RW	WORD	Hr.|Min.
40116	Time Delay Engine Start	RW	WORD	Min. | Sec.
40117	Time Delay Starting Aid	RW	WORD	Min. | Sec.
40118	Time Delay Crank On	RW	WORD	Min. | Sec.
40119	Time Delay Crank Pause	RW	WORD	Min. | Sec.
40120	Time Delay Engine Cooldown	RW	WORD	Min. | Sec.
40121	Time Delay Crank Cycles	RW	WORD	Cycles
40122	Time Delay Overvoltage	RW	WORD	Min. | Sec.
40123	Time Delay Undervoltage	RW	WORD	Min. | Sec.
40124	Time Delay Load Shed kW	RW	WORD	Min. | Sec.
40125	Operating Mode	RW	WORD	1=Standby, 2=Prime Power
40126	System Voltage	RW	WORD	Volts AC
40127	System Frequency	RW	WORD	Hz
40128	System Phase	RW	WORD	1=3 Phase Delta, 2=3 Phase Wye, 3=Single Phase
40129	kW Rating	RW	WORD	kW
40130	Load Shed Output	RW	WORD	% of kW Rating
40131	Overvoltage	RW	WORD	% of System Voltage
40132	Undervoltage	RW	WORD	% of System Voltage
40133	Overfrequency	RW	WORD	% of System Frequency
40134	Underfrequency	RW	WORD	% of System Frequency
40135	Overspeed	RW	WORD	Hz
40136	Battery Voltage	RW	WORD	Volts DC x 10
40137	Low Battery Voltage	RW	WORD	Volts DC x 10
40138	High Battery Voltage	RW	WORD	Volts DC x 10
40139	Metric Units	RW	WORD	1=True, 0=False
40140	NFPA 110 Defaults Enabled	RW	WORD	1=True, 0=False
40141	Rated Current	RO	WORD	Amps AC
40142	*Reserved for Future Use*	RO	WORD	
40143	*Reserved for Future Use*	RO	WORD	
40144	*Reserved for Future Use*	RO	WORD	
40145	*Reserved for Future Use*	RO	WORD	
40146	*Reserved for Future Use*	RO	WORD	
40147	Final Assembly Date	RO	2 WORDS	Day| Month, Year
40149	Final Assembly Clock No.	RO	LONG	99999 Max (LSW First)
40151	Total Operating Days	RO	WORD	Days
40152	Model No.	RO	13 WORDS	26 Character String
40165	Spec. No.	RO	8 WORDS	16 Character String
40173	Genset Serial No.	RO	10 WORDS	20 Character String
40183	Alternator Part No.	RO	10 WORDS	20 Character String
*0x7FD6= data unavailable. 0x7FFF=data is out of range.				

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Modbus Registers, continued

Address	Parameter	Access	Type/Size	Type/Range/Units/Scale
40193	Engine Part Number	RO	10 WORDS	20 Character String
40203	Control No.	RO	LONG	(LSW First)
40205	Code Version	RO	3 WORDS	6 Character String
40208	Setup Lock	RO	WORD	1=Locked, 0=Unlocked
40209	Engine Model Number	RO	4 WORDS	8 Character String (ECM only)
40213	Engine Serial Number	RO	5 WORDS	10 Character String (ECM only)
40218	Unit Number	RO	5 WORDS	10 Character String (ECM only)
40223	ECM Serial Number	RO	4 WORDS	8 Character String (ECM only)
*0x7FD6= data unavailable. 0x7FFF=data is out of range.				

2.4.2 Digital Inputs 1-21 Setup

Address	Parameter	Access	Type/Size	Type/Range/Units/Scale
40227	Digital Input 01	RW	13 WORDS PER INPUT	For each digital input: Word #1: Enabled (1=True, 0=False) | Function Code Word #2: Inhibit Time (Min.|Sec.) Word #3: Delay Time (Min.|Sec.) Words #4–13: 10 words for 20-character description string Refer to Section 2.4.9 for digital input function codes.
40240	Digital Input 02	RW	13 WORDS	
40253	Digital Input 03	RW	13 WORDS	
40266	Digital Input 04	RW	13 WORDS	
40279	Digital Input 05	RW	13 WORDS	
40292	Digital Input 06	RW	13 WORDS	
40305	Digital Input 07	RW	13 WORDS	
40318	Digital Input 08	RW	13 WORDS	
40331	Digital Input 09	RW	13 WORDS	
40344	Digital Input 10	RW	13 WORDS	
40357	Digital Input 11	RW	13 WORDS	
40370	Digital Input 12	RW	13 WORDS	
40383	Digital Input 13	RW	13 WORDS	
40396	Digital Input 14	RW	13 WORDS	
40409	Digital Input 15	RW	13 WORDS	
40422	Digital Input 16	RW	13 WORDS	
40435	Digital Input 17	RW	13 WORDS	
40448	Digital Input 18	RW	13 WORDS	
40461	Digital Input 19	RW	13 WORDS	
40474	Digital Input 20	RW	13 WORDS	
40487	Digital Input 21	RW	13 WORDS	
Note: *Cannot read past end of block*				

2.4.3 Analog Inputs

Address	Parameter	Access	Type/Size	Type/Range/Units/Scale
Analog Inputs 1-7 Setup		RO	16 WORDS PER INPUT	For each analog input: Word #1: Warning/Shutdown Enable [bits 8,9] (1=True, 0=False) | Inhibit Time (Sec.) Word #2: Warn Time (Sec) | Sdwn Time (Sec.) Word #3: Lower Warn Limit Word #4: Upper Warn Limit Word #5: Lower Sdwn Limit Word #6: Upper Sdwn Limit Words #7-16: 10 words for 20-character description string
40500	Analog Input 01 *(ECM only)*	RO	16 WORDS	
40516	Analog Input 02 *(ECM only)*	RO	16 WORDS	
40532	Analog Input 03	RO	16 WORDS	
40548	Analog Input 04	RO	16 WORDS	
40564	Analog Input 05	RO	16 WORDS	
40580	Analog Input 06	RO	16 WORDS	
40596	Analog Input 07	RO	16 WORDS	
Note: *Cannot read past end of block*				
Analog Inputs 8-15 Setup		RO	16 WORDS PER INPUT	
40612	*Reserved for additional input*	RO	16 WORDS	
40628	*Reserved for additional input*	RO	16 WORDS	
40644	*Reserved for additional input*	RO	16 WORDS	
40660	*Reserved for additional input*	RO	16 WORDS	
40676	*Reserved for additional input*	RO	16 WORDS	
40692	*Reserved for additional input*	RO	16 WORDS	
40708	*Reserved for additional input*	RO	16 WORDS	
40724	*Reserved for additional input*	RO	16 WORDS	
Note: *Cannot read past end of block*				

2.4.4 Define/Inspect Defined Common Faults (DCFs)

Address	Description	Access	Type/Size	Type/Range/Units/Scale
40740	Emergency Stop	RW	1 WORD per DCF	For all DCFs: Selected (1=True, 0=False) | Setpoint (Analog inputs only)
40741	Overspeed	RW	1 WORD	
40742	Overcrank	RW	1 WORD	
40743	High Coolant Temp Shutdown	RW	1 WORD	
40744	Oil Pressure Shutdown	RW	1 WORD	
40745	Low Coolant Temp	RW	1 WORD	**Note:** DCF and RDO on ECM only
40746	Low Fuel	RW	1 WORD	
40747	High Coolant Temp Warning	RW	1 WORD	
40748	Oil Pressure Warning	RW	1 WORD	
40749	Master Not In Auto	RW	1 WORD	
40750	NFPA 110 Fault	RW	1 WORD	
40751	Low Battery Voltage	RW	1 WORD	
40752	High Battery Voltage	RW	1 WORD	
40753	Battery Charger Fault	RW	1 WORD	
40754	System Ready	RW	1 WORD	
40755	Loss of ECM Comm	RW	1 WORD	**Note:** DCF and RDO on ECM only
40756	No Oil Pressure Signal	RW	1 WORD	
40757	High Oil Temp Shutdown	RW	1 WORD	
40758	No Coolant Temp Signal	RW	1 WORD	
40759	Low Coolant Level	RW	1 WORD	
40760	Speed Sensor Fault	RW	1 WORD	
40761	Locked Rotor	RW	1 WORD	
40762	Master Switch Error	RW	1 WORD	
40763	Master Switch Open	RW	1 WORD	
40764	Master Switch Off	RW	1 WORD	
40765	AC Sensing Loss	RW	1 WORD	
40766	Overvoltage	RW	1 WORD	
40767	Undervoltage	RW	1 WORD	
40768	Weak Battery	RW	1 WORD	
40769	Overfrequency	RW	1 WORD	
40770	Underfrequency	RW	1 WORD	
40771	Load Shed kW Overload	RW	1 WORD	
40772	Load Shed kW Underfrequency	RW	1 WORD	
40773	Over Current	RW	1 WORD	
40774	EPS Supplying Load	RW	1 WORD	
40775	Internal Fault	RW	1 WORD	
40776	Engine Cooldown Delay	RW	1 WORD	
40777	Engine Start Delay	RW	1 WORD	
40778	Starting Aid	RW	1 WORD	
40779	Generator Running	RW	1 WORD	
40780	Air Damper Control	RW	1 WORD	
40781	Ground Fault	RW	1 WORD	
40782	EEPROM Write Failure	RW	1 WORD	
40783	Critical Overvoltage	RW	1 WORD	
40784	Alternator Protect Shutdown	RW	1 WORD	
40785	Air Damper Indicator	RW	1 WORD	
40786	Digital Input 01	RW	1 WORD	
40787	Digital Input 02	RW	1 WORD	

Define/Inspect Defined Common Faults, continued

Address	Description	Access	Type/Size	Type/Range/Units/Scale
40788	Digital Input 03	RW	1 WORD	
40789	Digital Input 04	RW	1 WORD	
40790	Digital Input 05	RW	1 WORD	
40791	Digital Input 06	RW	1 WORD	
40792	Digital Input 07	RW	1 WORD	
40793	Digital Input 08	RW	1 WORD	
40794	Digital Input 09	RW	1 WORD	
40795	Digital Input 10	RW	1 WORD	
40796	Digital Input 11	RW	1 WORD	
40797	Digital Input 12	RW	1 WORD	
40798	Digital Input 13	RW	1 WORD	
40799	Digital Input 14	RW	1 WORD	
40800	Digital Input 15	RW	1 WORD	
40801	Digital Input 16	RW	1 WORD	
40802	Digital Input 17	RW	1 WORD	
40803	Digital Input 18	RW	1 WORD	
40804	Digital Input 19	RW	1 WORD	
40805	Digital Input 20	RW	1 WORD	
40806	Digital Input 21	RW	1 WORD	
40807	Analog Input 01	RW	1 WORD	**Note:** Non-zero setpoint values apply only to Analog Inputs 1–7.
40808	Analog Input 02	RW	1 WORD	
40809	Analog Input 03	RW	1 WORD	
40810	Analog Input 04	RW	1 WORD	
40811	Analog Input 05	RW	1 WORD	
40812	Analog Input 06	RW	1 WORD	
40813	Analog Input 07	RW	1 WORD	
40814	*Reserved for Additional Input*	RW	1 WORD	
40815	*Reserved for Additional Input*	RW	1 WORD	
40816	*Reserved for Additional Input*	RW	1 WORD	
40817	*Reserved for Additional Input*	RW	1 WORD	
40818	*Reserved for Additional Input*	RW	1 WORD	
40819	*Reserved for Additional Input*	RW	1 WORD	
40820	*Reserved for Additional Input*	RW	1 WORD	
40821	*Reserved for Additional Input*	RW	1 WORD	
40822 through 40837	*Reserved for Future Use*			
Note: *Cannot read past end of block*				

2.4.5 Relay Driver Outputs (RDOs)

Define/Inspect RDO Status

Address	Parameter	Access	Type/Size	Type/Range/Units/Scale
40838	RDO Status - RDO1 -> RDO16	RW	1 WORD	Output is high if individual bit is set. Bit 0 = RDO 1
40839	RDO Status - RDO17 -> RDO31	RW	1 WORD	Output is high if individual bit is set. Bit 0 = RDO 17
Note: *Cannot read past end of block*				

Define/Inspect RDOs

Address	Parameter	Access	Type/Size	Type/Range/Units/Scale
40840	Relay Driver Output 01	RW	1 WORD	For RDOs: Message Code | Setpoint **Note:** Non-zero setpoint values apply only to RDOs assigned to analog inputs. See Section 2.4.8 for message codes.
40841	Relay Driver Output 02	RW	1 WORD	
40842	Relay Driver Output 03	RW	1 WORD	
40843	Relay Driver Output 04	RW	1 WORD	
40844	Relay Driver Output 05	RW	1 WORD	
40845	Relay Driver Output 06	RW	1 WORD	
40846	Relay Driver Output 07	RW	1 WORD	
40847	Relay Driver Output 08	RW	1 WORD	
40848	Relay Driver Output 09	RW	1 WORD	
40849	Relay Driver Output 10	RW	1 WORD	
40850	Relay Driver Output 11	RW	1 WORD	
40851	Relay Driver Output 12	RW	1 WORD	
40852	Relay Driver Output 13	RW	1 WORD	
40853	Relay Driver Output 14	RW	1 WORD	
40854	Relay Driver Output 15	RW	1 WORD	
40855	Relay Driver Output 16	RW	1 WORD	
40856	Relay Driver Output 17	RW	1 WORD	
40857	Relay Driver Output 18	RW	1 WORD	
40858	Relay Driver Output 19	RW	1 WORD	
40859	Relay Driver Output 20	RW	1 WORD	
40860	Relay Driver Output 21	RW	1 WORD	
40861	Relay Driver Output 22	RW	1 WORD	
40862	Relay Driver Output 23	RW	1 WORD	
40863	Relay Driver Output 24	RW	1 WORD	
40864	Relay Driver Output 25	RW	1 WORD	
40865	Relay Driver Output 26	RW	1 WORD	
40866	Relay Driver Output 27	RW	1 WORD	
40867	Relay Driver Output 28	RW	1 WORD	
40868	Relay Driver Output 29	RW	1 WORD	
40869	Relay Driver Output 30	RW	1 WORD	
40870	Relay Driver Output 31	RW	1 WORD	
Note: *Cannot read past end of block*				

2.4.6 Event History

Address	Parameter	Access	Type/Size	Type/Range/Units/Scale
40871	Event History, Page 1 (1-10)	RO	40 WORDS	For event histroy: Message code|Setpoint* Hr.|Min. Day|Month, Year See Section 2.4.8 for message codes
40911	Event History, Page 2 (11-20)	RO	40 WORDS	
40951	Event History, Page 3 (21-30)	RO	40 WORDS	
40991	Event History, Page 4 (31-40)	RO	40 WORDS	
41031	Event History, Page 5 (41-50)	RO	40 WORDS	
41071	Event History, Page 6 (51-60)	RO	40 WORDS	
41111	Event History, Page 7 (61-70)	RO	40 WORDS	
41151	Event History, Page 8 (71-80)	RO	40 WORDS	
41191	Event History, Page 9 (81-90)	RO	40 WORDS	
41231	Event History, Page 10 (91-100)	RO	40 WORDS	

Note: *Cannot read past end of block.*
Note: *Message code = 0xFFat end of history.*

* Analog Inputs only

2.4.7 Miscellaneous Strings

Address	Parameter	Access	Type/Size	Type/Range/Units/Scale
41271	Designation	RW	5 WORDS	9-Character String
41276	Load	RW	10 WORDS	20-Character String
41286	Location	RW	10 WORDS	20-Character String
Note: *Cannot read past end of block*				
41296	*Reserved for Future Use*	RO	WORD	
41297	*Reserved for Future Use*	RO	WORD	
41298	*Reserved for Future Use*	RO	WORD	
41299	*Reserved for Future Use*	RO	WORD	
41300	*Reserved for Future Use*	RO	WORD	
41301	*Reserved for Future Use*	RO	WORD	
41302	*Reserved for Future Use*	RO	WORD	
41303	*Reserved for Future Use*	RO	WORD	
41304	*Reserved for Future Use*	RO	WORD	
41305	*Reserved for Future Use*	RO	WORD	
Note: *Cannot read past end of block*				
41306	Start Timed Run	WO	WORD	1=Start, 0 =No Start
41307	Stop Timed Run	WO	WORD	1=Stop, 0 = No Stop
41308	Reset Maintenance Records	WO	WORD	1=Reset, 0 =No Reset

2.4.8 Message Codes: Event History, Common Fault, and RDO Byte Summary

Code	Display Message
0	Emergency Stop
1	Overspeed
2	Overcrank
3	High Coolant Temp Shutdown
4	Oil Pressure Shutdown
5	Low Coolant Temp **Note:** DCF and RDO on ECM only
6	Low Fuel
7	High Coolant Temp Warning
8	Oil Pressure Warning
9	Master Not In Auto
10	NFPA 110 Fault
11	Low Battery Voltage
12	High Battery Voltage
13	Battery Charger Fault
14	System Ready
15	Loss of ECM Comm **Note:** DCF and RDO on ECM only
16	No Oil Pressure Signal
17	High Oil Temp Shutdown
18	No Coolant Temp Signal
19	Low Coolant Level
20	Speed Sensor Fault
21	Locked Rotor
22	Master Switch Error
23	Master Switch Open
24	Master Switch Off
25	AC Sensing Loss
26	Overvoltage
27	Undervoltage
28	Weak Battery
29	Overfrequency
30	Underfrequency
31	Load Shed kW Overload
32	Load Shed kW Underfrequency
33	Over Current
34	Emergency power supply (EPS) Supplying Load
35	Internal Fault
36	Engine Cooldown Delay
37	Engine Start Delay
38	Starting Aid
39	Generator Running
40	Air Damper Control
41	Ground Fault
42	EEPROM Write Failure
43	Critical Overvoltage
44	Alternator Protect Shutdown
45	Air Damper Indicator

Code	Display Message
46	Digital Input 01
47	Digital Input 02
48	Digital Input 03
49	Digital Input 04
50	Digital Input 05
51	Digital Input 06
52	Digital Input 07
53	Digital Input 08
54	Digital Input 09
55	Digital Input 10
56	Digital Input 11
57	Digital Input 12
58	Digital Input 13
59	Digital Input 14
60	Digital Input 15
61	Digital Input 16
62	Digital Input 17
63	Digital Input 18
64	Digital Input 19
65	Digital Input 20
66	Digital Input 21
67	Analog Input 01
68	Analog Input 02
69	Analog Input 03
70	Analog Input 04
71	Analog Input 05
72	Analog Input 06
73	Analog Input 07
74–81	*Reserved for Future Use*
Note:	If the digital or analog input descriptions are reprogrammed, the display reflects the programmed description rather than the default descriptions D01–D21 or A01–A07.

The following system message codes cannot be defined as common faults but can be assigned to RDOs and are referenced in the event stack and history.

Message Code	Description
82	Defined Common Fault
83	Software-Controlled RDO #1
84	Software-Controlled RDO #2
85	Software-Controlled RDO #3
86	Software-Controlled RDO #4
87–98	*Reserved*

The following system message codes cannot be defined as common faults or assigned to RDOs but can be referenced in the event stack and history.

Message Code	Description
99	Genset Parameter Warning
100	Genset S/N Mismatch Warning
101	Genset S/N Mismatch Shutdown

2.4.9 Function Codes: Digital Auxiliary Input

Code	Name	Notes
1	Warning	
2	Shutdown Type A	
3	Shutdown Type B	
4	Voltage Raise	
5	Voltage Lower	
6	Var Pf Mode	
7	Remote Shutdown	
8	Remote Reset	
9	Air Damper	
10	Low Fuel	
11	Field Over Voltage	
12	Idle Mode	*ECM only*
13	Battle Switch	
14	Ground Fault	
15	Bat Chgr Fault	
16	High Oil Temp	
17	Low Coolant Lvl	
18	Low Coolant Temp	*ECM only. Not user-assignable.*

Notes

Appendix A Abbreviations

The following list contains abbreviations that may appear in this publication.

A, amp	ampere
ABDC	after bottom dead center
AC	alternating current
A/D	analog to digital
ADC	analog to digital converter
adj.	adjust, adjustment
ADV	advertising dimensional drawing
AHWT	anticipatory high water temperature
AISI	American Iron and Steel Institute
ALOP	anticipatory low oil pressure
alt.	alternator
Al	aluminum
ANSI	American National Standards Institute (formerly American Standards Association, ASA)
AO	anticipatory only
API	American Petroleum Institute
approx.	approximate, approximately
AR	as required, as requested
AS	as supplied, as stated, as suggested
ASE	American Society of Engineers
ASME	American Society of Mechanical Engineers
assy.	assembly
ASTM	American Society for Testing Materials
ATDC	after top dead center
ATS	automatic transfer switch
auto.	automatic
aux.	auxiliary
A/V	audiovisual
avg.	average
AVR	automatic voltage regulator
AWG	American Wire Gauge
AWM	appliance wiring material
bat.	battery
BBDC	before bottom dead center
BC	battery charger, battery charging
BCA	battery charging alternator
BCI	Battery Council International
BDC	before dead center
BHP	brake horsepower
blk.	black (paint color), block (engine)
blk. htr.	block heater
BMEP	brake mean effective pressure
bps	bits per second
br.	brass
BTDC	before top dead center
Btu	British thermal unit
Btu/min.	British thermal units per minute
C	Celsius, centigrade
cal.	calorie
CARB	California Air Resources Board
CB	circuit breaker
cc	cubic centimeter
CCA	cold cranking amps
ccw.	counterclockwise
CEC	Canadian Electrical Code
cfh	cubic feet per hour
cfm	cubic feet per minute
CG	center of gravity
CID	cubic inch displacement
CL	centerline
cm	centimeter
CMOS	complementary metal oxide substrate (semiconductor)
cogen.	cogeneration
Com	communications (port)
conn.	connection
cont.	continued
CPVC	chlorinated polyvinyl chloride
crit.	critical
CRT	cathode ray tube
CSA	Canadian Standards Association
CT	current transformer
Cu	copper
cu. in.	cubic inch
cw.	clockwise
CWC	city water-cooled
cyl.	cylinder
D/A	digital to analog
DAC	digital to analog converter
dB	decibel
dBA	decibel (A weighted)
DC	direct current
DCR	direct current resistance
deg., °	degree
dept.	department
dia.	diameter
DI/EO	dual inlet/end outlet
DIN	Deutsches Institut fur Normung e. V. (also Deutsche Industrie Normenausschuss)
DIP	dual inline package
DPDT	double-pole, double-throw
DPST	double-pole, single-throw
DS	disconnect switch
DVR	digital voltage regulator
E, emer.	emergency (power source)
EDI	electronic data interchange
EFR	emergency frequency relay
e.g.	for example (*exempli gratia)*
EG	electronic governor
EGSA	Electrical Generating Systems Association
EIA	Electronic Industries Association
EI/EO	end inlet/end outlet
EMI	electromagnetic interference
emiss.	emission
eng.	engine
EPA	Environmental Protection Agency
EPS	emergency power system
ER	emergency relay
ES	engineering special, engineered special
ESD	electrostatic discharge
est.	estimated
E-Stop	emergency stop
etc.	et cetera (and so forth)
exh.	exhaust
ext.	external
F	Fahrenheit, female
fglass.	fiberglass
FHM	flat head machine (screw)
fl. oz.	fluid ounce
flex.	flexible
freq.	frequency
FS	full scale
ft.	foot, feet
ft. lbs.	foot pounds (torque)
ft./min.	feet per minute
g	gram
ga.	gauge (meters, wire size)
gal.	gallon
gen.	generator
genset	generator set
GFI	ground fault interrupter
GND, ⏚	ground
gov.	governor
gph	gallons per hour
gpm	gallons per minute
gr.	grade, gross
GRD	equipment ground
gr. wt.	gross weight
H x W x D	height by width by depth
HC	hex cap
HCHT	high cylinder head temperature
HD	heavy duty
HET	high exhaust temperature
hex	hexagon
Hg	mercury (element)
HH	hex head
HHC	hex head cap
HP	horsepower
hr.	hour
HS	heat shrink
hsg.	housing
HVAC	heating, ventilation, and air conditioning
HWT	high water temperature
Hz	hertz (cycles per second)
IC	integrated circuit
ID	inside diameter, identification
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IMS	improved motor starting
in.	inch
in. H_2O	inches of water
in. Hg	inches of mercury
in. lbs.	inch pounds
Inc.	incorporated
ind.	industrial
int.	internal
int./ext.	internal/external
I/O	input/output
IP	iron pipe
ISO	International Organization for Standardization
J	joule
JIS	Japanese Industry Standard
k	kilo (1000)
K	kelvin
kA	kiloampere
KB	kilobyte (2^{10} bytes)

kg	kilogram
kg/cm^2	kilograms per square centimeter
kgm	kilogram-meter
kg/m^3	kilograms per cubic meter
kHz	kilohertz
kJ	kilojoule
km	kilometer
kOhm, kΩ	kilo-ohm
kPa	kilopascal
kph	kilometers per hour
kV	kilovolt
kVA	kilovolt ampere
kVAR	kilovolt ampere reactive
kW	kilowatt
kWh	kilowatt-hour
kWm	kilowatt mechanical
L	liter
LAN	local area network
L x W x H	length by width by height
lb.	pound, pounds
lbm/ft^3	pounds mass per cubic feet
LCB	line circuit breaker
LCD	liquid crystal display
ld. shd.	load shed
LED	light emitting diode
Lph	liters per hour
Lpm	liters per minute
LOP	low oil pressure
LP	liquefied petroleum
LPG	liquefied petroleum gas
LS	left side
L_{wa}	sound power level, A weighted
LWL	low water level
LWT	low water temperature
m	meter, milli (1/1000)
M	mega (10^6 when used with SI units), male
m^3	cubic meter
m^3/min.	cubic meters per minute
mA	milliampere
man.	manual
max.	maximum
MB	megabyte (2^{20} bytes)
MCM	one thousand circular mils
MCCB	molded-case circuit breaker
meggar	megohmmeter
MHz	megahertz
mi.	mile
mil	one one-thousandth of an inch
min.	minimum, minute
misc.	miscellaneous
MJ	megajoule
mJ	millijoule
mm	millimeter
mOhm, mΩ	milliohm
MOhm, MΩ	megohm
MOV	metal oxide varistor
MPa	megapascal
mpg	miles per gallon
mph	miles per hour
MS	military standard
m/sec.	meters per second
MTBF	mean time between failure
MTBO	mean time between overhauls
mtg.	mounting
MW	megawatt
mW	milliwatt
μF	microfarad
N, norm.	normal (power source)
NA	not available, not applicable
nat. gas	natural gas
NBS	National Bureau of Standards
NC	normally closed
NEC	National Electrical Code
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association
Nm	newton meter
NO	normally open
no., nos.	number, numbers
NPS	National Pipe, Straight
NPSC	National Pipe, Straight-coupling
NPT	National Standard taper pipe thread per general use
NPTF	National Pipe, Taper-Fine
NR	not required, normal relay
ns	nanosecond
OC	overcrank
OD	outside diameter
OEM	original equipment manufacturer
OF	overfrequency
opt.	option, optional
OS	oversize, overspeed
OSHA	Occupational Safety and Health Administration
OV	overvoltage
oz.	ounce
p., pp.	page, pages
PC	personal computer
PCB	printed circuit board
pF	picofarad
PF	power factor
ph., ∅	phase
PHC	Phillips head crimptite (screw)
PHH	Phillips hex head (screw)
PHM	pan head machine (screw)
PLC	programmable logic control
PMG	permanent-magnet generator
pot	potentiometer, potential
ppm	parts per million
PROM	programmable read-only memory
psi	pounds per square inch
pt.	pint
PTC	positive temperature coefficient
PTO	power takeoff
PVC	polyvinyl chloride
qt.	quart
qty.	quantity
R	replacement (emergency) power source
rad.	radiator, radius
RAM	random access memory
RDO	relay driver output
ref.	reference
rem.	remote
RFI	radio frequency interference
RH	round head
RHM	round head machine (screw)
rly.	relay
rms	root mean square
rnd.	round
ROM	read only memory
rot.	rotate, rotating
rpm	revolutions per minute
RS	right side
RTV	room temperature vulcanization
SAE	Society of Automotive Engineers
scfm	standard cubic feet per minute
SCR	silicon controlled rectifier
s, sec.	second
SI	*Systeme international d'unites,* International System of Units
SI/EO	side in/end out
sil.	silencer
SN	serial number
SPDT	single-pole, double-throw
SPST	single-pole, single-throw
spec, specs	specification(s)
sq.	square
sq. cm	square centimeter
sq. in.	square inch
SS	stainless steel
std.	standard
stl.	steel
tach.	tachometer
TD	time delay
TDC	top dead center
TDEC	time delay engine cooldown
TDEN	time delay emergency to normal
TDES	time delay engine start
TDNE	time delay normal to emergency
TDOE	time delay off to emergency
TDON	time delay off to normal
temp.	temperature
term.	terminal
TIF	telephone influence factor
TIR	total indicator reading
tol.	tolerance
turbo.	turbocharger
typ.	typical (same in multiple locations)
UF	underfrequency
UHF	ultrahigh frequency
UL	Underwriter's Laboratories, Inc.
UNC	unified coarse thread (was NC)
UNF	unified fine thread (was NF)
univ.	universal
US	undersize, underspeed
UV	ultraviolet, undervoltage
V	volt
VAC	volts alternating current
VAR	voltampere reactive
VDC	volts direct current
VFD	vacuum fluorescent display
VGA	video graphics adapter
VHF	very high frequency
W	watt
WCR	withstand and closing rating
w/	with
w/o	without
wt.	weight
xfmr	transformer

Appendix B Noise and Wiring Practices

Electrical noise is an unwanted electrical signal that can cause errors in measurement, loss of control, malfunctions in microprocessor-based control systems, errors in data transfer between systems over communication links, or reductions in system performance.

Good system design and wiring practices can minimize noise levels and the effects of noise.

Noise, because of its random nature, is typically characterized by frequency distribution. Many noise sources are broad-spectrum, that is, they produce many frequencies distributed over a wide range. Broad-spectrum noise is particularly troublesome because it cannot be removed easily by filtering, and because it can affect a variety of systems in unpredictable ways. One common source of broad-spectrum noise is a switch, which can produce voltage and current changes when an electrical circuit is connected and disconnected.

Coupling is the transfer of signals between separate circuits. Signals from one circuit become noise in another. The amount of coupling is cumulative and is a function of the proximity of the circuits, their orientation, exposed area, and length of run. Minimize coupling by the following:

- Isolating circuits from each other by using separate raceways or conduit
- Separating circuits from each other by locating them as far apart as possible
- Enclosing circuits with a grounded metallic shield such as an enclosure, metallic conduit, or cable shield
- Running conductors perpendicular, rather than parallel, to each other
- Running wires loosely and randomly rather than bundling them tightly together
- Twisting a circuit's wires together in pairs

In an industrial environment, there are typically five types of circuits with different noise emission and rejection capabilities. The five types of circuits are as follows:

- **High-Power Distribution.** Circuits to high-power loads such as large electric motors and heaters can emit transient high levels of broad-spectrum noise. Loads on high-power distribution circuits are nearly immune to noise.
- **General Purpose Power Distribution.** Circuits to medium-power loads such as lighting, offices, light-duty equipment, and small motors such as fans and pumps can emit transient, medium levels of broad-spectrum noise. Some electronic equipment, such as computers, emits constant levels of broad-spectrum noise in addition to transient broad-spectrum noise. Loads on general-purpose circuits, except for sensitive electronic equipment, are nearly immune to noise.
- **Control.** Control circuits include DC circuits and 120 VAC maximum AC circuits that operate at a low power level (less than 1 W). Typical circuits include circuits to switches, actuators, and dry-contact relays, including the generator engine-start circuit. Control circuits emit transient low levels of broad-spectrum noise and are fairly immune to noise.
- **Analog.** Analog circuits are low-voltage DC circuits that convey measurement information as relatively small changes in current or voltage. Typical circuits include those connected to the controller's analog inputs. Analog circuits create the lowest noise levels and are the most sensitive to noise.
- **Communication and Signaling.** Communication and signaling circuits are low-voltage circuits that convey information. Typical circuits include RS-232 and RS-485 serial communication lines, telephone lines, and computer network lines. These circuits create noise with frequencies related to the communication signaling rate. These circuits have some level of built-in noise immunity. Typical systems will detect or correct errors caused by noise below certain levels, but with a corresponding reduction in the data transfer rate.

When planning an installation, separate all of these types of circuits as much as possible to minimize the hazards of insulation failure, accidental miswiring, and noise coupling. For best results, install control circuits, analog circuits, and communication and signaling circuits separately. Combining circuit types is unavoidable in the controller's enclosure and some other areas.

Note: It is very important to isolate high- and medium-power circuits in raceways or conduit separate from the other types of circuits.

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