REM 543 MODBUS AUTOMATION GUIDE

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Contents

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Section 1 - Introduction

With the introduction of a microprocessor based protective relay, today's relay protection engineer must be familiar with topics outside of traditional relaying schemes. It is intended that the production of this manual will enable the relay engineer to understand the principles of a microprocessor-based relay's inclusion in a substation automation project.

Substation automation is heavily dependent upon integration of the appropriate components to allow reporting of metering and event data. The foundation of a successful automation solution is thorough engineering of a communication system. The REM 543 is the culmination of intensive design efforts and relaying experience, which combine protective relaying and communication capabilities at an economical price. Through the evolution of protective relays, it was decided that a special manual needed to serve today's power automation specialist.

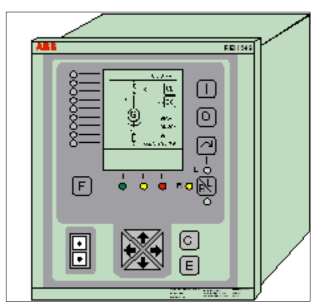
This manual is intended to give the reader an in-depth explanation of the communication interfaces available with the REM 543. Successful integration of microprocessor based relays like the REM depends on not just understanding the bits and bytes of a particular protocol. It is the inherent understanding and application of such esoteric topics as physical interfaces, real time control, manufacturer independent device integration, throughput vs. speed of communication, … which influences the success of an automation project.

In many cases the individual performing the SCADA integration is not a relay protection engineer. This manual departs from the standard type of relay manual in that each data type is explained and each bit, byte and word meaning is explained. Several application examples are given within each section. A description of each protocol command is illustrated for the benefit of the user. Appendices are included detailing application notes, which augment the text. An explanation of the product's physical interfaces and the connectivity required is explored in depth. Explanations of register's uses to increase overall throughput are also explored. Throughput is always an issue when the system is commissioned. Understanding ways to improve the system data update is explained.
Several steps are required to permit successful communication between devices:

1. Identification of the hardware components (Section 2)
2. Correct physical connection between devices (Section 3).
3. Correct device configuration of port protocol and operation parameters (Section 4).
4. Generation and interpretation of the protocol command strings (Section 5).

The following sections shall explore the following procedures in depth when establishing a communication automation system, utilizing the REM 543.

Figure 1-1 shows the general look of the REM 543 as viewed from the front.



REM 543

Figure 1-1. REM 543 Unit Physical Characteristics

The products differentiate themselves as listed in Table 1-1. Table 1-1 lists the available protocols within the relays. SPA protocol is a standard protocol within the REM. CAPTOOLS uses this interface to attach to the REM 543 when changing settings or obtaining the firmware of the unit. SPA is an asynchronous byte oriented protocol.

The programming software CAP 501 or CAP 505 allows configuration of the relay through a port on the units. SPA is available through an RS 232 or RS 485 port on the REM 543.

Modbus is an industrial de-facto standard protocol, which has been widely embraced by the utility industry. Modbus has two emulation's, RTU, which is a synchronous protocol and ASCII which is an asynchronous protocol. Modbus uses only one command set, but two emulation's. Modbus strengths are that it uses a standard RS 232 or RS 485 interface to interconnect nodes on a network.

LON is a hybrid protocol and is also used as a high speed data network and configuration network. Lon uses a proprietary chipset and physical interface to obtain rapid data communications and response. It is supported by some models of the REM 543. The interface offers greater speed and communication features than Modbus.

Within this document, only **Modbus,** protocol shall be covered in depth. If other protocols within the REM wish to be explored, please consult the REM 543 documentation.

Section 2 – Product Identification and Physical Port Characteristics

The communication connector at the front of the unit (near the target LED's) communicates to the CAP 501 or CAP 505 configuration program. This communication port is referred to as the OPTICAL PORT. The protocol emulated through this front port is an addressable emulation of SPA COM. Modbus is included with each of the REM 543 units and is available on the REAR PORT, labeled X3.2.

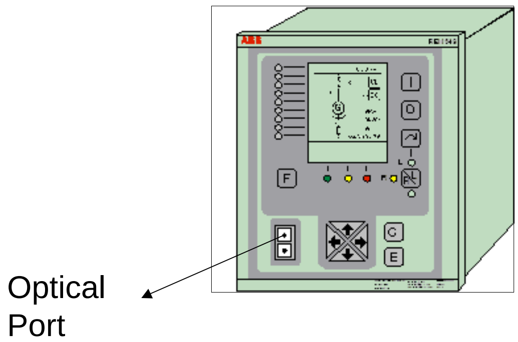


Figure 2-1. Optical Port Location

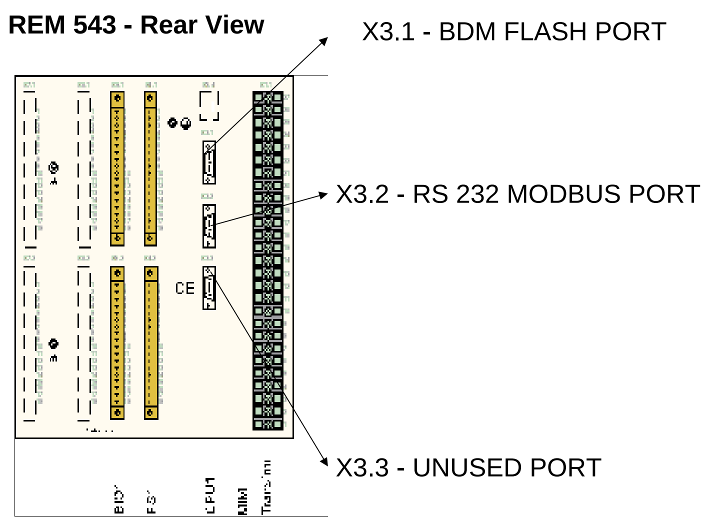


Figure 2-2. Physical Optional Communication Card Port Locations

The REM 543 differ in physical appearance. The communication cards inserted within the unit also differ in form, fit and construction. A typical REM 543 communication card is illustrated in Figure 2-3 of this document. As shown, the REM 543 has two physical interface connectors built onto the unit.

The REM 543 is a pre-configured device. A BASE UNIT NUMBER is preprogrammed with a configuration which was previously downloaded to the BASE UNIT. The REM 543 is identified by the SERIAL NUMBER available on the unit as well as the BASE HARDWARE NUMBER and USSAP Catalog Number. The two most important numbers on the device are:

1. SERIAL NUMBER
2. USSAP CATALOG NUMBER

When accessing US technical support for assistance, please have these two numbers available when calling. Additional numbers which may be helpful to have when requesting support are, BASE HARDWARE NUMBER and CPU SOFTWARE NUMBERS.

Unit Verification

There are several ways to identify the REM 543 units. Since all preconfigured REM 543's include MODBUS communications, it is important to obtain the essential identification numbers for product identification and support. Two important numbers to obtain are the CATALOG NUMBER and the SERIAL NUMBER.

Catalog Number Identification

As illustrated in Figure 2-3, the CATALOG NUMBER is found on a label located on the side of the unit. Table 2-1 lists the CATALOG NUMBER of the REM 543. The right most digit in the CATALOG NUMBER determines the configuration of the REM as being a MODEL 1, MODEL 2, or MODEL 3.

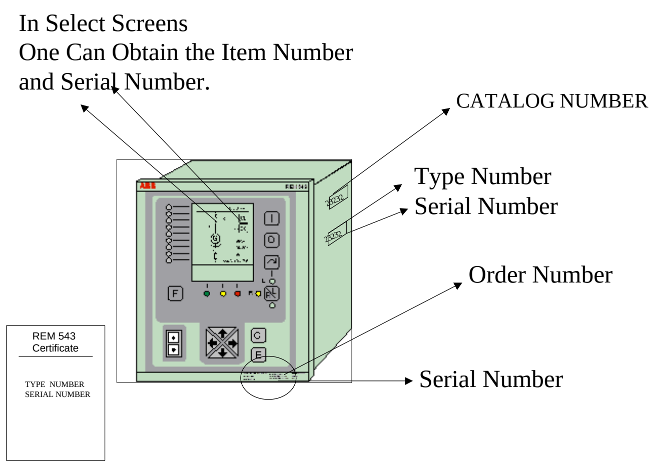
Table 2-1. Catalog Number REM 543 Assignment

Model	Catalog Number	Control Voltage	RTD Motor Windings	RTD Motor Bearings	RTD Load Bearings	RTD Ambient
1	272M0301	24-60 Vdc	3	2	2	1
1	272M0401	110-240 Vac/dc	3	2	2	1
2	272M0302	24-60 Vdc	6	2	0	0
2	272M0403	110-240 Vac/dc	6	2	0	0
3	272M0303	24-60 Vdc	0	0	0	0
3	272M0403	110-240 Vac/dc	0	0	0	0

Base Hardware Number and Serial Number Idenfitication

Since the REM 543 is a pre-configured unit, additional identification numbers are required for identification. Some of the methods require the unit to be powered up. Other methods require the unit to be taken out of service.

To identify the BASE HARDWARE of the REM 543, the following steps may be executed to facilitate unit identification. As per Figure 2-3, several identifying numbers are present on the REM 543. A PRODUCT CERTIFICATE is also included with the relay identifying the hardware as illustrated in Figure 2-4.



NOTE:TYPE NUMBER= ITEM NUMBER = ORDER NUMBER

Figure 2-3. REM 543 Unit Identification Number

Additional methods to ascertain the BASE HARDWARE model of REM 543 may also be completed through the use of CAPTOOLS, or navigation of the REM 543 MIMIC PANEL menu screens. Several methods of unit identification may be undertaken as follows:

Method 1: REM Identification – As illustrated in Figure 2-3, the REM 543 has an identification label on the front side of the unit. The two identification numbers visible on the IED are:

ORDER NUMBER
SERIAL NUMBER

Also as illustrated in Figure 2-3, as one faces the front MIMIC PANEL, on the right side of the unit, several labels are visible, the top most bar code label lists following numbers for the device. These identification numbers are:

TYPE NUMBER
SERIAL NUMBER

However, other bar code labels are on the BASE HARDWARE REM 543. These labels designate the internal components of various discrete boards and are of no consequence to this update procedure.

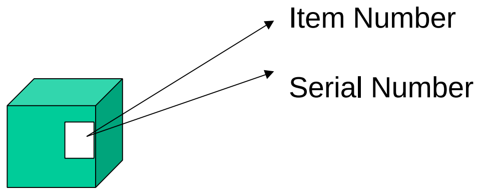
These numbers should match the box in which the REM 543 was delivered. As illustrated in Figure 2-4, the box has two numbers on the unit identification label. The box numbers are:

ITEM NUMBER
SERIAL NUMBER

It should be remembered that the serial numbers are the same for the BASE HARDWARE. Additionally, the ORDER NUMBER, TYPE NUMBER, and ITEM NUMBER must all be the same for the IED.

Within the REM 543 box, is included a PRODUCT CERTIFICATE. On this PRODUCT CERTIFICATE are two numbers of interest which match the numbers previously explained. The numbers on the certificate are:

TYPE NUMBER
SERIAL NUMBER



NOTE : MUST MATCH REM 543 SERIAL NUMBERS, ITEM NUMBER - TYPE NUMBER- ORDER NUMBER ON THE APPROPRIATE DEVICE.

Figure 2-4. Box Identification

Method 2: REM 543 POWERUP IDENTIFICATION VIA THE MIMIC PANEL

If one wishes to identify the REM 543 unit, this can be accomplished via the MIMIC PANEL. Execute the following procedure to identify the HARDWARE NUMBER and SERIAL NUMBER of your unit.

1. If the LCD MIMIC PANEL is not backlit. Depress any key to illuminate the LCD MIMIC PANEL, else proceed to STEP 2.
2. Depress the “E” key for 2 seconds.
3. The prompt “ENTER PASSWORD” is displayed with a series of asterisks “*” showing the password entry field.

4. With the cursor resident in the leftmost asterisk field. Depress the "↑" key three times to display the number '3' in that field location. [NOTE – '3' is the default password for a REM 543; consult the REM 543 Operators Manual for a description of changing the default password].
5. Depress the "E" key to accept the password entry.
6. The MAIN MENU should now be displayed. Depress the "↓" seven times to highlight the submenu selection titled " INFORMATION".
7. Depress the " →" key to display the INFORMATION submenu.
8. Several submenu's will be displayed on the INFORMATION submenu. The IDENTIFICATION submenu is the first selection and is highlighted. Depress the " →" key to display the IDENTIFICATION submenu.

Several numbers will be displayed the two of interest are:

HARDWARE NUMBER = XXX <u>ABC</u>

SERIAL NUMBER = 123456

The SERIAL NUMBER shall match the hardware numbers as identified in the METHOD 1 section of this procedure. The HARDWARE NUMBER must be decoded as follows:

The hardware numbers of interest are:
RIV 2: ___________________________ (Serial Number)
RIV 3: ___________________________ (Software Number)
RIV 4: ___________________________ (Hardware Number)
RIV 5: ___________________________(Old Test Date)

The underlined <u>ABC</u> number shall match the ORDER NUMBER, TYPE NUMBER, ITEM NUMBER in the following numeric slots: REM543 XX <u>ABC</u>XXXX. The ABC of the MIMIC panel display shall match the numbers shown in the following steps.

OTHER NUMBERS OF INTEREST:

If MIMIC PANEL IDENTIFICATION PROCEEDURE STEPS 1-7 are followed, the following procedural steps will allow the user to identify the BASE SOFTWARE CONFIGURATION NUMERS of interest for the remainder of the configuration procedure.

1. Depress the "↓" key once to highlight the submenu selection "CPU 1"
2. Depress the " →" key once to display the contents of the submenu which display the following information:

SW BUILD
= X.XX.XX
SW REVISION
=X
SW VERSION
= XXXXXX
SERIAL NUMBER
XXXX

[NOTE – the serial number version is only for internal identification of an individual card, and is not of use for this procedure]

Section 3 - REM 543 Device Connectivity

Two communication interfaces are available for the REM 543, the front panel port OPTICAL INTERFACE and the REAR RS 232 Port. Communication between devices is only possible through connectivity of the units through a physical media interface

Table 3-1 lists the characteristics for each of the port types.

Table 3-1. Physical Interface Options

	REM 543	Notes
COM 0 - Front Panel Port	Optical	Optical Spa Com Port – Requires Optical Port Converter to RS 232 (Part Number Part Number 1MKL950001-1)
X3.1	Reserved	Reserved
X3.2	RS 232 Non Isolated	Modbus Protocol Port
X3.3	Unused	Unused

Front Panel Port Connectivity

The front panel port on the REM 543 is an optical port. An OPTICAL cable is included with the REM 543 to allow for connectivity to the device. The usual communication connection is between a REM 543 and a personal computer executing the CAP 501 configuration program. As illustrated in Figure 3-1, the addressable SPA OPTICAL PORT on the REM 543 is attached to an RS 232 port on a personal computer. Cable Part Number 1MKL950001-1 is attached to the REM's front panel OPTICAL PORT. The cable is a DTE RS 232 connection with a DB 9 male interface. There are no other converters or connectors required to attach the cable between a personal computer and the REM 543.

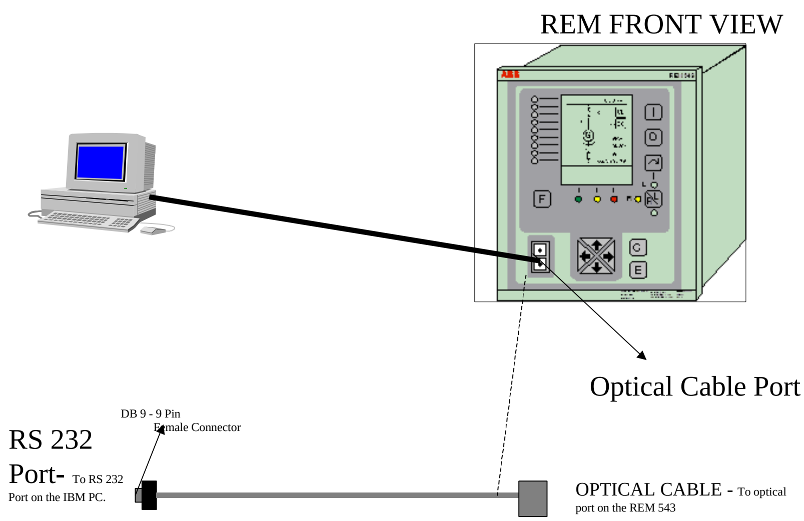


Figure 3-1. Optical Cable Connection

RS 232 Interface Connectivity

RS 232 is perhaps the most utilized and least understood communication interface in use. RS 232 is sometimes misinterpreted to be a protocol; it is in fact a physical interface. A physical interface is the hardware and network physical media used to propagate a signal between devices. Examples of physical interfaces are RS 232 serial link, printer parallel port, current loop, V. 24, IEEE Bus… Examples of network media are, twisted copper pair, coaxial cable, free air…

RS 232 gained widespread acceptance due to its ability to connect to another RS 232 device or modem. A modem is a device, which takes a communication signal and modulates it into another form. Common forms of modems include telephone, fiber optic, microwave, and radio frequency. Modem connectivity allows attachment of multiple devices on a communication network or allows extension of communication distances in a network with two nodes. Physical connection of two devices or more than two devices require differing approaches. Figure 3-2 illustrates a topology using two devices (point to point topology). Figure 3-3 illustrates a multi-drop topology between many nodes. RS 232 was designed to allow two devices to communicate without using intermediate devices.

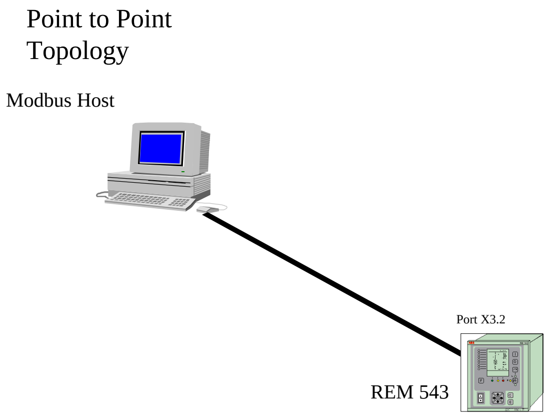


Figure 3-2. Point to Point Architecture Using RS 232

RS 232 Handshaking Defined

Handshaking is the ability of the device to control the flow of data between devices. There are two types of “handshaking”, hardware and software. Hardware handshaking involves the manipulation of the RTS (Request to Send) and CTS (Clear to Send) card control signal lines allowing data communication direction and data flow rates to be controlled by the DTE device. Also the flow is controlled by the DTR (Data Terminal Ready) signal which allows the DCE operation.

Software handshaking involves the data flow control by sending specific characters in the data streams. To enable transmission, the XON character is transmitted. To disable reception of data, the transmitting device sends an XOFF character. If the XOFF character is imbedded within the data stream as information, the receiving node automatically turns off. This is the main weakness of software handshaking, inadvertent operation due to control characters being imbedded within data streams. Software handshaking is usually used in printer control.

The REM 543 does not incorporate handshaking, therefore, the control lines may be ignored as illustrated in Figure 3-4. However, some PC software utilizes handshaking, thus the port on the personal computer may require a special hardware configuration of the cable to the port. Consult with the software vendor to determine RS 232 control and buffering requirements and the need for signal jumpers required in RS 232 cabling.

The ports on the REM 543 has been tested for operation up to a speed of 9600 baud. 9600 baud is a typical data rate applicable for the operation of an asynchronous communication connection over RS 232 without the use of additional timing lines.

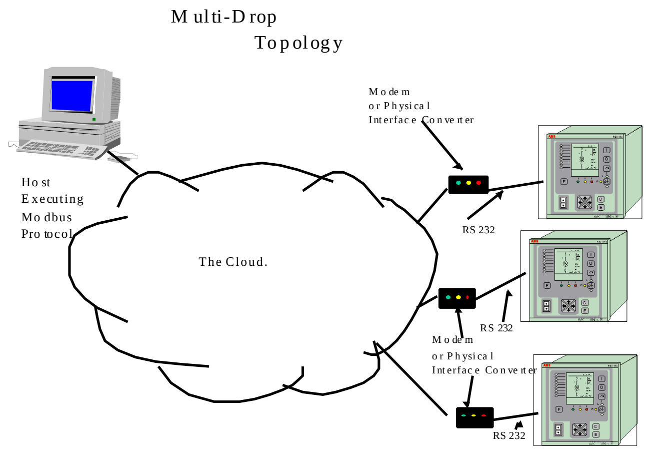
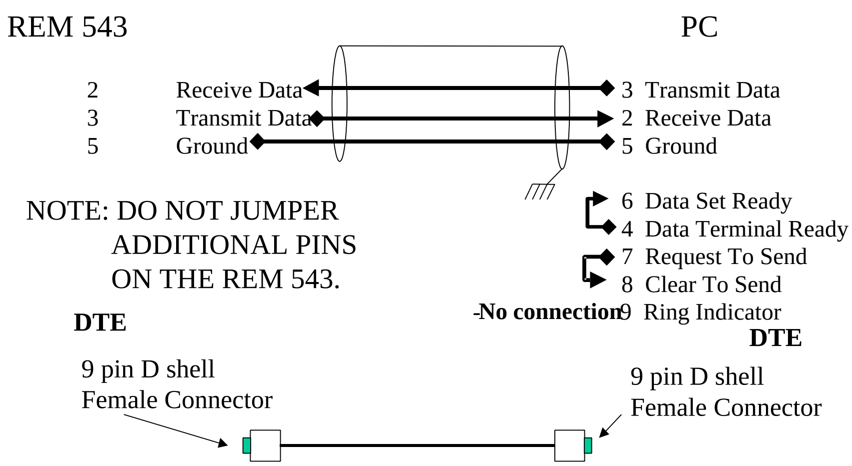


Figure 3-3. Multi-Drop Topology Using RS 232

REM 543 RS 232 Port X3.2 Cable Connectivity

A cable diagram is illustrated in Figure 3-4 and 3-5. Figure 3-4 shows the direction of communication signal transmission and the gender of the connectors used in constructing a communication cable.



REM 543 to PC Cable 9 to 9 Pin-out

Figure 3-4. Modbus RS 232 Port X3.2 Cable Diagram

An RS 232 interface was designed to simplify the interconnection of devices. Definition of terms may demystify issues concerning RS 232 interconnection. Two types of RS 232 devices are available, DTE and DCE. DTE stands for **D**ata **T**erminal **E**quipment whereas DCE stands for **D**ata **C**ommunication **E**quipment. These definitions categorize whether the device originates/receives the data (DTE) or electrically modifies and transfers data from location to location (DCE). Personal Computers are generally DTE devices while line drivers/ modems/ converters are DCE devices. REM 543 devices have RS 232 DTE implementation. Generally, with a few exceptions, a "straight through cable" (a cable with each pin being passed through the cable without jumpering or modification) will allow a DTE device to communicate to a DCE device.

Connection of a PC to a REM 543 requires cable modification since the interconnected devices are both DTE. The same cabling would be utilized if one would connect two DCE devices. The classifications of DTE/DCE devices allow the implementers to determine which device generates the signal and which device receives the signal. Studying Figure 3-5, Pins 2 and 3 are data signals, pin 5 is ground whereas pins 1, 6, 7, 8, 9 are control signals. The arrows illustrate signal direction in a DTE device. The REM 543 series of protective devices do not incorporate hardware or software “handshaking’.

If a host device has an RS 232 physical interface with a DB 25 connector, reference Figure 3-5 for the correct wiring interconnection.

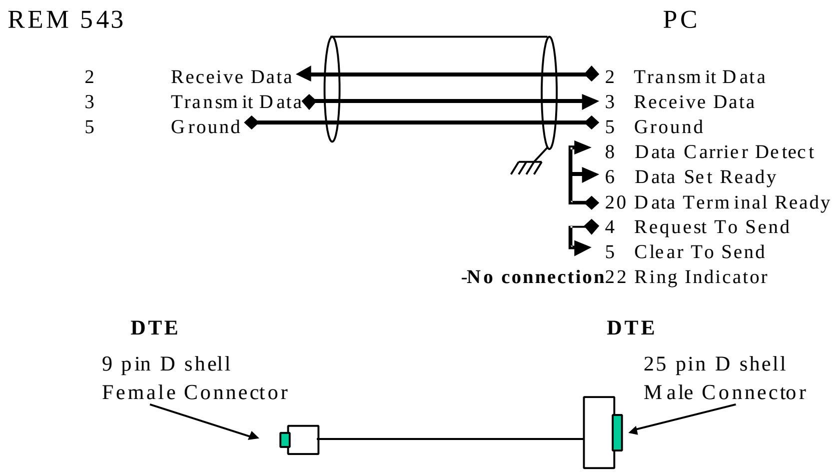


Figure 3-5. Connection of a DB 25 Connector to a REM 543

Connection between the REM 543 Modbus Port and a personal computer is illustrated in Figure 3-6.

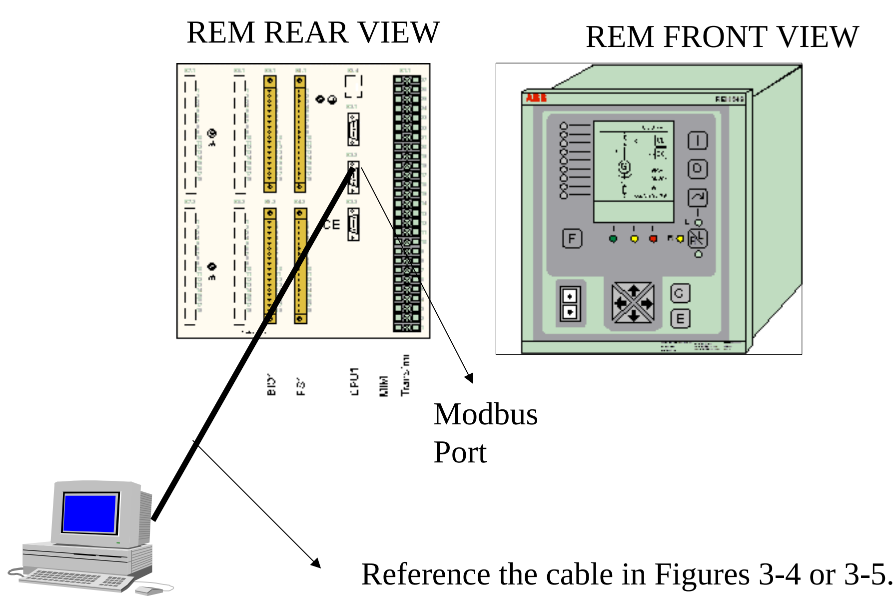


Figure 3-6. REM 543 Point to Point Topology Connection Using RS 232

Section 4 - REM 543 Device Parameterization

Establishing REM 543 communication depends upon correct parameterization of the communication menus within the unit. FRONT PORT (COM 0) Parameterization may occur via the unit's front panel interface using CAPTOOLS 501/505. MODBUS PORT PARAMETERS may only be configured using the REM 543 LCD front panel interface. The following sections cover the parameterization procedures to set the aforementioned ports.

COM 0 Port (Front Port Fiber Optic Configuration PORT)

In order to attach a configuration program to the REM 543, the correct parameters must be set up within the unit. The supported parameters are listed in Table 4-1 below. The protocol for the unit is addressable SPA protocol. To view the communication port parameters it is advised that they should be viewed via the unit's front panel interface since there is no capability for accessing the configuration parameters from the CAP 501 configuration program.

The keystrokes required for visualizing the communication port parameters from the metering display are:

Mimic Panel Identification Procedure

1. If the LCD MIMIC PANEL is not backlit. Depress any key to illuminate the LCD MIMIC PANEL, else proceed to STEP 2.
2. Depress the "E" key for 2 seconds.
3. The prompt "ENTER PASSWORD" is displayed with a series of asterisks "*" showing the password entry field.
4. With the cursor resident in the leftmost asterisk field. Depress the "↑" key three times to display the number '3' in that field location. '[NOTE – '3' is the default password for a REM 543; consult the REM 543 Operators Manual for a description of changing the default password].
5. Depress the "E" key to accept the password entry.
6. The MAIN MENU should now be displayed. Depress the "↓" five times to highlight the submenu selection titled " COMMUNICATIONS".
7. Depress the " →" key to display the additional submenus beneath the "COMMUNICATION" submenu.
8. Depress the "↓" key once to highlight the "SPA" submenu.
9. Depress the " →" key to display the ADDRESS and BAUD RATE submenu items for configuration.
10. For the ADDRESS or BAUD RATE submenu items, if one wishes to configure the items for proper communication, Depress the "↓" key to highlight the menu item for configuration.
11. If one depresses the "E" key, a PASSWORD query is visible on the screen. Depress the "↑" key two times to display the number '2' in that field location. '[NOTE – '2' is the default password for a REM 543; consult the REM 543 Operators Manual for a description of changing the default password].
12. Depress the "↓" or "↑" key to change the information in the associated field being modified.
13. To accept the data changed in the field, depress the "E" key or to discard the changes, depress the "C" key.
14. Depress the "←" key to return to the main MIMIC panel display. When the query, "ACCEPT CHANGES" appears, depress "E" to accept or "C" to discard the changes.
15. If the changes are accepted, monitor the bottom of the display for indication that the parameters are being stored in memory.
16. Reset the relay or power up or down the relay to re-initialize the device to accept the new parameters.

The parameters may not be changed via CAP 501 tools. Only Front Panel interface modification is possible with the REM 543. The selections for each parameter required in Front Panel Port configuration is shown in Table 4-1.

Table 4-1. REM 543 Com Port 0 Front Panel Interface Parameters

Option	Selection	Notes
Unit Node Address	1 to 255 (1 = default setting)	decimal node address
Baud Rate	300	Selectable Baud Rates for the Standard Ten Byte Front Panel Port.
	1200	
	2400	
	4800	
	9600 (default setting)	

Figure 4-1 illustrates the parameterization screen in CAP 501 tools allowing communication parameter visualization between the personal computer and the REM 543.

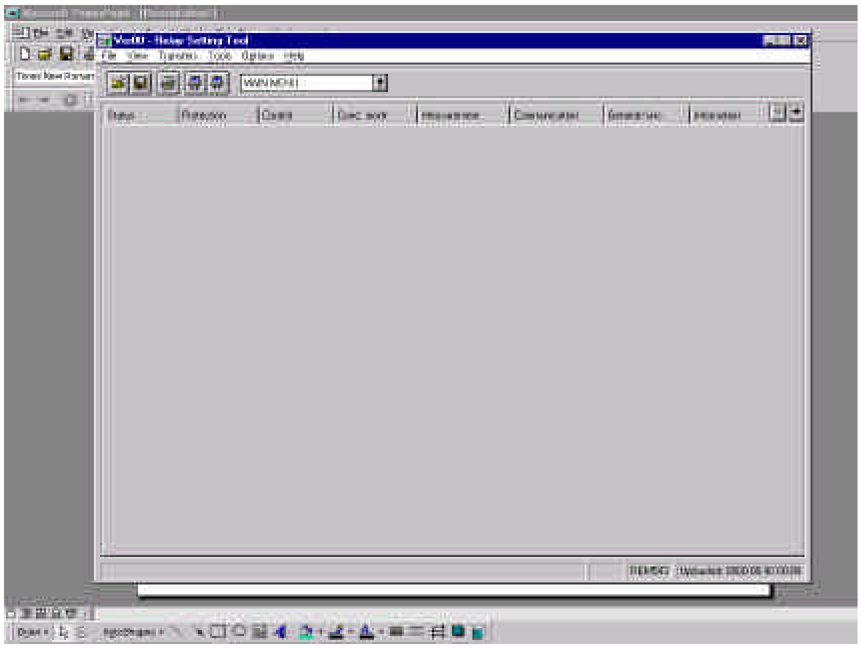


Figure 4-1. CAP 501 Initial Selection Screen

Modbus Port Settings (X3.2)

The Modbus port on the REM 543 can only be set using the LCD Front Panel Interface (FPI). The procedure for paramterizing the port is as follows.

The Baud and Frame Options allowable for RTU and ASCII communication are shown in Table 4-2.

Table 4-2. Valid Parameter Selections for Modbus Protocol

Protocol Selected	Selections	Comments
UNIT ADDRESS	0 – BROADCAST 1- 247	
BAUD RATE	300,1200, 2400, 4800, 9600	
MODBUS MODE	RTU, ASCII	
PASSWORD	4 Digits Space, 0-9, A-Z, a-z	Default is 4 Spaces – Used for control register operations.
No. of Data Bits	7 - (Must configure for ASCII MODE only) 8 - (Must configure for RTU MODE only)	Setup Dependent Upon MODBUS MODE SELECTED. Although the selection field offers parameters 0 through 9, only the listed parameters

		should be used.
No. of Stop Bits	1 or 2	Although the selection field offers parameters 0 through 9, only the listed parameters should be used.
Parity	Odd, Even, None	
Next Character Timeout	0 – 10000 mS	Set per ASCII MODE OR RTU MODE. ASCII MODE set to 1000 mS, RTU MODE set to 0 mS.
End Of Frame Timeout	0 – 10000 mS	Set per baud rate. **4** (9600 baud), **14** (4800 baud), **28** (2400 baud) **56** (1200 baud), **224** (300 baud).
Command Timeout	0 – 10000 mS.	Timeout Command for Interlocking Error Notification. Set to 1500 mS.
CRC Selection	Lo/Hi – CRC order (Default) RTU Mode only Hi/Lo – CRC Order	Selects if CRC-16 order is lo/hi or hi/lo

The procedure for parameterizing the MODBUS port X3.2 is as follows:

1. If the LCD MIMIC PANEL is not backlit. Depress any key to illuminate the LCD MIMIC PANEL, else proceed to STEP 2.
2. Depress the "E" key for 2 seconds.
3. The prompt "ENTER PASSWORD" is displayed with a series of asterisks "*" showing the password entry field.
4. With the cursor resident in the leftmost asterisk field. Depress the "↑" key three times to display the number '3' in that field location. '[NOTE – '3' is the default password for a REM 543; consult the REM 543 Operators Manual for a description of changing the default password].
5. Depress the "E" key to accept the password entry.
6. The MAIN MENU should now be displayed. Depress the "↓" five times to highlight the submenu selection titled "COMMUNICATIONS".
7. Depress the " →" key to display the additional submenus beneath the "COMMUNICATION" submenu.
8. Depress the "↓" key two times to highlight the "MODBUS" submenu.
9. Depress the " →" key to display the additional submenus beneath the "MODBUS" submenu.
10. Items available for configuration are listed in Table 4-5.

To modify the entry as per the aforementioned table, perform the following procedure.

1. Depress "E".
2. A query for PASSWORD will be presented to the user.
3. With the cursor resident in the leftmost asterisk field. Depress the "↑" key three times to display the number '2' in that field location. '[NOTE – '2' is the default password for a REM 543; consult the REM 543 Operators Manual for a description of changing the default password.
4. Depress the "E" key to accept the password entry.

Other Important Information to Obtain

Version information is possible to obtain via the MIMIC FRONT PANEL INTERFACE or by using CAP 501 configuration program.

To obtain information via the MIMIC FRONT PANEL INTERFACE follow the procedure as listed in the following steps:

Mimic Panel Identification Procedure

1. If the LCD MIMIC PANEL is not backlit. Depress any key to illuminate the LCD MIMIC PANEL, else proceed to STEP 2.
2. Depress the "E" key for 2 seconds.
3. The prompt "ENTER PASSWORD" is displayed with a series of asterisks "*" showing the password entry field.
4. With the cursor resident in the leftmost asterisk field. Depress the "↑" key three times to display the number '3' in that field location. '[NOTE – '3' is the default password for a REM 543; consult the REM 543 Operators Manual for a description of changing the default password].
5. Depress the "E" key to accept the password entry.
6. The MAIN MENU should now be displayed. Depress the "↓" seven times to highlight the submenu selection titled " INFORMATION".
7. Depress the " →" key to display the INFORMATION submenu.
8. Several submenu's will be displayed on the INFORMATION submenu. The IDENTIFICATION submenu is the first selection and is highlighted. Depress the " →" key to display the IDENTIFICATION submenu.
9. Several numbers will be displayed the two of interest are:

HARDWARE NUMBER = XXX ABC
SERIAL NUMBER = 123456

The SERIAL NUMBER shall match the hardware numbers as identified in the METHOD 1 section of this proceedure. The HARDWARE NUMBER must be decoded as follows:

The hardware numbers of interest are:
RIV 2: ___________________________ (Serial Number)
RIV 3: ___________________________ (Software Number)
RIV 4: ___________________________ (Hardware Number)
RIV 5: ___________________________ (Old Test Date)

The underlined ABC number shall match the ORDER NUMBER, TYPE NUMBER,, ITEM NUMBER in the following numeric slots: REM543 XX ABCXXXX. The ABC of the MIMIC panel display shall match the numbers shown in the following steps.

OTHER NUMBERS OF INTEREST:

If MIMIC PANEL IDENTIFICATION PROCEEDURE STEPS 1-7 are followed, the following procedural steps will allow the user to identify the BASE SOFTWARE CONFIGURATION NUMERS of interest for the remainder of the configuration procedure.

1. Depress the "↓" key once to highlight the submenu selection "CPU 1"
2. Depress the " →" key once to display the contents of the submenu which display the following information:

SW BUILD
= X.XX.XX
SW REVISION
=X
SW VERSION
= XXXXXX
SERIAL NUMBER
XXXX

[NOTE – the serial number version is only for internal identification of an individual card, and is not of use for this procedure]

If one wishes to obtain the information via the CAP 501 program, follow the procedure as listed.

1. If CAP 501 is entered, the screen illustrated in Figure 4-1 is visible.
2. Click on the TAB Labeled “INFORMATION”. The screen illustrated in Figure 4-2 is visible.
3. The screen in the INFORMATION TAB is illustrated in Figure 4-3.
4. If one wishes to obtain the information for CPU VERSION BUILD NUMBER via CAP 501, This screen is resident in the CPU 1 – Submenu as illustrated in Figure 4-5.

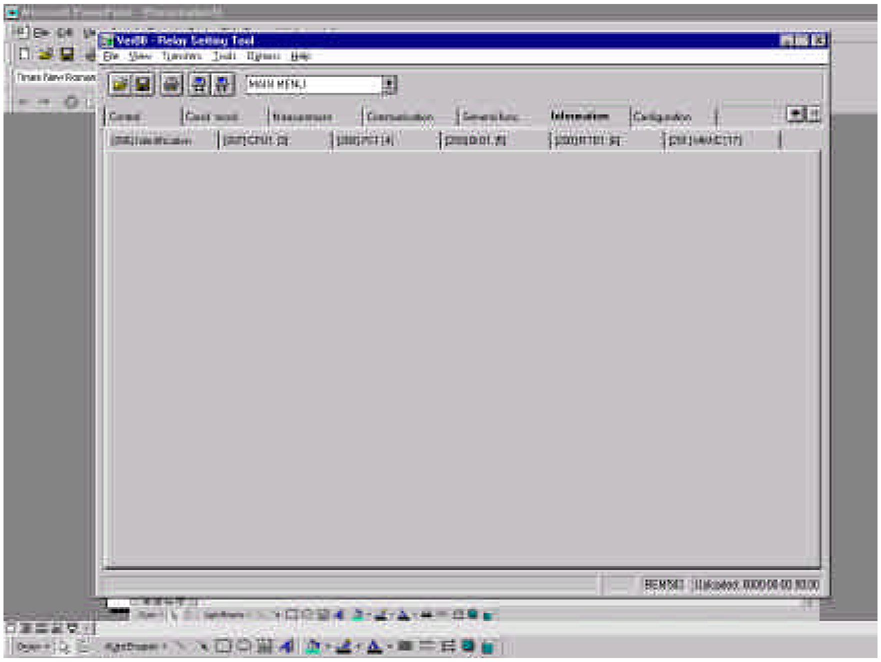


Figure 4-2. Submenu for Information Menu

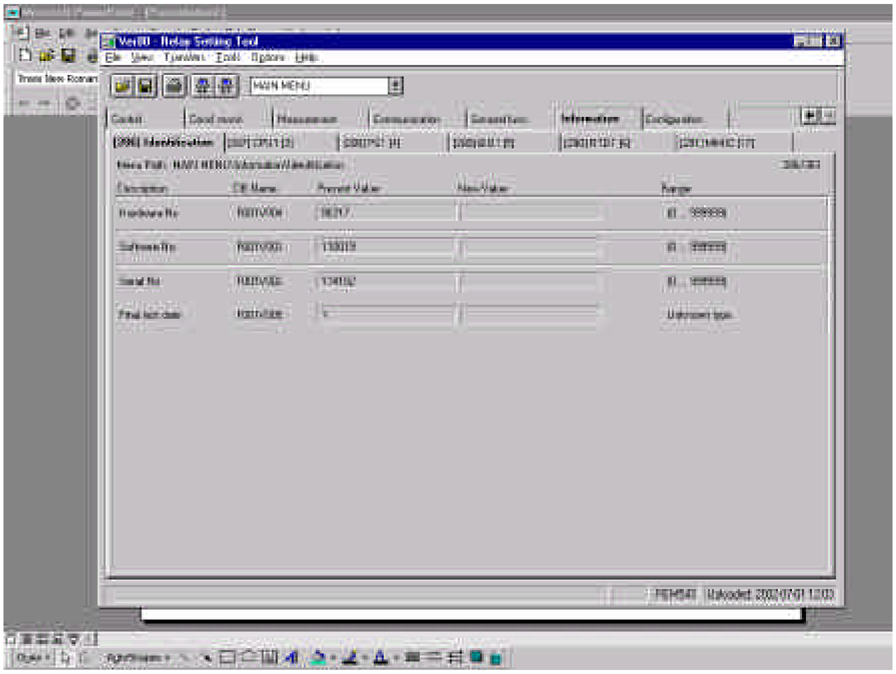


Figure 4-3. Information Menu Contents

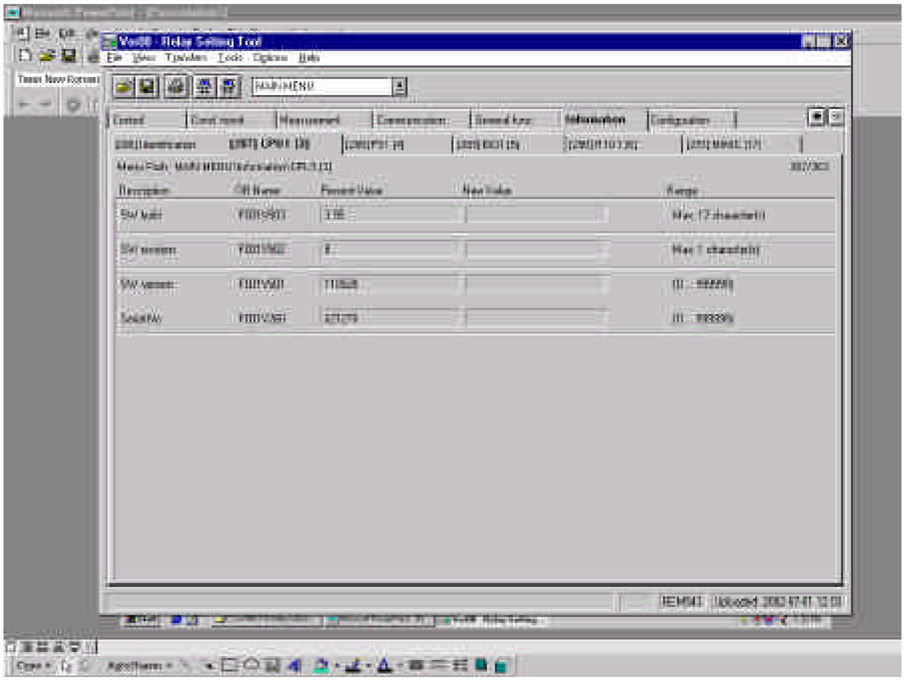


Figure 4-4. CPU Version Submenu Contents

Section 5 -Modbus

Modbus is available in two emulation's, Modbus RTU and Modbus ASCII. Modbus RTU is a bit oriented protocol (normally referred to as synchronous), and Modbus ASCII is a byte-oriented protocol (normally referred to as asynchronous). Both emulations support the same command set. **Networked nodes cannot communicate unless the same emulation of the Modbus protocol is interpreted.** This is an extremely important issue. The REM 543 supports the Modbus ASCII and RTU protocol emulations.

Modbus Protocol

Modbus operates in the following fashion. A host device transmits a command, and one of the attached device(s) respond. Each device has a unique address assigned to it. Each device is configured for the same protocol emulation of Modbus. Figure 5-1 illustrates the polling sequence.

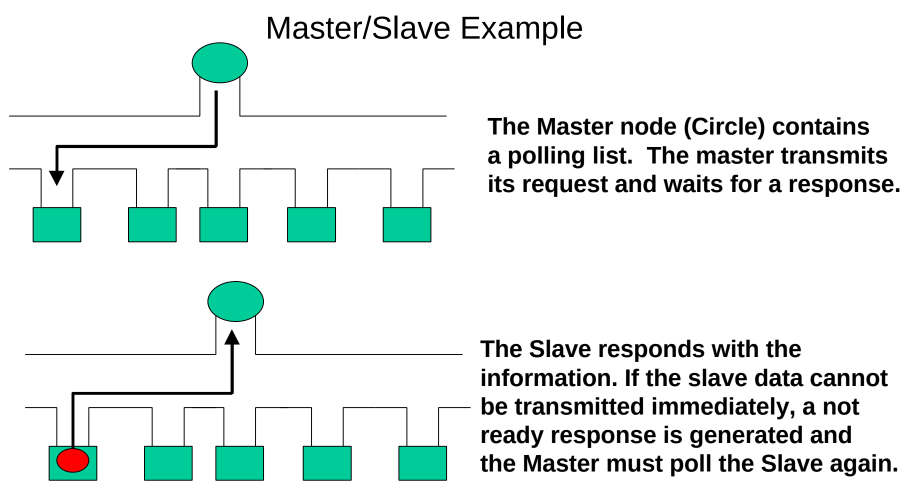


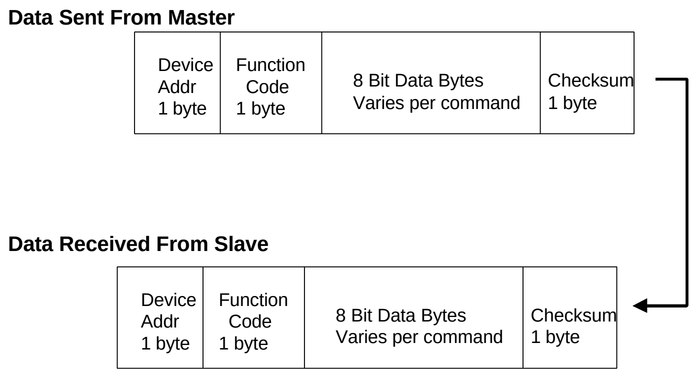
Figure 5-1. Modbus Polling Sequence

The REM 543, are designed as Modbus slave emulation devices. That is, a device, a host, (illustrated in Figure 5-1) must be able to generate Master Requests in a Modbus format so that the slave, (REM 543 is able to receive the commands).

Modbus ASCII Emulation

An ASCII character is defined as 7 data bits. A character is represented as a number from 00 HEX to 7F HEX. Appendix B contains an ASCII character conversion chart. If a 0 is transmitted, it must be decoded to an ASCII representation to be interpreted by the receiving device. 0 decimal is 30 hex for an ASCII representation. The frame format for Modbus is represented in Figure 5-2. The device address, function code and checksum is part of the transmitted frame. The Checksum is a Longitudinal Redundancy Check (LRC). Its calculation shall be described later in this guide.

The generic Modbus Frame is analyzed in Figure 5-3. The start of an ASCII frame is always a colon (: = 3A HEX) and a termination of the command is a line feed and carriage return (lf cr = 0D 0A). The format is the same for the host transmitting the frame and the slave node responding to the host's transmission. The device address is imbedded within the frame along with the Modbus command function code. A checksum is appended to the entire command. The checksum is a Longitudinal Redundancy Checksum. The LRC checksum combined with parity and internal field length detection determination provides good security in detection of data packet errors. Many devices easily calculate LRC, which results in ASCII emulation's popularity.



(Device Address = 0 (Null Command), 1 - 247, 255 (Broadcast)

Figure 5-2. Modbus ASCII Transmitted and Received Frame Formats

START	ADDRESS	FUNCTION	DATA	LRC	END
1 Char :	2 Chars	2 Chars	N Chars	2 Chars	2 Chars CR LF

Figure 5-3. Modbus ASCII Frame Format

The Modbus characters are encoded with a variety of frame sizes. An analysis of each frame is illustrated in Figure 5-4. When selecting a common frame size, (as explained in the configuration setup examples), parity, word length, and stop bits are selected to form a 10 bit data frame (1 start bit + 7 data bits + 1 stop bit + 1 Parity bit "OR" 1 start bit + 2 stop bits + 7 data bits + NO Parity = 10 bits per frame). It is important to note this distinction since if REM 543 device attachment is to occur through a device, the device must support 10 bit asynchronous data framing.

Least Significant Bit ………………………………………Most Significant Bit

START	1	2	3	4	5	6	7	PARITY	STOP

With Parity Checking

START	1	2	3	4	5	6	7	STOP	STOP

Without Parity Checking

Figure 5-4. Modbus ASCII Frame Analysis

The REM 543 offers a variety of frame sizes. If the frame size, 8N1 is selected (8 Data Bits, No Parity, 1 Stop Bit), then an additional stop bit is inserted. The frame format follows that of Figure 5-4 "Without Parity Checking". However, when using ASCII protocol with many other devices, the data is limited to 7 bits. Selection of 8 bits for the data frame will automatically require that the device receive/transmit RTU mode. The ABB REM 543, does not allow for this override, however several programmable logic controller manufacturers allow for this.

The receiving device determines that a frame is on the network by sensing the first character (: colon) and then determining that the message address is the same as that assigned to itself. If the Modbus device does not receive a carriage return line feed (lf cf 0A 0D) within an appreciable amount of time, the host will timeout. The length of characters in the message determines Timeout. Modbus ASCII will timeout is the time delay between each character exceeds 1 second delay between each character's transmission. If 100 characters are required to transmit a complete Modbus ASCII frame, then the timeout for the message could be in excess of 100 seconds for that specific exchange.

Modbus RTU Emulation

In contrast to the ASCII representation, Modbus allows for no encoding of the transmitted or received data message. If a data byte of 00 (zero zero) is sent to an IED from a Host, the data would be sent as a single byte of data (binary 0000 0000). If data would be sent as an ASCII data string the data would be composed of the encoded ASCII string 30 30 hex (binary 0011 0000 0011 0000). The Modbus RTU emulation is twice as efficient as Modbus ASCII mode.

START	ADDRESS	FUNCTION	DATA	LRC	END
4 Char Delays	8 Bits	8 Bits	N * 8 bits	16 Bits	4 Char Delays

Figure 5-5. Modbus RTU Format

RTU Framing

Least Significant Bit ………………………………………… Most Significant Bit

START	1	2	3	4	5	6	7	8	PARITY	STOP

With Parity Checking

START	1	2	3	4	5	6	7	8	STOP	STOP

Without Parity Checking

Figure 5-6. RTU Frame Format

Figures 5-5 and 5-6 illustrate the format of the Modbus RTU emulation. An analysis of each frame is illustrated in Figure 5-6. When selecting a common frame size, (as explained in the configuration setup examples), parity, word length, and stop bits are selected to form a 11 bit data frame (1 start bit + 8 data bits + 1 stop bit + 1 Parity bit "OR" 1 start bit + 2 stop bits + 8 data bits + NO Parity = 11 bits per frame). It is important to note this distinction since if REM 543 device attachment is to occur through a device, the device must support 11 bit asynchronous data framing.

Modbus ASCII protocol synchronizes host to IED messaging through monitoring the leading character (: colon). Modbus RTU synchronizes the host to IED messaging through time delays. Modbus RTU emulation. Modbus RTU timeout depends on the following rules.

- If delay between transmissions is < 3.5 Character Times, the message is received.
- If delay < 3.5 character times, receiving device appends characters to last message.
- If delay is sensed > 1.5 message times, receiving device flushes the buffer. Next character is new message.

The Modbus RTU emulation senses timeouts quicker than the Modbus ASCII emulation. The Modbus RTU emulation also uses a CRC-16 checksum in contrast to the Modbus ASCII using a LRC (Longitudinal Redundancy Check). The CRC-16 is a much more robust checksum. With parity, internal protocol message length field checks and the CRC-16, the error detection is exceptional.

> **IMPLEMENTATION TIP-**When commissioning a Modbus system, it is always advisable to connect a communication analyzer in-line with the host. It is always uncertain whether the host is sending the command correctly. Within the REM 543, an incorrect address request will always generate an exception response from the relay. If an exception response is generated, many host devices will not display the Modbus exception response generated by the unit. A communication analyzer allows for rapid troubleshooting of a malfunctioning network connection.

Modbus General Notes

Modbus is an exceptional protocol for bridging a majority of vendor devices to communicate to each other. The generation of each protocol, throughput, robust capabilities and troubleshooting techniques shall be covered in later sections. The understanding of each of these principles shall aid the implement in exploiting the capabilities within their own automation system.

Modbus ASCII, Modbus RTU, and Modbus Plus have the following capacities implemented within the REM 543 (All codes are in hex).

- 01 - Read 0X Coil Status
- 02 - Read 1X Contact Status
- 03 - Read 4X Holding Registers
- 05 - Force Single Coil
- 06 - Preset Single Register
- 16 - Write 4X Holding Registers
- 08 - Diagnostics
- 0B - Get Comm Event Counters
- 23 - Write 4X and Read 4X Holding Registers
- OF - Force Multiple Coils

The REM 543 emulates a slave device. Any other Modbus command sent to the REM 543 shall result in a Modbus exception code being sent to the transmitting device. The following sections will further describe the Modbus functionality within the REM 543.

> **IMPLEMENTATION TIP-**Although the REM 543 allows configuration of Modbus for a Frame of N-8-1, some implementations will interpret this emulation of Modbus to be RTU Mode. The REM 543 does not support this mode. It is advisable to contact the manufacturer of the host and host software to determine the interpretation of the command string. For example, the Modicon XMIT and COMM BLOCK allowing the PLC to emulate a host device only allows block frame size designation of 7 data bits.

Modbus/Modbus Plus Register Map

0X Discrete Coils

Discrete Modbus Coil status is available via a function 01 request via Modbus. Figure 5-7 illustrates a typical command sequence. The Host polls the REM 543 for the Data. The REM 543 receives the request and responds with the expected data. The Host then interprets the command response, checks the checksum (LRC if ASCII, CRC 16 if RTU mode) and then displays the interpreted data. Additional information is available in Modicon's protocol manual references listed at the beginning of this document.

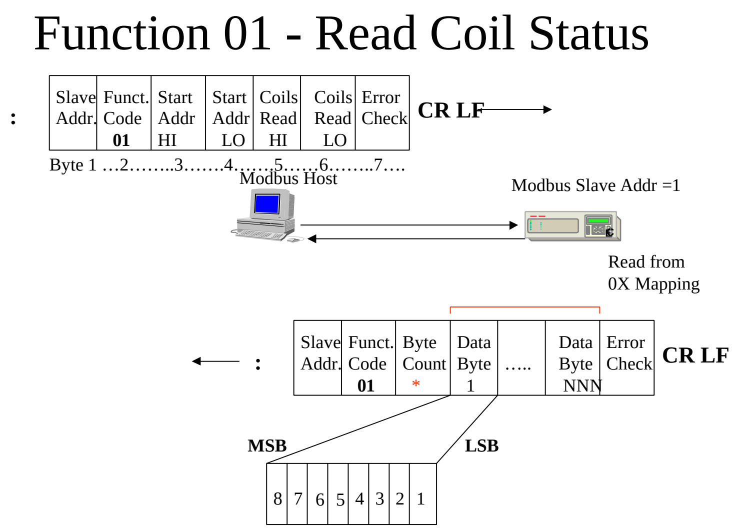


Figure 5-7. Modbus Protocol Function 01 Frame Format

Function Code 1 (Read Coil Status) – Read Only Data

The 0X read command allows for access of Logical and Physical I/O data. The information listed in Table 5-1, is that which is reported in real time. In other words, if the bits are polled as per the table, the status of each data bit is reported at the time the data is requested. If the data is momentary in nature, then access of status is dependent upon reading the information at the time the function or signal is present.

Table 5-1 lists the Logical Output Single Bit Data. The data listed within the table includes real time status bits , which may be briefly reported status bits. In other words, they follow the real time status of the point. Other points reported in the table are latched.

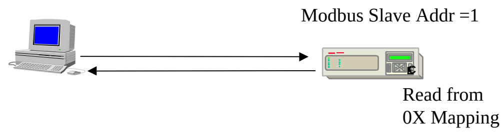
A Latched point (sometimes referred to as Sealed In Output Point or in the REM 543 terminology a TRIP point). These points stay energized until they are reset by a group control function. The function is reset via the method described in the 4X or 0X element control explanation and an example is shown in Figure 5-8. Within the REM 543 each of the functions listed with the designator (L) may be configured for LATCH or MOMENTARY operation. For each of the bits to maintain the state change until reset, the function must be configured in CAPTOOLS or via the Front Panel Interface (FPI) screen for latched operation.

Momentary data reporting is available at the present time. Some bit statuses are brief in reporting nature. Modbus and Modbus Plus do not have a method of time-stamping events, nor is there a "protocol defined" method to ensure that an event is not lost. ABB incorporates a method called "Momentary Bit Status Reporting" allowing a host to poll a protective device at any time and ensure that a contact change notification occurs. The method shall be explained later in this document.

If data is requested from memory addresses not defined within this document, a Modbus Exception Code shall be generated.

Figures 5-8 and 5-9 illustrate a simple example of a host requesting data from a REM 543 relay where Physical Relay Coil Status is requested of the REM 543. This example illustrates that data is requested in the Modbus ASCII frame format illustrated in Figure 5-8, raw data received by the host is decoded from ASCII to HEX . The host as illustrated in Figure 5-9 parses the individual status bits.

Example - Read Output 1-6



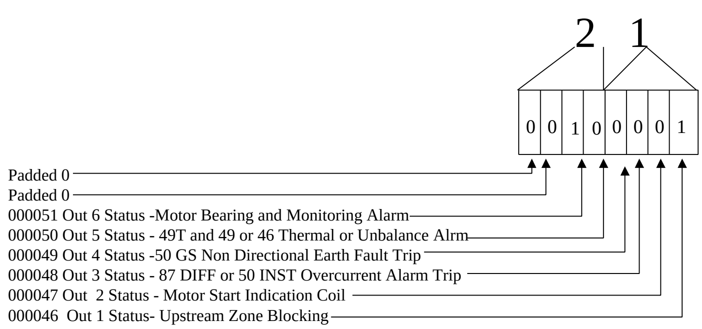
Obtain Output 6 Through Output 1 Status Indication (00046 to 00051 per the memory map). (MODBUS RTU Ex.)

Host Sends : 01 01 01 08 00 06 3C 36
IED Addr = 01
Function = 01
Data Start Address = 00 2D (which is 2D in hex =00 45 in decimal)
Amount of Data Requested = 6 Coils
CRC-16 Checksum = 3C 36 Hex
Note: RTU does not code data in ASCII header and trailer is three character delays.
Relay Responds:01 01 01 21 91 90
IED Addr = 01
Function = 01
Data Bytes Received = 1
Data Received = 21
CRC-16 Checksum = 91 90 Hex

Figure 5-8. Example Transaction Request for Six Physical Output Coils

Function 01- Read Coil Status

Example - Analysis of Data Received



RESULT : Output 1 and Output 6 are energized.

Figure 5-9. Example of Raw Data Decode

Modbus 0X Implementation Features

Modbus is a protocol often used in the industrial sector. The protocol was developed to operate between hosts and programmable logic controllers. The controlling device, in most cases was a PLC (Programmable Logic Controller), which had the capability of detecting and storing fast events and indicating to the polling device that an event had occurred. The change detect feature was not part of the protocol, but part of the monitoring device (namely the Modicon PLC).

Utility devices require that no event is to be missed in the field IED. ABB has incorporated two methods in which a device is notified that events have occurred in the field IED between host polls. The two methods employed for 0x data (Modbus Function Code 01) are:

- ❑ MOMENTARY CHANGE DETECT
- ❑ LATCHED ELEMENT RETENTION

MOMENTARY CHANGE DETECT and LATCHED ELEMENT RETENTION are independent of the protocol. These ABB innovations allow Modbus protocol to address and satisfy the concerns common to a utility installation. The two functionality's are those in excess of the real time status access that Modbus function code 01 affords.

Momentary Change Detect status is incorporated using two bits to indicate present status and momentary indication status. The odd bit is the status bit and the even bit is the momentary bit. The status bit indicates the present state of the element accessed. The momentary bit indicates element transitioning more than once between IED reads. The momentary bit is set to a "1" if the element has transitioned more than once. The bit is reset upon a host access Addresses 02048 through 02161 are allocated for momentary change bit detect status detection. NOTE: MOMENTARY BITS MUST BE READ IN PAIRS.

An example of momentary change detect is illustrated in Figure 5-10. Suppose a host device monitors the REM 543 physical output bit 1. Figure 5-10 illustrates the physical output transitions of output 1. At each output rising edge/falling edge transition, the status of the Modbus coil 0x addresses are listed. The dotted line arrows indicate the poll received by the REM 543 and the state of both the status bit and the momentary indication bit. Note that the even bit (momentary change detect) resets itself to a zero state after a host read.

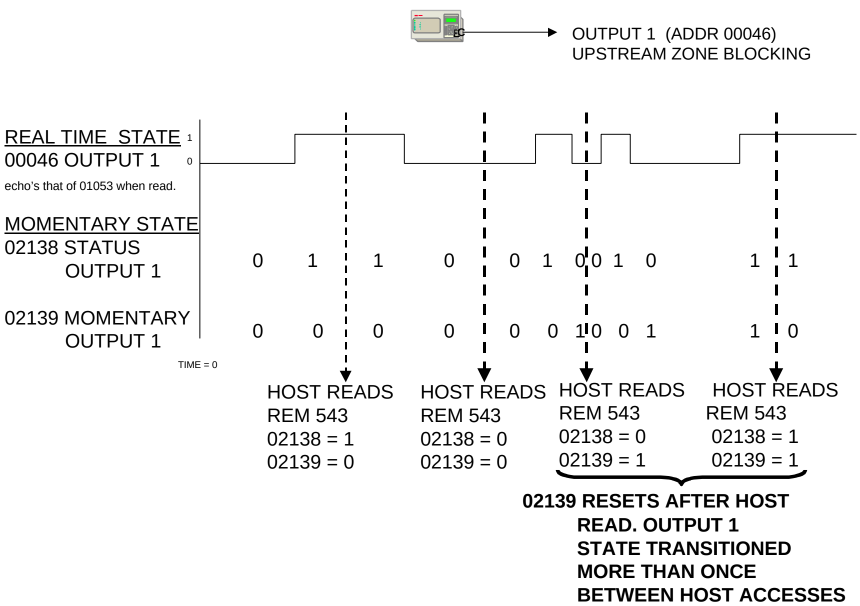


Figure 5-10. Momentary Change Detect Example

Latched Element Retention is a method by which when an element has transitions from a 0 (inactive), to a 1 (active) status, the element is set to "1". The element stays at a status of 1 until the operator executes a reset sequence. The reset of latched points may occur:

- ❑ Depress the "C", "E", keys simultaneously on the membrane keypad (REM 543)
- ❑ Initiate a supervisory bit reset sequence for the individual bits requiring reset. Reference Section 4 of this guide for a detailed explanation of the reset procedure.

Figure 5-11 illustrates the operation of a latched bit sequence. The LATCHED elements are denoted with the symbol **(L)** within the tables.

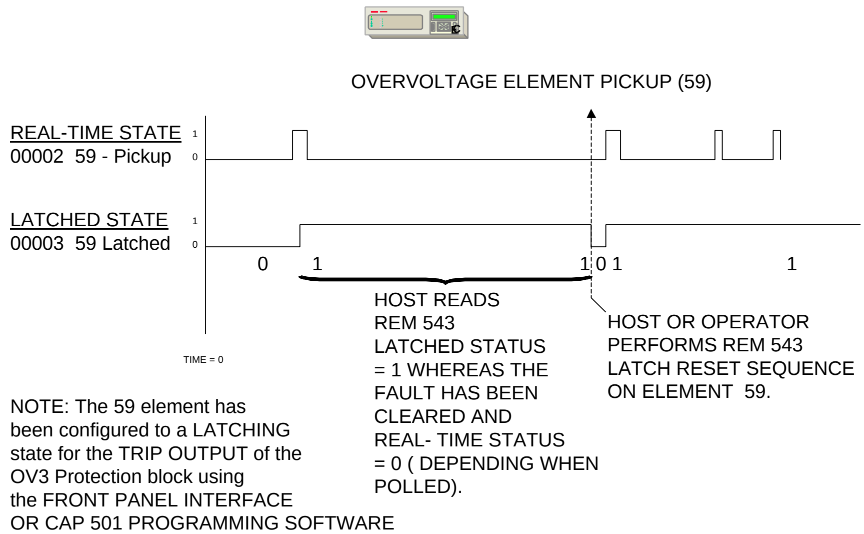


Figure 5-11. Latched Element Status Example

Logical Output Block (Single Bit Data) – 57 Discrete Coils (57 Elements Defined)

Relay Element Status as described in Table 5-1. Additional coil status has been added in the latest version of REM 543 executive firmware. Consult the symbol keys in the table for revision level feature inclusion.

The status information reported in Table 5-1 is reported as real time status bits. For example if the breaker is the process of tripping the status of 0052 and 00053 shall report the breaker action. If the status of 00052 or 00053 is polled after the trip or close has been completed, the status of these bits shall report a status of 0.

> **IMPLEMENTATION TIP-** If breaker status is to be required after the event occurs, it is advisable to read the seal in bits described in Table 5-1 (Address 02150 and 02151, Address 10027 or 12101 and 12102) could be polled to monitor the actual state of 52a. The polled state may then be saved and compared to the earlier values to determine whether a trip of close has occurred between device polls or in the case of reading momentary bits, the status of status changes between scans will be available.

Table 5-1. Real Time Output Modbus Address Map Definition

Modbus Address	ANSI Description	REM Protection Function Description	Comments
00001	87 Differential Output (L)	Diff 3 Output Trip	(See Note 1)
00002	59 Overvoltage Pickup	OV3 Low Output Start	
00003	59 Overvoltage (L)	OV3 Low Output Trip	(See Note 1)
00004	27 Undervoltage Pickup	UV3Low Output Start	
00005	27 Undervoltage (L)	UV3Low Output Trip	(See Note 1)
00006	37-1 Undercurrent Pickup	NUC3St1 Output Start	
00007	37-1 Undercurrent (L)	NUC3St1 Output Trip	(See Note 1)
00008	37-1 Undercurrent Alarm	NUC3St1 Output Alarm	
00009	50GS Non Directional Earth Fault Pickup	NEF1Low Output Start	
00010	50GS Non Directional Earth Fault (L)	NEF1Low Output Trip	(See Note 1)
00011	47 Phase Sequence Voltage Pickup	PSV3St1 Output Start	
00012	47 Phase Sequence Voltage (L)	PSV3St1 Output Trip	(See Note 1)
00013	46 Current Phase Unbalance Pickup	NPS3Low Output Start	
00014	46 Current Phase Unbalance (L)	NPS3Low Output Trip	(See Note 1)
00015	46 Current Phase Unbalance Block	NPS3Low Output Block	

Modbus Address	ANSI Description	REM Protection Function Description	Comments
00016	81-1 Under/Over Frequency (Inc Rate of Change) Stage 1 Pickup 1	Freq1St1 Output Start1	
00017	81-1 Under/Over Frequency (Inc Rate of Change) Stage 1 (L) 1	Freq1St1 Output Trip 1	(See Note 1)
00018	81-1 Under/Over Frequency (Inc Rate of Change) Stage 1 Pickup 2	Freq1St1 Output Start 2	
00019	81-1 Under/Over Frequency (Inc Rate of Change) Stage 1 (L) 2	Freq1St1 Output Trip 2	(See Note 1)
00020	81-2 Under/Over Frequency (Inc Rate of Change) Stage 2 Pickup 1	Freq1St2 Output Start 1	
00021	81-2 Under/Over Frequency (Inc Rate of Change) Stage 2 (L) 1	Freq1St2 Output Trip 1	(See Note 1)
00022	81-2 Under/Over Frequency (Inc Rate of Change) Stage 2 Pickup 2	Freq1St2 Output Start 2	
00023	81-2 Under/Over Frequency (Inc Rate of Change) Stage 2 (L) 2	Freq1St2 Output Trip 2	(See Note 1)
00024	50 Inst. 3 Phase Non Directional Overcurrent Pickup	NOC3Inst Output Start	
00025	50 Inst. 3 Phase Non Directional Overcurrent (L)	NOC3Inst Output Trip	(See Note 1)
00026	55 Power Factor Pickup	OPOW6St1 Output Start	
00027	55 Power Factor (L)	OPOW6St1 Output Trip	(See Note 1)
00028	51 Motor Pickup	MotStart Output Start	
00029	51 Motor (L)	MotStart Output Trip	(See Note 1)
00030	51 Motor Stall	MotStart Output Stall	
00031	Reserved	Reserved	
00032	Reserved	Reserved	
00033	Circuit Breaker Electric Wear Alarm	CMBWEAR1 Alarm state	
00034	Reserved	Reserved	
00035	Reserved	Reserved	
00036	Reserved	Reserved	
00037	Excessive Cycle/Time - Alarm	COCB1 Cycle Alarm	
00038	49 3 Phase Thermal Overload Pickup	TOL3Dev Output Start	
00039	49 3 Phase Thermal Overload (L)	TOL3Dev Output Trip	(See Note 1)
00040	Supervisory Current Input Alarm	CMCU3 Output Alarm	
00041	Supervisory Voltage Input Alarm	CMCV3 Output Alarm	
00042	Trip Circuit Supervisory 1 Trip Alarm	CMTCS1 Alarm state	
00043	Close Circuit Supervisory 2 Close Alarm	CMTCS2 Alarm state	
00044	Operation Time Counter Alarm	CMTIME1 Alarm state	
00045	Schedule Maintenance Alarm	CMSCHED Alarm state	
00046	Upstream Zone Blocking Coil	BIO1_5 Output 1 state	Physical Out 1
00047	Motor Start Indication Coil	BIO1_5 Output 2 state	Physical Out 2
00048	87 Diff or 50 Inst Overcurrent Trip Alarm Coil	BIO1_5 Output 3 state	Physical Out 3
00049	50GS Non Directional Earth Fault Trip Alarm Coil	BIO1_5 Output 4 state	Physical Out 4
00050	49T and 49 and 46 Thermal or Unbalance Trip Alarm Coil	BIO1_5 Output 5 state	Physical Out 5
00051	Motor Bearing and Winding Condition Monitoring Alarm Coil	BIO1_5 Output 6 state	Physical Out 6
00052	Trip Coil	PS1_4 Output 1 state	Physical High Speed Out 1
00053	Close Coil	PS1_4 Output 2 state	Physical High Speed Out 2

Modbus Address	ANSI Description	REM Protection Function Description	Comments
00054	Circuit Breaker Failure Alarm	PS1_4 Output 3 state	Physical High Speed Out 3
00055	Block/Start/Restart Enable	PS1_4 Output 4 state	Physical High Speed Out 4
00056	81-1 Under Frequency Stage 1 Alarm	PS1_4 Output 5 state	Physical High Speed Out 5
00057	Motor Fault Pickup Alarm	PS1_4 Output 6 state	Physical High Speed Out 6
00058	Block Restart	MotStart Output Restart	1 = OK to Restart 0 = Block Restart
Note 1: These elements must be configured in Cap Tools or via the front panel interface for the latch status of the device to be available.			

The physical outputs on the REM 543 are predefined for certain functions as listed in Table 5-1. There are two physical output cards in the REM 543, a Dry Contact physical output board and an Electronic High Speed Output board. The memory map lists the outputs as 1 through 6 for the Dry Contact Outputs and HS 1 through HS 6 for the high speed output contacts. The status of these outputs are available in the real time format (Coils 00046 through 00057) or in the Momentary Change Detect Format (0002138 to 02161).

Momentary Change Detect Status

As described above, momentary change detection is available for many of the output bits. The designation of each of the bits is described in Table 5-2.

Table 5-2. Momentary Change Detect Element Designations

Modbus Address	ANSI Description	REM Protection Function Description	Comments
02048	87 Differential Output (L)	Diff 3 Output Trip	(See Note 1)
02049	87 Differential Output (L) Momentary	Diff 3 Output Trip Change Detect	
02050	59 Overvoltage Pickup	OV3 Low Output Start	
02051	59 Overvoltage Pickup Momentary	OV3 Low Output Start Change Detect	
02052	59 Overvoltage (L)	OV3 Low Output Trip	(See Note 1)
02053	59 Overvoltage (L) Momentary	OV3 Low Output Trip Change Detect	
02054	27 Undervoltage Pickup	UV3Low Output Start	
02055	27 Undervoltage Momentary	UV3Low Output Start Change Detect	
02056	27 Undervoltage (L)	UV3Low Output Trip	(See Note 1)
02057	27 Undervoltage (L) Momentary	UV3Low Output Trip Change Detect	
02058	37-1 Undercurrent Pickup	NUC3St1 Output Start	
02059	37-1 Undercurrent Pickup Momentary	NUC3St1 Output Start Change Detect	
02060	37-1 Undercurrent (L)	NUC3St1 Output Trip	(See Note 1)
02061	37-1 Undercurrent (L) Momentary	NUC3St1 Output Trip Change Detect	
02062	37-1 Undercurrent Alarm	NUC3St1 Output Alarm	
02063	37-1 Undercurrent Alarm Momentary	NUC3St1 Output Alarm Change Detect	
02064	50GS Non Directional Earth Fault Pickup	NEF1Low Output Start	
02065	50GS Non Directional Earth Fault Pickup Momentary	NEF1Low Output Start Change Detect	

Modbus Address	ANSI Description	REM Protection Function Description	Comments
02066	50GS Non Directional Earth Fault (L)	NEF1Low Output Trip	(See Note 1)
02067	50GS Non Directional Earth Fault (L) Momentary	NEF1Low Output Trip Change Detect	
02068	47 Phase Sequence Voltage Pickup	PSV3St1 Output Start	
02069	47 Phase Sequence Voltage Pickup Momentary	PSV3St1 Output Start Change Detect	
02070	47 Phase Sequence Voltage (L)	PSV3St1 Output Trip	
02071	47 Phase Sequence Voltage (L) Momentary	PSV3St1 Output Trip Change Detect	
02072	46 Current Phase Unbalance Pickup	NPS3Low Output Start	
02073	46 Current Phase Unbalance Pickup Momentary	NPS3Low Output Start Change Detect Change Detect	
02074	46 Current Phase Unbalance (L)	NPS3Low Output Trip	
02075	46 Current Phase Unbalance (L) Momentary	NPS3Low Output Trip Change Detect	
02076	46 Current Phase Unbalance Block	NPS3Low Output Block	
02077	46 Current Phase Unbalance Block Momentary	NPS3Low Output Block Change Detect	
02078	81-1 Under/Over Frequency (Inc Rate of Change) Stage 1 Pickup 1	Freq1St1 Output Start 1	
02079	81-1 Under/Over Frequency (Inc Rate of Change) Stage 1 Pickup 1 Momentary	Freq1St1 Output Start 1 Change Detect	
02080	81-1 Under/Over Frequency (Inc Rate of Change) Stage 1 (L) 1	Freq1St1 Output Trip 1	(See Note 1)
02081	81-1 Under/Over Frequency (Inc Rate of Change) Stage 1 (L) 1 Momentary	Freq1St1 Output Trip 1 Change Detect	
02082	81-1 Under/Over Frequency (Inc Rate of Change) Stage 1 PICKUP 2	Freq1St1 Output Start 2	
02083	81-1 Under/Over Frequency (Inc Rate of Change) Stage 1 PICKUP 2 Momentary	Freq1St1 Output Start 2 Change Detect	
02084	81-1 Under/Over Frequency (Inc Rate of Change) Stage 1 (L) 2	Freq1St1 Output Trip 2	(See Note 1)
02085	81-1 Under/Over Frequency (Inc Rate of Change) Stage 1 (L) 2 Momentary	Freq1St1 Output Trip 2 Change Detect	
02086	81-2 Under/Over Frequency (Inc Rate of Change) Stage 2 Pickup 1	Freq1St2 Output Start 1	
02087	81-2 Under/Over Frequency (Inc Rate of Change) Stage 2 Pickup 1 Momentary	Freq1St2 Output Start 1 Change Detect	
02088	81-2 Under/Over Frequency (Inc Rate of Change) Stage 2 (L) 1	Freq1St2 Output Trip 1	(See Note 1)
02089	81-2 Under/Over Frequency (Inc Rate of Change) Stage 2 (L) 1 Momentary	Freq1St2 Output Trip 1 Change Detect	
02090	81-2 Under/Over Frequency (Inc Rate of Change) Stage 2 Pickup 2	Freq1St2 Output Start 2	
02091	81-2 Under/Over Frequency (Inc Rate of Change) Stage 2 Pickup 2 Momentary	Freq1St2 Output Start 2 Change Detect	
02092	81-2 Under/Over Frequency (Inc Rate of Change) Stage 2 (L) 2	Freq1St2 Output Trip 2	(See Note 1)
02093	81-2 Under/Over Frequency (Inc Rate of Change) Stage 2 (L) 2 Momentary	Freq1St2 Output Trip 2 Change Detect	
02094	50 Inst. 3 Phase Non Directional Overcurrent Pickup	NOC3Inst Output Start	
02095	50 Inst. 3 Phase Non Directional Overcurrent Pickup Momentary	NOC3Inst Output Start Change Detect	

Modbus Address	ANSI Description	REM Protection Function Description	Comments
02096	50 Inst. 3 Phase Non Directional Overcurrent (L)	NOC3Inst Output Trip	(See Note 1)
02097	50 Inst. 3 Phase Non Directional Overcurrent (L) Momentary	NOC3Inst Output Trip Change Detect	
02098	55 Power Factor Pickup	OPOW6St1 Output Start	
02099	55 Power Factor Pickup Momentary	OPOW6St1 Output Start Change Detect	
02100	55 Power Factor (L)	OPOW6St1 Output Trip	(See Note 1)
02101	55 Power Factor (L) Momentary	OPOW6St1 Output Trip Change Detect	
02102	51 Motor Pickup	MotStart Output Start	
02103	51 Motor Pickup Momentary	MotStart Output Start Change Detect	
02104	51 Motor (L)	MotStart Output Trip	(See Note 1)
02105	51 Motor (L) Momentary	MotStart Output Trip Change Detect	
02106	51 Motor Stall	MotStart Output Stall	
02107	51 Motor Stall Momentary	MotStart Output Stall Change Detect	
02108	Reserved	Reserved	
02109	Reserved	Reserved	
02110	Reserved	Reserved	
02111	Reserved	Reserved	
02112	Circuit Breaker Electric Wear ALARM	CMBWEAR1 Alarm state	
02113	Circuit Breaker Electric Wear ALARM Momentary	CMBWEAR1 Alarm state Change Detect	
02114	Reserved	Reserved	
02115	Reserved	Reserved	
02116	Reserved	Reserved	
02117	Reserved	Reserved	
02118	Reserved	Reserved	
02119	Reserved	Reserved	
02120	Excessive Cycle/Time - Alarm	COCB1 Cycle Alarm	
02121	Excessive Cycle/Time - Alarm Momentary	COCB1 Cycle Alarm Change Detect	
02122	49 3 Phase Thermal Overload Pickup	TOL3Dev Output Start	
02123	49 3 Phase Thermal Overload Pickup Momentary	TOL3Dev Output Start Change Detect	
02124	49 3 Phase Thermal Overload (L)	TOL3Dev Output Trip	(See Note 1)
02125	49 3 Phase Thermal Overload (L) Momentary	TOL3Dev Output Trip Change Detect	
02126	Supervisory Current Input Alarm	CMCU3 Output Alarm	
02127	Supervisory Current Input Alarm Momentary	CMCU3 Output Alarm Change Detect	
02128	Supervisory Voltage Input Alarm	CMCV3 Output Alarm	
02129	Supervisory Voltage Input Alarm Momentary	CMCV3 Output Alarm Change Detect	
02130	Trip Circuit Supervisory 1 Trip Alarm	CMTCS1 Alarm state	
02131	Trip Circuit Supervisory 1 Trip Alarm Momentary	CMTCS1 Alarm state Change Detect	
02132	Close Circuit Supervisory 2 Close Alarm	CMTCS2 Alarm state	
02133	Close Circuit Supervisory 2 Close Alarm Momentary	CMTCS2 Alarm state Change Detect	
02134	Operation Time Counter Alarm	CMTIME1 Alarm state	

Modbus Address	ANSI Description	REM Protection Function Description	Comments
02135	Operation Time Counter Alarm Momentary	CMTIME1 Alarm state Change Detect	
02136	Schedule Maintenance Alarm	CMSCHED Alarm state	
02137	Schedule Maintenance Alarm Momentary	CMSCHED Alarm state Change Detect	
02138	Upstream Zone Blocking Coil	BIO1_5 Output 1 state	Physical Out 1
02139	Upstream Zone Blocking Coil Momentary	BIO1_5 Output 1 state Change Detect	
02140	Motor Start Indication Coil	BIO1_5 Output 2 state	Physical Out 2
02141	Motor Start Indication Coil Momentary	BIO1_5 Output 2 state Change Detect	
02142	87 Diff or 50 Inst Overcurrent Trip Alarm Coil	BIO1_5 Output 3 state	Physical Out 3
02143	87 Diff or 50 Inst Overcurrent Trip Alarm Coil Momentary	BIO1_5 Output 3 state Change Detect	
02144	50GS Non Directional Earth Fault Trip Alarm Coil	BIO1_5 Output 4 state	Physical Out 4
02145	50GS Non Directional Earth Fault Trip Alarm Coil Momentary	BIO1_5 Output 4 state Change Detect	
02146	49T and 49 and 46 Thermal or Unbalance Trip Alarm Coil	BIO1_5 Output 5 state	Physical Out 5
02147	49T and 49 and 46 Thermal or Unbalance Trip Alarm Coil Momentary	BIO1_5 Output 5 state Change Detect	
02148	Motor Bearing and Winding Condition Monitoring Alarm Coil	BIO1_5 Output 6 state	Physical Out 6
02149	Motor Bearing and Winding Condition Monitoring Alarm Coil Momentary	BIO1_5 Output 6 state Change Detect	
02150	Trip Coil	PS1_4 Output 1 state	Physical High Speed Out 1
02151	Trip Coil Momentary	PS1_4 Output 1 state Change Detect	
02152	Close Coil	PS1_4 Output 2 state	Physical High Speed Out 2
02153	Close Coil Momentary	PS1_4 Output 2 state Change Detect	
02154	Circuit Breaker Failure Alarm	PS1_4 Output 3 state	Physical High Speed Out 3
02155	Circuit Breaker Failure Alarm Momentary	PS1_4 Output 3 state Change Detect	
02156	Block/Start/Restart Enable	PS1_4 Output 4 state	Physical High Speed Out 4
02157	Block/Start/Restart Enable Momentary	PS1_4 Output 4 state Change Detect	
02158	81-1 Under Frequency Stage 1 Alarm	PS1_4 Output 5 state	Physical High Speed Out 5
02159	81-1 Under Frequency Stage 1 Alarm Momentary	PS1_4 Output 5 state Change Detect	
02160	Motor Fault Pickup Alarm	PS1_4 Output 6 state	Physical High Speed Out 6
02161	Motor Fault Pickup Alarm Momentary	PS1_4 Output 6 state Change Detect	
Note 1: Output elements must be configured via Cap Tools or the front panel interface for trip element being latched instead of momentary.			

Latching Element Configuration

Within Tables 5-1 and 5-2, several elements are designated as (L) for latched. The Latched status is configured via the front panel interface of the REM 543 or via the CAP 501 configuration package. What follows is an explanation of the configuration process for each of the methods.

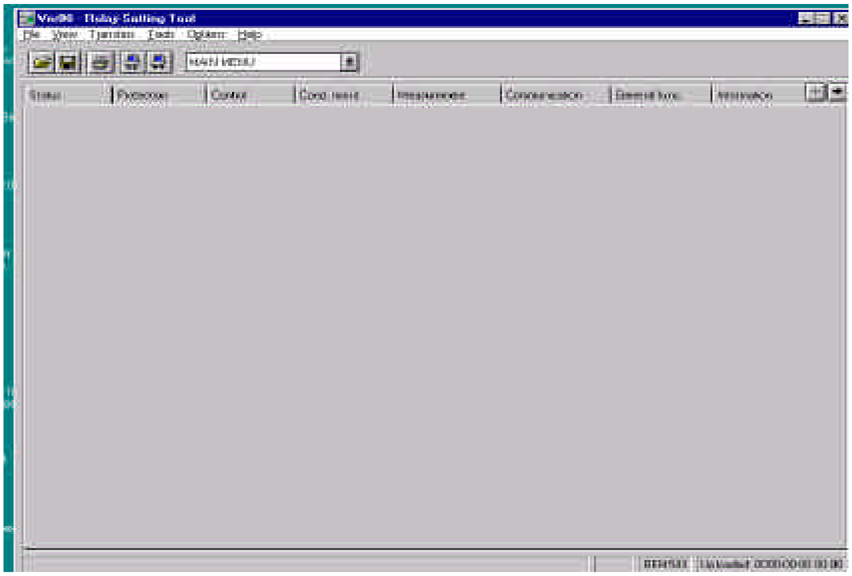


Figure 5-12. Initial CAP 501 Block Configuration Screen

After selecting the project for the REM 543, the initial configuration screen is visible as illustrated in Figure 5-12.

Select the Protection tab visible on the Window. From that selection the blocks available in the REM 543 are visible. Each one of the protection blocks is represented by a tab visible on the screen as illustrated in Figure 5-13.

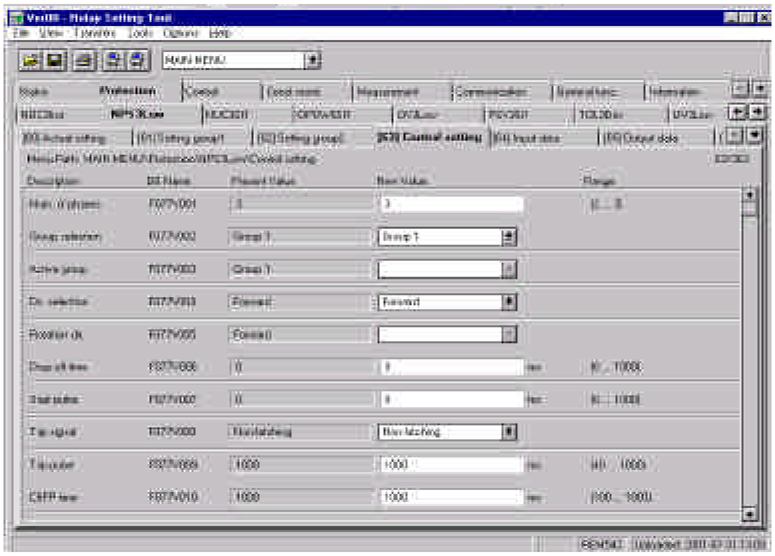


Figure 5-13. Protection Tab Options for Each Protection Element Block

For this example, the NPS 3 Low block has been selected and the TRIP signal shall be selected for LATCH or NON-LATCH configuration. This procedure shall configure the 46 Element as defined in the memory map element 00014 Modbus Address as shown in Table 5-1. The protection blocks shown in the REM 543 are listed for each of the signals beneath the heading “REM PROTECTION FUNCTION DESCRIPTION” as defined in Tables 5-1 and 5-2.

The Trip signal is at a default state of Non-Latching. Select the Pull down box for the TRIP Signal to which a LATCHING or NON –LATCHING state shall be visible.

Select the LATCHING selection from the pull down menu. Exit the menu and when the configuration has been downloaded to the REM 543, the signal shall be reported as a latched signal when read from the Modbus address 00014 – 46 Current Phase Unbalance. NOTE EACH ELEMENT MUST BE CONFIGURED FOR LATCH CAPABILITY TO MATCH THE CAPABILITIES SHOWN IN THE TABLE.

To configure the element to a latched state via the REM 543 FPI (Front Panel Interface), the following steps should be followed to configure an element.

Follow these steps to configure the 50 - Instantaneous 3 Phase Non Directional Overcurrent Protection Element (Modbus Element 00025):

1. Press “E” until “ENTER PASSWORD” appears at the bottom of the relay display (assisting window). Using the up arrows set the password to 3 (default value) and press “E”. MAIN MENU is entered starting with Status;
2. Using the up and down navigation keys, highlight the Protection;
3. Press the right navigation key, Protection menu starting with Diff3 is entered;
4. Highlight the NOC3Inst using up and down navigation keys;
5. Press the right navigation key, NOC3Inst menu starting with Actual setting is entered;
6. Enter the setting highlighting the “CONTROL SETTING” and press the right navigation key. The CONTROL SETTING menu is entered;
7. Press Enter “E” to set NOC3Inst to default value, i.e. “Operation Mode = Definite Time”, accept setting by pressing “E”. “Start Current = 0.10 In[1]”, “Operate Time = 0.05s”. Default password is = 1;
8. From the NOC3Inst enter and set the TRIP Control Setting to a LATCHED state functionality.
9. Exit the menu and save the changed configuration.

This procedure may be used to configure the each of the elements as defined in Tables 5-1 and 5-2.

1X Discrete Contact Inputs

Discrete physical input and relay element status are available via a function 02 request through Modbus. Figure 5-14 illustrates a typical command sequence. The Host polls the REM 543 for the Data. The REM 543 receives the request and responds with the expected data. The Host then interprets the command response, checks the checksum and then displays the interpreted data. If the node is configured for RTU Modbus, the start of message character is three character delays, and the end of message consists of a CRC-16 checksum and three character delays. Additional information is available in Modicon’s protocol manual references listed at the beginning of this document. The same information is available through a 4X register read command, which allows a host without 1X data accesses capabilities to obtain physical input and relay element information. Tables 5-1 through 5-2 list the 1X discrete contact memory map as defined for Modbus RTU and ASCII.

Function Code 2 -Read Input Status (Read Only Data)

Figure 5-14 illustrates the command format required for execution of function code 2.

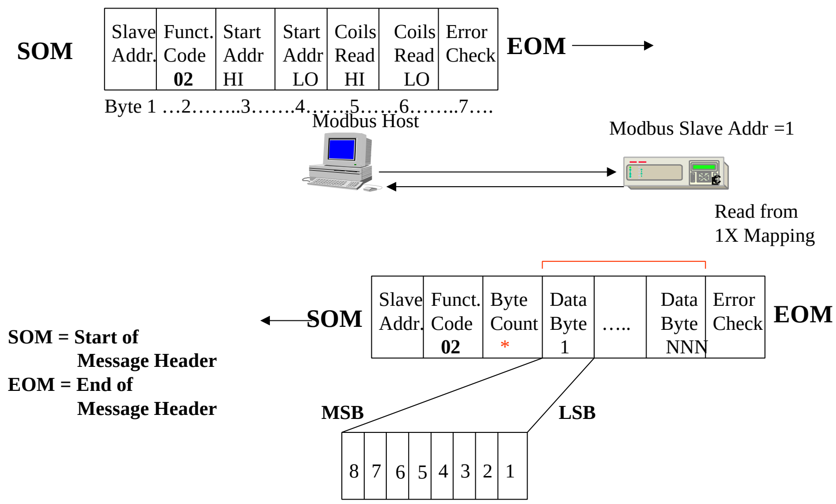


Figure 5-14. 1X Input Request Using Modbus Command 02

It should be noted that every REM 543 allows real time status reporting when the unit is polled. If a status is momentary and is missed during the host poll, then the data is lost. Polling using the status Momentary Change Detect Feature insures that the host device does not miss the momentary change. It should also be noted that data requested from 1X data address ranges not defined within this document generates Modbus exception codes.

Utility devices require that no event is to be missed in the field IED. ABB has incorporated two methods in which a device is notified that events have occurred in the field IED between host polls. The two methods employed for 1x data (Modbus Function Code 02) are:

- ❑ MOMENTARY CHANGE DETECT

MOMENTARY CHANGE DETECT is independent of the protocol. These ABB innovations allow Modbus protocol to address and satisfy the concerns common to a utility installation. The two functionality's are those in excess of the real time status access that Modbus function code 02 affords.

Momentary Change Detect status is incorporated using two bits to indicate present status and momentary indication status. The odd bit is the status bit and the even bit is the momentary bit. The status bit indicates the present state of the element accessed. The momentary bit indicates element transitioning more than once between IED reads. The momentary bit is set to a "1" if the element has transitioned more than once. The bit is reset upon a host access Addresses 12048 through 12136 are allocated for momentary change bit detect status detection. NOTE: MOMENTARY BITS MUST BE READ IN PAIRS.

An example of momentary change detect is illustrated in Figure 5-15. Suppose a host device monitors REM 543 physical input bit 1. Figure 5-15 illustrates the physical input transitions of input 1. At each field voltage rising edge/falling edge transition, the status of the Modbus contact 1x addresses are listed. The dotted line arrows indicate the poll received by the REM 543 and the state of both the status bit and the momentary indication bit. Note that the even bit (momentary change detect) resets itself to a zero state after a host read.

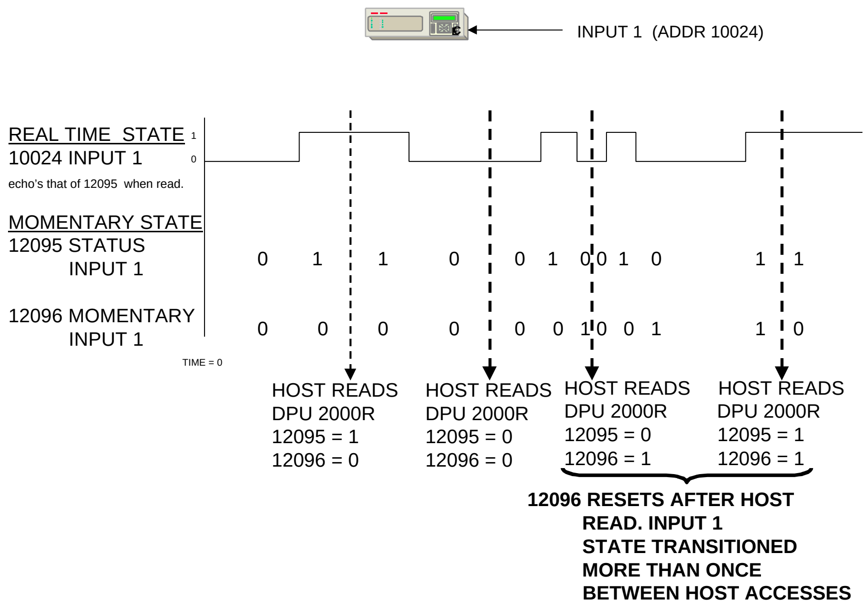


Figure 5-15. Momentary Change Detect Example

Input Status (59 Elements Defined)

This section of relay information allows access of relay element data. Some of the status bit information reported in 1X discrete response is available as 0X-register definition table. All of the individual information is available in the 4X-register definition table (Modbus Function Code 03). Table 5-3 lists the discrete point address assignment for physical inputs and control elements within the REM 543

Listed in Table 5-3 is both the ANSI description of each signal as well as the IEC function block signal from which each signal is derived. The data list is comprised of logical data, Alarm status, as well as physical input signal status bits of hardwired devices.

As also illustrated, the input terminals for the REM 543 are predefined in their mapping functionality. Different Inputs are defined to be wired to specific input signals. Additionally, certain addresses report the signal state depending upon the REM 543 model. An example of this is temperature signals which report the signal state for REM 543 Models 1 and 2. If one reads temperature alarm statuses from a REM 543 Model 3, a value of 0 will be reported for these alarm points.

Table 5-3. Static 1X Input Status Data Map

Modbus Address	ANSI Description	REM Protection Function Description	Comments
10001	87 Differential Blocked	Diff3 Input Block	
10002	27 Undervoltage Input BS 1 Enabled	UV3Low Input BS1	
10003	37-1 Undercurrent Stage 1 Externally Blocked	NUC3St1 Extern. Block	
10004	50 GS Non Directional Earth Fault Element Enabled	NEF1Low Input BS1	
10005	81-1 Under/Over Frequency (Inc. Rate of Change) Stage 1 Enabled	Freq1St1 Input BS1	
10006	81-2 Under/Over Frequency (Inc. Rate of Change) Stage 2 Enabled	Freq1St2 Input BS1	
10007	50-3 Instantaneous 3 Phase Non Directional Overcurrent Element Enabled	NOC3Inst Input BS1	

Modbus Address	ANSI Description	REM Protection Function Description	Comments
10008	52a Status	COCB1 Object state closed	
10009	52b Status	COCB1 Object state open	
10010	Breaker Fault	COCB1 Object state faulty	
10011	Motor Running	COIND8 Object state closed	
10012	Motor Stopped	COIND8 Object state open	
10013	Winding Temp Phase A Out Of Range Alarm	MEAI1 Input invalid 1 = Input Invalid 0 = Input Valid	0 for Model 3 Valid Model 1,2
10014	Winding Temp Phase B Out Of Range Alarm	MEAI2 Input invalid 1 = Input Invalid 0 = Input Valid	0 for Model 3 Valid Model 1,2
10015	Winding Temp Phase C Out Of Range Alarm	MEAI3 Input invalid 1 = Input Invalid 0 = Input Valid	0 for Model 3 Valid Model 1,2
10016	Motor Bearing Temp 1 Out Of Range Alarm	MEAI4 Input invalid 1 = Input Invalid 0 = Input Valid	0 for Model 3 Valid Model 1,2
10017	Motor Bearing Temp 2 Out Of Range Alarm	MEAI5 Input invalid 1 = Input Invalid 0 = Input Valid	0 for Model 3 Valid Model 1,2
10018	Load Bearing Temp1 Out Of Range Alarm	MEAI6 Input invalid 1 = Input Invalid 0 = Input Valid	0 for Model 3 Valid Model 1,2
10019	Load Bearing Temp2 Out Of Range Alarm	MEAI7 Input invalid 1 = Input Invalid 0 = Input Valid	0 for Model 2 Valid Model 1
10020	Ambient Temperature Out of Range Alarm	MEAI8 Input Invalid 1 = Input Invalid 0 = Input Valid	0 for Model 3 Valid Model 1,2
10021	Close Circuit Supervision Blocked	CMTCS1 BS state	
10022	Trip Circuit Supervision Blocked	CMTCS2 BS state	
10023	Motor Operation Time Monitoring Enabled	CMTIME1 BININP state	
10024	Open Command [Input 1]	BIO1_5 Input 1 state	
10025	Closed Command [Input 2]	BIO1_5 Input 2 state	
10026	49 Override Thermal Overload [Input 3]	BIO1_5 Input 3 state	
10027	52A Status [Input 4]	BIO1_5 Input 4 state	
10028	Extended Emergency Trip [Input 5]	BIO1_5 Input 5 state	
10029	Reserved [Input 6]	BIO1_5 Input 6 state	Customer Use
10030	Reserved [Input 7]	BIO1_5 Input 7 state	Customer Use
10031	Reserved [Input 8]	BIO1_5 Input 8 state	Customer Use
10032	Speed Switch [Input 9]	BIO1_5 Input 9 state	
10033	Restart Inhibit [Input 10]	BIO1_5 Input 10 state	
10034	37 External Blocking for Undercurrent [Input 11]	BIO1_5 Input 11 state	
10035	Reserved [Input 12]	BIO1_5 Input 12 state	Customer Use
10036	Open Command [Input 1] Signal Valid	BIO1_5 Input 1 state Valid	1 = Input Valid 0 = Input Invalid
10037	Closed Command [Input 2] Signal Valid	BIO1_5 Input 2 state Valid	1 = Input Valid 0 = Input Invalid
10038	49 Override Thermal Overlaod [Input 3] Signal Valid	BIO1_5 Input 3 state Valid	1 = Input Valid 0 = Input Invalid
10039	52A Status [Input 4] Signal Valid	BIO1_5 Input 4 state Valid	1 = Input Valid 0 = Input Invalid
10040	Extended Emergency Trip [Input 5]	BIO1_5 Input 5 state Valid	1 = Input Valid

Modbus Address	ANSI Description	REM Protection Function Description	Comments
	Signal Valid		0 = Input Invalid
10041	Reserved [Input 6] Signal Valid	BIO1_5 Input 6 state Valid	1 = Input Valid 0 = Input Invalid
10042	Reserved [Input 7] Signal Valid	BIO1_5 Input 7 state Valid	1 = Input Valid 0 = Input Invalid
10043	Reserved [Input 8] Signal Valid	BIO1_5 Input 8 state Valid	1 = Input Valid 0 = Input Invalid
10044	Speed Switch [Input 9] Signal Valid	BIO1_5 Input 9 state Valid	1 = Input Valid 0 = Input Invalid
10045	Restart Inhibit [Input 10] Signal Valid	BIO1_5 Input 10 state Valid	1 = Input Valid 0 = Input Invalid
10046	37 External Blocking for Undercurrent [Input 11] Signal Valid	BIO1_5 Input 11 state Valid	1 = Input Valid 0 = Input Invalid
10047	Reserved [Input 12] Signal Valid	BIO1_5 Input 12 state Valid	1 = Input Valid 0 = Input Invalid
10048	[HSI Input 1] Reserved	PS1_4 Input 1 state	
10049	[HSI Input 2] Reserved	PS1_4 Input 2 state	
10050	[HSI Input 3] Reserved	PS1_4 Input 3 state	
10051	Trip Circuit Supervision Enabled	PS1_4 TCS 1 state	
10052	Close Circuit Supervision State	PS1_4 TCS 2 state	
10053	Relay Over Temperature Indicator	PS1_4 TCS 2 Over Tmp	
10054	Power Supply Failure	PS1_4 TCS 2 AC Fail	1 = Valid 0 = Invalid
10055	[HSI Input 1] Reserved	PS1_4 Input 1 state	1 = Valid 0 = Invalid
10056	[HSI Input 2] Reserved	PS1_4 Input 2 state	1 = Valid 0 = Invalid
10057	[HSI Input 3] Reserved	PS1_4 Input 3 state	1 = Valid 0 = Invalid
10058	Local/Remote Control Status	Glovar A 1 = Local Control 0 = Remote Control	
10059	Enable Restart	TOL3Dev Output Restart	0 = Disabled 1 = Enabled

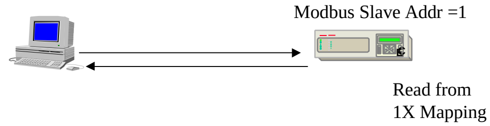
Momentary Change Detect Logical Inputs (88 Elements Defined)

Whereas the information presented in Tables 5-3 illustrate the real time status of the designated data points, the status in Table 5-4 lists the data in Momentary Change Detect status. The momentary change detect decoding follows the same philosophy as that presented in Section 5 for the 0X logical and physical data presentation.

Application Example: Obtain the Breaker Status from REM 543 Address 1. The relay status is available from inputs 12061 and 12062 using Momentary Change Detect Bits. Figures 5-16 and 5-17 illustrate the polling sequence and raw data returned over the network utilizing function code 02 using Momentary change detect notification.

Function 02 - Read Input Status

Example - Read Breaker Status 52 a.. Although only 2 data bits are needed, 16 shall be read.

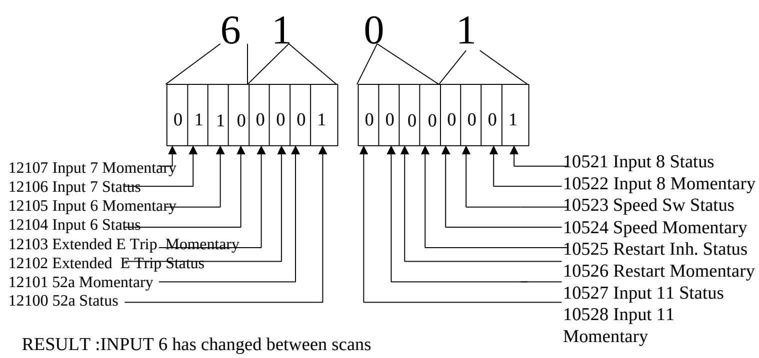


Host Sends : 01 02 08 33 00 10 78 7E   Modbus RTU Mode Used
Node Addr = 01
Function = 02
Data Address = 2100 (which is 2099 [Modbus is offset by 1] in hex =0833)
Amount of Data Requested = 16 Inputs
CRC-16 Checksum = 78 7E
Relay Responds: 01 02 02 61 01 51 E8
Addr = 01
Function = 02
Data Bytes Received = 2
Data Received = 61 01
CRC - 16 Checksum = 51 E8

Figure 5-16. Read Input Breaker Status Example

Function 02- Read Input Status

Example - Analysis of Data Received



RESULT :INPUT 6 has changed between scans
All other inputs have remained the same between scans.

Figure 5-17. Decode of Raw Data Bits as Seen on Data Scope Analyzer

Table 5-4. REM 543 1X Momentary Change Detect Bit Status

Modbus Address	ANSI Description	REM Protection Function Description	Comments
12048	87 Differential Blocked	Diff3 Input Block	
12049	87 Differential Blocked Momentary	Diff3 Input Block	
12050	27 Undervoltage Input BS 1 Enabled	UV3Low Input BS1	
12051	27 Undervoltage Input BS 1 Enabled Momentary	UV3Low Input BS1 Momentary	
12052	37-1 Undercurrent Stage 1 Externally Blocked	NUC3St1 Extern. Block	
12053	37-1 Undercurrent Stage 1 Externally Blocked Momentary	NUC3St1 Extern. Block Momentary	
12054	50 GS Non Directional Earth Fault	NEF1Low Input BS1	

Modbus Address	ANSI Description	REM Protection Function Description	Comments
	Element BS1 Enabled		
12055	50 GS Non Directional Earth Fault Element BS1 Enabled Momentary	NEF1Low Input BS1 Momentary	
12056	81-1 Under/Over Frequency (Inc. Rate of Change) Stage 1 Enabled	Freq1St1 Input BS1	
12057	81-1 Under/Over Frequency (Inc. Rate of Change) Stage 1 Enabled Momentary	Freq1St1 Input BS1Momentary	
12058	81-2 Under/Over Frequency (Inc. Rate of Change) Stage 2 Enabled	Freq1St2 Input BS1	
12059	81-2 Under/Over Frequency (Inc. Rate of Change) Stage 2 Enabled Momentary	Freq1St2 Input BS1 Momentary	
12060	50-3 Instantaneous 3 Phase Non Directional Overcurrent Element Enabled	NOC3Inst Input BS1	
12061	50-3 Instantaneous 3 Phase Non Directional Overcurrent Element Enabled Momentary	NOC3Inst Input BS1 Momentary	
12062	52a Status	COCB1 Object state closed	
12063	52a Status Momentary	COCB1 Object state closed Momentary	
12064	52b Status	COCB1 Object state open	
12065	52b Status Momentary	COCB1 Object state open Momentary	
12066	Breaker Fault	COCB1 Object state faulty	
12067	Breaker Fault Momentary	COCB1 Object state faulty Momentary	
12068	Motor Running	COIND8 Object state closed	
12069	Motor Running Momentary	COIND8 Object state closed Momentary	
12070	Motor Stopped	COIND8 Object state open	
12071	Motor Stopped Momentary	COIND8 Object state open Momentary	
12072	Motor Operation Fault (L)	COIND8 IV state	
12073	Motor Operation Fault (L) Momentary	COIND8 IV state Momentary	
12074	Winding Temp Phase A Out Of Range Alarm	MEAI1 Input	0 for Model 3 Valid Model 1,2
12075	Winding Temp Phase A Out Of Range Alarm Momentary	MEAI1 Input Momentary	0 for Model 3 Valid Model 1,2
12076	Winding Temp Phase B Out Of Range Alarm	MEAI2 Input	0 for Model 3 Valid Model 1,2
12077	Winding Temp Phase B Out Of Range Alarm Momentary	MEAI2 Input Momentary	0 for Model 3 Valid Model 1,2
12078	Winding Temp Phase C Out Of Range Alarm	MEAI3 Input	0 for Model 3 Valid Model 1,2
12079	Winding Temp Phase C Out Of Range Alarm Momentary	MEAI3 Input Momentary	0 for Model 3 Valid Model 1,2
12080	Motor Bearing Temp 1 Out Of Range Alarm	MEAI4 Input invalid	0 for Model 3 Valid Model 1,2
12081	Motor Bearing Temp 1 Out Of Range Alarm Momentary	MEAI4 Input invalid Momentary	0 for Model 3 Valid Model 1,2
12082	Motor Bearing Temp 2 Out Of Range Alarm	MEAI5 Input invalid	0 for Model 3 Valid Model 1,2

Modbus Address	ANSI Description	REM Protection Function Description	Comments
12083	Motor Bearing Temp 2 Out Of Range Alarm Momentary	MEAI5 Input invalid Momentary	0 for Model 3 Valid Model 1,2
12084	Load Bearing Temp1 Out Of Range Alarm	MEAI6 Input invalid	0 for Model 3 Valid Model 1,2
12085	Load Bearing Temp1 Out Of Range Alarm Momentary	MEAI6 Input invalid Momentary	0 for Model 3 Valid Model 1,2
12086	Load Bearing Temp2 Out Of Range Alarm	MEAI7 Input invalid	0 for Model 3 Valid Model 1,2
12087	Load Bearing Temp2 Out Of Range Alarm Momentary	MEAI7 Input invalid Momentary	0 for Model 3 Valid Model 1,2
12088	Ambient Temperature Out of Range Alarm	MEAI8 Input Invalid	0 for Model 3 Valid Model 1,2
12089	Ambient Temperature Out of Range Alarm Momentary	MEAI8 Input Invalid Momentary	0 for Model 3 Valid Model 1,2
12090	Trip Circuit Supervision Blocked	CMTCS1 BS state	
12091	Trip Circuit Supervision Blocked Momentary	CMTCS1 BS state Momentary	
12092	Close Circuit Supervision Blocked	CMTCS2 BS state	
12093	Close Circuit Supervision Blocked Momentary	CMTCS2 BS state Momentary	
12094	Closed Circuit SupervisionBlocked	CMTIME1 BININP state	
12095	Closed Circuit Supervision Blocked Momentary	CMTIME1 BININP state Momentary	
12096	Open Command [Input 1]	BIO1_5 Input 1 state	
12097	Open Command [Input 1] Momentary	BIO1_5 Input 1 state Momentary	
12098	Closed Command [Input 2]	BIO1_5 Input 2 state	
12099	Closed Command [Input 2] Momentary	BIO1_5 Input 2 state Momentary	
12100	49 Override Thermal Overload [Input 3]	BIO1_5 Input 3 state	
12101	49 Override Thermal Overload [Input 3] Momentary	BIO1_5 Input 3 state Momentary	
12102	52A Status [Input 4]	BIO1_5 Input 4 state	
12103	52A Status [Input 4] Momentary	BIO1_5 Input 4 state Momentary	
12104	Extended Emergency Trip [Input 5]	BIO1_5 Input 5 state	
12105	Extended Emergency Trip [Input 5] Momentary	BIO1_5 Input 5 state Momentary	
12106	[Input 6]	BIO1_5 Input 6 state	
12107	[Input 6] Momentary	BIO1_5 Input 6 state Momentary	
12108	[Input 7]	BIO1_5 Input 7 state	
12109	[Input 7] Mometary	BIO1_5 Input 7 state Momentary	
12110	[Input 8]	BIO1_5 Input 8 state	
12111	[Input 8] Momentary	BIO1_5 Input 8 state Momentary	
12112	Speed Switch [Input 9]	BIO1_5 Input 9 state	
12113	Speed Switch [Input 9] Momentary	BIO1_5 Input 9 state Momentary	
12114	Restart Inhibit [Input 10]	BIO1_5 Input 10 state	
12115	Restart Inhibit [Input 10] Momentary	BIO1_5 Input 10 state Momentary	
12116	37 External Blocking for	BIO1_5 Input 11 state	

Modbus Address	ANSI Description	REM Protection Function Description	Comments
	Undercurrent [Input 11]		
12117	37 External Blocking for Undercurrent [Input 11] Momentary	BIO1_5 Input 11 state Momentary	
12118	[Input 12]	BIO1_5 Input 12 state	Customer Use
12119	[Input 12] Momentary	BIO1_5 Input 12 state Momentary	
12120	Open Command [Input 1] Physical Input State Valid	BIO1_5 Input 1 state	
12121	Open Command [Input 1] Physcial Input State Valid Momentary	BIO1_5 Input 1 state Momentary	
12122	Closed Command [Input 2] Physical Input State Valid	BIO1_5 Input 2 state	
12123	Closed Command [Input 2] Physical Input State Valid Momentary	BIO1_5 Input 2 state Momentary	
12124	49 Override Thermal Overload [Input 3] Physical Input State Valid	BIO1_5 Input 3 state	
12125	49 Override Thermal Overload [Input 3] Physical Input State Valid Momentary	BIO1_5 Input 3 state Momentary	
12126	52A Status [Input 4] Physical Input State Valid	BIO1_5 Input 4 state	
12127	52A Status [Input 4] Physical Input State Valid Momentary	BIO1_5 Input 4 state Momentary	
12128	Extended Emergency Trip [Input 5] Physcial Input State Valid	BIO1_5 Input 5 state	
12129	Extended Emergency Trip [Input 5] Physcial Input State Valid Momentary	BIO1_5 Input 5 state Momentary	
12130	[Input 6] Physical Input State Valid	BIO1_5 Input 6 state	
12131	[Input 6] Physical Input State Valid Momentary	BIO1_5 Input 6 state Momentary	
12132	[Input 7] Physical Input State Valid	BIO1_5 Input 7 state	
12133	[Input 7] Physical Input State Valid Mometary	BIO1_5 Input 7 state Momentary	
12134	[Input 8] Physical Input State Valid	BIO1_5 Input 8 state	
12135	[Input 8] Physical Input State Valid Momentary	BIO1_5 Input 8 state Momentary	
12136	Speed Switch [Input 9] Physical Input State Valid	BIO1_5 Input 9 state	
12137	Speed Switch [Input 9] Physical Input State Valid Momentary	BIO1_5 Input 9 state Momentary	
12138	Restart Inhibit [Input 10] Physical Input State Valid	BIO1_5 Input 10 state	
12139	Restart Inhibit [Input 10] Physical Input State Valid Momentary	BIO1_5 Input 10 state Momentary	
12140	37 External Blocking for Undercurrent [Input 11] Physical Input State Valid	BIO1_5 Input 11 state	
12141	37 External Blocking for Undercurrent [Input 11] Physical Input State Valid Momentary	BIO1_5 Input 11 state Momentary	
12142	[Input 12] Physical Input State Valid	BIO1_5 Input 12 state	
12143	[Input 12] Physical Input State	BIO1_5 Input 12 state	

Modbus Address	ANSI Description	REM Protection Function Description	Comments
	Valid Momentary	Momentary	
12144	[HSI Input 1] Reserved	PS1_4 Input 1 state	
12145	[HSI Input 1] Reserved Momentary	PS1_4 Input 1 state Momentary	
12146	[HSI Input 2] Reserved	PS1_4 Input 2 state	
12147	[HSI Input 2] Reserved Momentary	PS1_4 Input 2 state Momentary	
12148	[HSI Input 3] Reserved	PS1_4 Input 3 state	
12149	[HSI Input 3] Reserved Momentary	PS1_4 Input 3 state Momentary	
12150	Trip Circuit Supervision Enabled	PS1_4 TCS 1 state	
12151	Trip Circuit Supervision Enabled Momentary	PS1_4 TCS 1 state Momentary	
12152	Close Circuit Supervision Enabled	PS1_4 TCS 2 state	
12153	Close Circuit Supervision Enabled Momentary	PS1_4 TCS 2 state Momentary	
12154	Relay Over Temperature Indicator	PS1_4 TCS 2 Over Tmp	
12155	Relay Over Temperature Indicator Momentary	PS1_4 TCS 2 Over Tmp Momentary	
12156	Power Supply Failure	PS1_4 TCS 2 AC Fail	
12157	Power Supply Failure Momentary	PS1_4 TCS 2 AC Fail Momentary	
12158	[HSI Input 1] Reserved Input Valid	PS1_4 Input 1 Input Valid state	
12159	[HSI Input 1] Reserved Input Valid Momentary	PS1_4 Input 1 Input Valid state Momentary	
12160	[HSI Input 2] Input Valid Reserved	PS1_4 Input 2 Input Valid state	
12161	[HSI Input 2] Input Valid Reserved Momentary	PS1_4 Input 2 Input Valid state Momentary	
12162	[HSI Input 3] Input Valid Reserved	PS1_4 Input 3 Input Valid state	
12163	[HSI Input 3] Input Valid Reserved Momentary	PS1_4 Input 3 Input Valid state Momentary	
12164	Local/Remote Control Status	Glovar A 1 = Local Control 0 = Remote Control	
12165	Local/Remote Control Status Momentary	Glovar A 1 = Local Control 0 = Remote Control Momentary	

4X Register Read Capabilities

The REM 543 implementation of 4X registers allows for both status reads and in limited cases for control register writes. Many host devices do not allow the access of data from discrete data types (such as 0X and 1X discrete output and input function codes). The Modbus register read or write implementation within the relay allows for Modbus commands 03 (Read Multiple 4X holding registers), 16 (10 hex, Write/Preset Multiple Holding Registers), 06 (Preset Single 4X holding register) and 23 (17 hex, Read Write 4X Registers). Real time relay status is available for the following relay data types and functionality:

- Metering Information
- Diagnostic Status
- Unit Information

- Logical Input Status
- Logical Output Status

Each function code and data type shall be explained in detail, within the following sections.

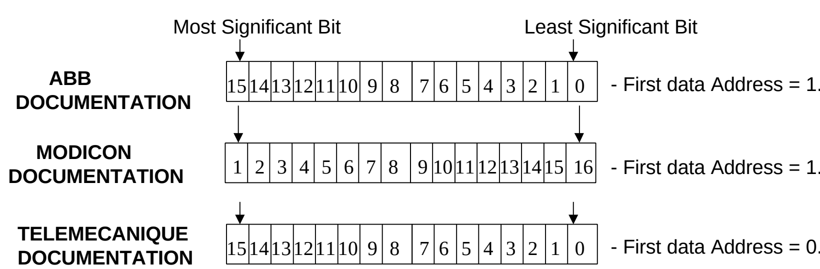
Modbus protocol allows a variety of information to be placed within the 4X register types. The interpretation of the returned data is key to data received in the request. Modbus protocol is predicated upon register information being returned. A register is 2 bytes, or 16 bits which translates into one word. Multiple words may be combined to form a longer word which allows a larger read to obtained from the REM 543. The REM 543 supports the following data return types for 4X formats:

- Unsigned - 16 bits - 2 bytes - Range 0 to + 65,535
- Signed - 16 bits - 2 bytes - Range –32,768 to 32,767
- Unsigned Long - 32 bits - 4 bytes - Range 0 to +4,294,967,295
- Signed Long - 32 bits - 4 bytes - Range -2,147,483,648 to +2,147,483,647
- ASCII - 16 bits - 2 bytes - 2 characters per register (Reference Appendix A)

The tables contained within this document reference the above definitions and give the cadence of bytes or words as:

- MSB Most Significant Byte
- LSB Least Significant Byte
- MSW Most Significant Word
- LSW Least Significant Word
- Msb Most significant bit
- Lsb Least significant bit

One must take particular note when interpreting the data bits returned from the IED. Different manufacturers input data from Modbus devices however, each manufacturer starts its address start addresses taking into account the zero offset whereas, other manufacturers do not. Some manufacturers number their data bit presentations in the registers differently. Figure 5-18 illustrates the register decoding differences.



For Example: If a Telemechanique PLC was serving as a Modbus host, the ABB documentation for bit interpretation most significant bit = bit 15 leftmost bit, least significant bit = bit 0 rightmost bit. However, to access a register the host would need to subtract the value of 1 from the data address to obtain the correct data.

If a Modicon PLC was serving as a Modbus host, the ABB documentation would need to be transposed to acknowledge that any data analyzed by the host in the bit 16 position would reflect the status described as Bit 0 lsb nomenclature. No data address offset would need to be performed to obtain the correct information from the protective relay.

Figure 5-18. Vendor Documentation Translation Example

Function Code 03 – Read Holding Registers (Read Only)

The 4x frame sequence is illustrated in Figure 5-19 for Function 03 (Read Holding Registers). The Host sends the protocol request and the REM 543 responds. The host decodes the data requested dependent upon the definition of the register data. The reader should note that Modbus ASCII denotes a Colon (:) and Carriage Return/Line Feed combination for Start of Message and End Of Message designators. Modbus RTU designates 3 character delays for a Start of Message and End Of Message designator. Tables 5-5 through 5-8 list the register mapping for Modbus reads. Access of Momentary data is available through 4X reads if the User Definable Registers are remapped using the standard supplied REM 543 remapping utility..

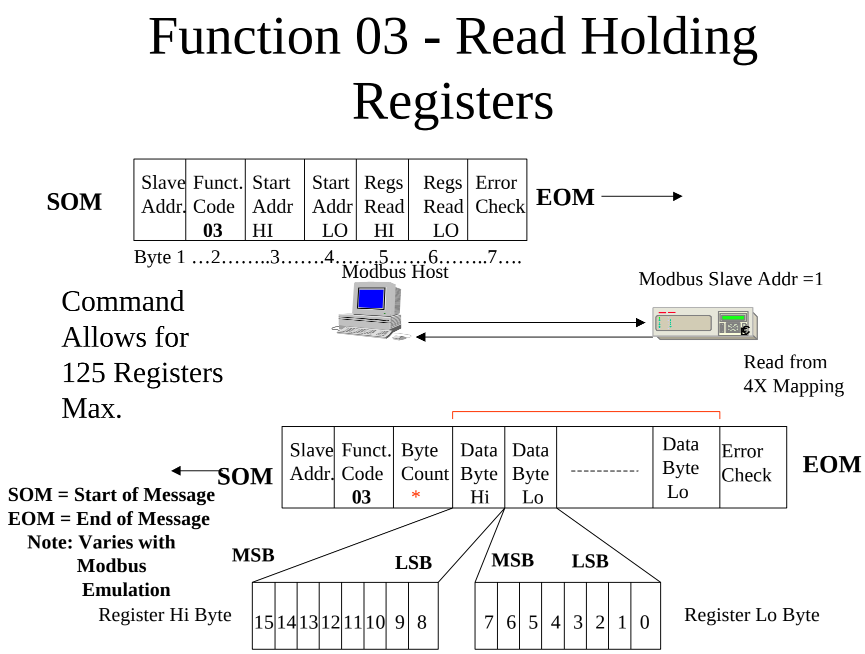


Figure 5-19. 4X Data Read Frame Format

The registers listed in Table 5-5 are read using a Modbus 03 read register command. Within the first release of the REM 543, the first 17 addresses are fixed within the REM 0XXXX, 1XXXX or 4XXXX memory.

In future version a tool may be available and the values fixed within 0X, 1X, and 4X memory may be mapped to these addresses via a mapping tool provided to the customer. LISTED IN THE FOLLOWING TABLE ARE THE DEFAULT DEFINITIONS OF THE 17 configurable UDR (User Definable Registers).

Table 5-5. Default User Definable Register Address Definition

Modbus Address	ANSI Description	REM Description	Description
40001	User Definable Register 1		Bit 0 rightmost bit Bit 15 leftmost bit
	87 Differential Output (L)	Diff 3 Output Trip	(See Note 1)
	87 Differential Output (L) Momentary	Diff 3 Output Trip Change Detect	
	59 Overvoltage Pickup	OV3 Low Output Start	
	59 Overvoltage Pickup Momentary	OV3 Low Output Start Change Detect	
	27 Undervoltage Pickup	UV3Low Output Start	
	27 Undervoltage Momentary	UV3Low Output Start Change Detect	

Modbus Address	ANSI Description	REM Description	Description
	37-1 Undercurrent (L)	NUC3St1 Output Trip	(See Note 1)
	37-1 Undercurrent (L) Momentary	NUC3St1 Output Trip Change Detect	
	50GS Non Directional Earth Fault (L)	NEF1Low Output Trip	(See Note 1)
	50GS Non Directional Earth Fault (L) Momentary	NEF1Low Output Trip Change Detect	
	47 Phase Sequence Voltage (L)	PSV3St1 Output Trip	
	47 Phase Sequence Voltage (L) Momentary	PSV3St1 Output Trip Change Detect	
	46 Current Phase Unbalance (L)	NPS3Low Output Trip	
	46 Current Phase Unbalance (L) Momentary	NPS3Low Output Trip Change Detect	
	81-1 Under/Over Frequency (Inc Rate of Change) Stage 1 (L) 1	Freq1St1 Output Trip 1	(See Note 1)
	81-1 Under/Over Frequency (Inc Rate of Change) Stage 1 (L) 1 Momentary	Freq1St1 Output Trip 1 Change Detect	
40002	User Definable Register 2		Bit 0 rightmost bit Bit 15 leftmost bit
	81-1 Under/Over Frequency (Inc Rate of Change) Stage 1 Pickup 2	Freq1St1 Output START 2	
	81-1 Under/Over Frequency (Inc Rate of Change) Stage 1 Pickup 2 Momentary	Freq1St1 Output START 2 Change Detect	
	81-2 Under/Over Frequency (Inc Rate of Change) Stage 2 (L) 1	Freq1St2 Output Trip 1	(See Note 1)
	81-2 Under/Over Frequency (Inc Rate of Change) Stage 2 (L) 1 Momentary	Freq1St2 Output Trip 1 Change Detect	
	81-2 Under/Over Frequency (Inc Rate of Change) Stage 2 (L) 2	Freq1St2 Output Trip 2	(See Note 1)
	81-2 Under/Over Frequency (Inc Rate of Change) Stage 2 (L) 2 Momentary	Freq1St2 Output Trip 2 Change Detect	
	50 Inst. 3 Phase Non Directional Overcurrent (L)	NOC3Inst Output Trip	(See Note 1)
	50 Inst. 3 Phase Non Directional Overcurrent (L) Momentary	NOC3Inst Output Trip Change Detect	
	55 Power Factor (L)	OPOW6St1 Output Trip	(See Note 1)
	55 Power Factor (L) Momentary	OPOW6St1 Output Trip Change Detect	
	51 Motor (L)	MotStart Output Trip	(See Note 1)
	51 Motor (L) Momentary	MotStart Output Trip Change Detect	
	49 3 Phase Thermal Overload (L)	TOL3Dev Output Trip	(See Note 1)
	49 3 Phase Thermal Overload (L) Momentary	TOL3Dev Output Trip Change Detect	
	Undefined	Undefined	
	Undefined	Undefined	
40003	User Definable Register 3		Bit 0 rightmost bit Bit 15 leftmost bit
	52a Status	COCB1 Object state closed	

Modbus Address	ANSI Description	REM Description	Description
	52a Status Momentary	COCB1 Object state closed Momentary	
	52b Status	COCB1 Object state open	
	52b Status Momentary	COCB1 Object state open Momentary	
	Breaker Fault	COCB1 Object state faulty	
	Breaker Fault Momentary	COCB1 Object state faulty Momentary	
	Undefined	Undefined	
	Undefined	Undefined	
	Undefined	Undefined	
	Undefined	Undefined	
	Undefined	Undefined	
	Undefined	Undefined	
	Undefined	Undefined	
	Undefined	Undefined	
	Undefined	Undefined	
	Undefined	Undefined	
40004	User Definable Register 4		Bit 0 rightmost bit Bit 15 leftmost bit
	Motor Running	COIND8 Object state closed	
	Motor Running Momentary	COIND8 Object state closed Momentary	
	Motor Stopped	COIND8 Object state open	
	Motor Stopped Momentary	COIND8 Object state open Momentary	
	Undefined	Undefined	
	Undefined	Undefined	
	Undefined	Undefined	
	Undefined	Undefined	
	Undefined	Undefined	
	Undefined	Undefined	
	Undefined	Undefined	
	Undefined	Undefined	
	Undefined	Undefined	
	Undefined	Undefined	
	Undefined	Undefined	
	Undefined	Undefined	
40005	Phase A Winding Temperature	MEAI1 Input value	Degrees C – Signed Integer Model 1,2 Only - 0 Otherwise 0
40006	Phase B Winding Temperature	MEAI2 Input value	Degrees C – Signed Integer Model 1,2 Only - 0 Otherwise 0
40007	Phase C Winding Temperature	MEAI3 Input value	Degrees C – Signed Integer Model 1,2 Only - 0 Otherwise 0
40008	Phase A Winding Temperature Model 2	MEAI4 Input value	Degrees C – Unsigned Integer Model 1,2 Only - 0 Otherwise -10,000<=X<=10,000
	Motor Bearing Temperature – Model 1		
40009	Phase B Winding Temperature – Model 2	MEAI5 Input value	Degrees C – Unsigned Integer Model 1,2 Only - 0 Otherwise -10,000<=X<=10,000

Modbus Address	ANSI Description	REM Description	Description
	Motor Bearing Temperature –Model 1		
40010	Phase C Winding Temperature – Model 2 Load Bearing Temperature –Model 1	MEAI6 Input value	Degrees C – Unsigned Integer Model 1,2 Only - 0 Otherwise -10,000<=X<=10,000
40011	Motor Bearing Temperature- Model 2 Load Bearing Temperature- Model 1	MEAI7 Input value	Degrees C – Unsigned Integer Model 1,2 Only - 0 Otherwise -10,000<=X<=10,000
40012	Motor Bearing Temperature- Model 2 Ambient Temperature –Model 1	MEAI8 Input value	Degrees C – Unsigned Integer Model 1,2 Only - 0 Otherwise -10,000<=X<=10,000
40013	% Temperature Rise of Rotor or Stator	TOL3Dev Output TEMP(%)	Displays greatest temperature rise in % of motor or stator – Unsigned Integer (* 10 scale factor) Model 1,2 Only - 0 Otherwise
40014	Motor Cool Time – Hi	TOL3Dev Output COOL_TIME high word	Seconds -Unsigned 32 Bit High Word
40015	Motor Trip Time – Lo	TOL3Dev Output TRIP_TIME low word	Seconds- Unsigned 32 Bit Low Word 0<=X<=86,400
40016	Motor Trip Time- Hi	TOL3Dev Output TRIP_TIME high word	Seconds- Unsigned 32 Bit High Word
40017	Motor Trip Time- Lo	TOL3Dev Output TRIP_TIME low word	Seconds- Unsigned 32 Bit Low Word

Metering Values (46 Values Defined – Read Only)

Metering Values are defined Table 5-6. Various data types are associated with each element. Some values, such as Kwatts (32 Bit, 4 byte, 2 word) are signed to denote power flow. It should be noted that several values (Registers 42048 through 42056) are reported as per unit values reflected as % of nominal currents and voltages. Other values such as phase to phase currents, and voltages are listed afterwards in the table.

Table 5-6. REM 543 Metering Values

Modbus Address	ANSI Description	REM Protection Function Description	Comments
42048	Iab –Differential Phase AB Per Unit Current	Diff3 Current Id1	Display of % of I nominal Unsigned Integer (*100 Scale) 0<=X<=60,000
42049	Ibc – Differential Phase BC Per Unit Current	Diff3 Current Id2	Display of % of I nominal Unsigned Integer (*100 Scale) 0<=X<=60,000
42050	Ica –Differential Phase CA Per Unit Current	Diff3 Current Id3	Display of % of I nominal Unsigned Integer (*100 Scale) 0<=X<=60,000
42051	Vab –Phase AB Per Unit Voltage	OV3Low Voltage UL1_U12	Display of % of V nominal Unsigned Integer 0<=X<=200
42052	Vbc –Phase BC Per Unit Voltage	OV3Low Voltage UL2_U23	Display of % of V nominal Unsigned Integer 0<=X<=200
42053	Vca –Phase CA Per Unit Voltage	OV3Low Voltage	Display of % of V nominal

Modbus Address	ANSI Description	REM Protection Function Description	Comments
		UL3_U31	Unsigned Integer 0<=X<=200
42054	Positive Sequence Per Unit Voltage	PSV3St1 Pos. seq. volt.	Display of % of V nominal Unsigned Integer 0<=X<=200
42055	Negative Sequence Per Unit Voltage	PSV3St1 Neg. seq. volt.	Display of % of V nominal Unsigned Integer 0<=X<=200
42056	Negative Sequence Per Unit Current	NPS3Low Neg. seq. cur	Display of % of I nominal Unsigned Integer 0<=X<=60,000
42057	System Frequency Stage 1	Freq1St1 Frequency	Hertz – Unsigned Integer 2,000<=X<=8,000
42058	Frequency Rate of Change Stage 1	Freq1St1 Rate of change	Hertz/Sec –Signed Integer -150<=X<=150
42059	Frequency Rate of Change Stage 2	Freq1St2 Frequency	Hertz – Unsigned Integer 2,000<=X<=8,000
42060	Frequency Rate of Change Stage 2	Freq1St2 Rate of change	Hertz/Sec –Signed Integer -150<=X<=150
42061	Phase A Winding Temperature	MEAI1 Input value	Degrees C – Signed Integer Model 1,2 Only - 0 Otherwise 0
42062	Phase B Winding Temperature	MEAI2 Input value	Degrees C – Signed Integer Model 1,2 Only - 0 Otherwise 0
42063	Phase C Winding Temperature	MEAI3 Input value	Degrees C – Signed Integer Model 1,2 Only - 0 Otherwise 0
42064	Phase A Winding Temperature Model 2 Motor Bearing Temperature – Model 1	MEAI4 Input value	Degrees C – Unsigned Integer Model 1,2 Only - 0 Otherwise -10,000<=X<=10,000
42065	Phase B Winding Temperature – Model 2 Motor Bearing Temperature – Model 1	MEAI5 Input value	Degrees C – Unsigned Integer Model 1,2 Only - 0 Otherwise -10,000<=X<=10,000
42066	Phase C Winding Temperature – Model 2 Load Bearing Temperature - Model 1	MEAI6 Input value	Degrees C – Unsigned Integer Model 1,2 Only - 0 Otherwise -10,000<=X<=10,000
42067	Motor Bearing Temperature-Model 2 Load Bearing Temperature-Model 1	MEAI7 Input value	Degrees C – Unsigned Integer Model 1,2 Only - 0 Otherwise -10,000<=X<=10,000
42068	Motor Bearing Temperature-Model 2 Ambient Temperature -Model 1	MEAI8 Input value	Degrees C – Unsigned Integer Model 1,2 Only - 0 Otherwise -10,000<=X<=10,000
42069	% Temperature Rise of Rotor or Stator	TOL3Dev Output Temp (%)	Displays greatest temperature rise in % of motor or stator – Unsigned Integer (* 10 scale factor) Model 1,2 Only - 0 Otherwise
42070	Maximum % Temperature Rise of Rotor	TOL3Dev Output Rotor (%)	Temperature rise in % of motor or stator – Unsigned Integer (* 10 scale factor) Model 1,2 Only - 0 Otherwise
42071	% Temperature Rise of Stator	TOL3Dev Output Stator (%)	Temperature rise in % of motor or stator –Unsigned Integer

Modbus Address	ANSI Description	REM Protection Function Description	Comments
			(* 10 scale factor) Model 1,2 Only - 0 Otherwise
42072	Motor Frequency	MEFR1 Frequency	Hertz – Unsigned Integer (*100 scale factor) 4,000<=X<=8,000
42073	Average Motor Frequency	MEFR1 Average Frequency	Hertz – Unsigned Integer (*100 scale factor) 4,000<=X<=8,000
42074	KW3 –3 Phase Power	MEPE7 P3 (kW)	Watts – Signed Integer (*100 Scale) -9,999<=X<=9,999
42075	KV3 – 3 Phase Reactive Power	MEPE7 Q3 (kvar)	Vars – Signed Integer (*100 Scale) -9,999<=X<=9,999
42076	DPF – Displacement Power Factor	MEPE7 Power factor DPF	Signed Integer (*10 Scale) -100<=X<=100
42077	PF – Power Factor	MEPE7 Power factor PF	Signed Integer (*10 Scale) -100<=X<=100
42078	KW3 –3 Phase Power Demand	MEPE7 P3 (kW)	Watts – Signed Integer (/100 Scale) -100<=x<=100
42079	KV3 – 3 Phase Reactive Power – Demand	MEPE7 Q3 (kvar)	Vars – Signed Integer (/100 Scale) -100<=x<=100
42080	In – Neutral Current	MECU1A Io	A – Unsigned Integer 0<=X<=20,000
42081	Ia – Phase A Current	MECU3A IL1	A – Unsigned Integer 0<=X<=20,000
42082	Ib – Phase B Current	MECU3A IL2	A – Unsigned Integer 0<=X<=20,000
42083	Ic – Phase C Current	MECU3A IL3	A – Unsigned Integer 0<=X<=20,000
42084	Ia – Phase A Demand Current	MECU3A IL1 Demand	A – Unsigned Integer 0<=X<=20,000
42085	Ib – Phase B Demand Current	MECU3A IL2 Demand	A – Unsigned Integer 0<=X<=20,000
42086	Ic – Phase C Demand Current	MECU3A IL3 Demand	A – Unsigned Integer 0<=X<=20,000
42087	Vab –Phase ab voltage	MEVO3A UL1_U12	KV – Unsigned Integer (scale *10) 0<=X<=9,999
42088	Vbc - Phase bc voltage	MEVO3A UL2_U23	KV – Unsigned Integer (scale *10) 0<=X<=9,999
42089	Vca - Phase ca voltage	MEVO3A UL3_U31	KV – Unsigned Integer (scale * 10) 0<=X<=9,999
42090	Vab –Phase ab voltage Average	MEVO3A UL1_U12 Average	KV – Unsigned Integer (scale *10) Average 0<=X<=9,999
42091	Vbc - Phase bc voltage Average	MEVO3A UL2_U23 Average	KV – Unsigned Integer (scale *10) Average 0<=X<=9,999
42092	Vca - Phase ca voltage Average	MEVO3A UL3_U31 Average	KV – Unsigned Integer (scale * 10) Average 0<=X<=9,999

Motor Diagnostic Information (26 Registers Defined-Read Only)

A variety of diagnostic information is also available from the REM 543. The next block of information lists the diagnostic information available from the REM. Table 5-7 lists the address assignment for the contained REM 543 diagnostic information.

Table 5-7. REM 543 Diagnostic Information Map

Modbus Address	ANSI Description	REM Protection Function Description	Comments
412288	Motor Start counter Hi	MotStart Start counter high word	Unsigned 32 Bit High Word 0<=X<=99,999
412289	Motor Start counter Lo	MotStart Start counter low word	Unsigned 32 Bit Low Word
412290	Motor Time To Start Hi	MotStart Start Time high word	Seconds - Unsigned 32 Bit High Word 0<=X<=99,999
412291	Motor Start counter Lo	MotStart Start Time low word	Seconds - Unsigned 32 Bit Low Word
412292	PHA Wear- Phase A Wear	CMBWEAR1 Wear L1	Unsigned Integer 0<=X<=10,000
412293	PHB Wear- Phase B Wear	CMBWEAR1 Wear L2	Unsigned Integer 0<=X<=10,000
412294	PHB Wear- Phase C Wear	CMBWEAR1 Wear L3	Unsigned Integer 0<=X<=10,000
412295	CB Cycle – Circuit Breaker Cycle Count	COCB1 Cycle Count	Unsigned Integer 0<=X<=10,000
412296	Motor Cool Time – Hi	TOL3Dev Output COOL_TIME high word	Seconds -Unsigned 32 Bit High Word 0<=X<=86,400
412297	Motor Cool Time – Lo	TOL3Dev Output COOL_TIME low word	Seconds -Unsigned 32 Bit Low Word
412298	Motor Trip Time – Hi	TOL3Dev Output TRIP_TIME high word	Seconds - Unsigned 32 Bit High Word 0<=X<=86,400
412299	Motor Trip Time – Lo	TOL3Dev Output TRIP_TIME low word	Seconds - Unsigned 32 Bit Low Word
412300	Motor Run Time – Hi	CMTIME1 Accum. Hours low word	Hours- Unsigned 32 Bit High Word 0<=X<=87,600
412301	Motor Run Time – Lo	CMTIME1 Accum. Hours low word	Hours- Unsigned 32 Bit Low Word
412302	Motor Run Time – Minutes	CMTIME1 Accum. Minutes	Minutes Unsigned Integer 0<=X<=59
412303	Motor Scheduled Maintenance Time Elapsed	CMSCHED Elapsed Time	Days – Unsigned Integer 0<=X<=3650
412304	REM Firmware Build Number	CH001 SW Build	ASCII - 2 Left Most Characters
412305	REM Firmware Build Number	CH001 SW Build	ASCII - 2 Characters
412306	REM Firmware Build Number	CH001 SW Build	ASCII - 2 Characters
412307	REM Firmware Build Number	CH001 SW Build	ASCII - 2 Right Most Characters
412308	REM Firmware Build Number	CH001 SW version hi word	Unsigned Integer Hi Word
412309	REM Firmware Build Number	CH001 SW version lo word	Unsigned Integer Lo Word
412310	REM Software Version	CH001 SW version	ASCII – 2 Characters
412311	REM Serial Number	CH001 Serial No hi word	Unsigned Integer Hi Word
412312	REM Serial Number	CH001 Serial No lo word	Unsigned Integer Lo Word

Real Time Clock Data (7 Registers Defined-Read Only)

The following registers illustrated in Table 5-8 contains the information in the REM 543 real time clock. The registers are updated immediately upon a host read. The clock can only be read from these 4X registers and they cannot be written. Time must be set through the front panel interface or through CAPTOOLS.

Table 5-8. Real Time Clock Memory Map

Modbus Address	ANSI Description	REM Protection Function Description	Comments
416384	RTC -Year	Modbus Modbus Clock Register	Unsigned Integer (0 – 99)
416385	RTC- Month	Modbus Modbus Clock Register	Unsigned Integer (0 – 12)
416386	RTC-Day	Modbus Modbus Clock Register	Unsigned Integer (0 – 31)
416387	RTC- Hour	Modbus Modbus Clock Register	Unsigned Integer (0 – 23)
416388	RTC-Minute	Modbus Modbus Clock Register	Unsigned Integer (0 – 59)
416389	RTC Second	Modbus Modbus Clock Register	Unsigned Integer (0 – 59)
416390	RTC- Millisecond	Modbus Modbus Clock Register	Unsigned Integer (0 – 99)

Providing Control Functionality in the REM 543

Two methods are available for providing control functionality within the REM 543. One method may be performed using coil control (no password required) and the other method is performed using the traditional method of control, using 4X control writes and a password.

Two groups of control blocks are resident in the REM 543. Each group is comprised of 6 registers. The two control block groups are defined in Tables 5-10 and 5-11.

ABB relays are designed to operate with a variety of host products. Some host products cannot send a password with the control algorithm. If this is the case, then it is suggested that control operations be performed using the discrete coil write method.

Discrete Point Control Capabilities

Modbus control is accomplished using one of two coil control commands. The commands used for control are listed as:

- 0F Force Multiple Coils
- 06 Force Single Coil

Figures 5-20 and 5-21 illustrate the Modbus command formats for the REM 543.

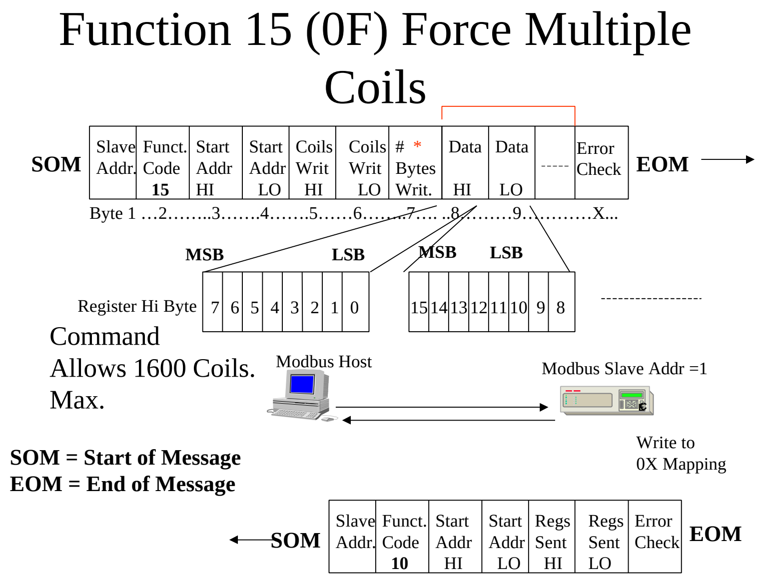


Figure 5-20. Multiple Coil Force Command

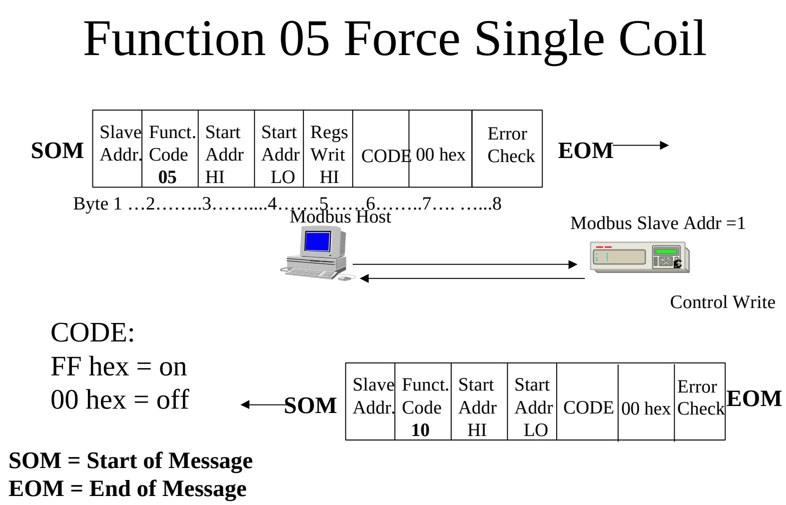


Figure 5-21. Single Coil Force Command

To perform control using the 05 Modbus Command (Set Single Coil) or 0F (Set Multiple Coils), one may send a value of “1” to the appropriate coil. However, Alarms Acknowledge commands need only be sent setting the bit to a value of 1. Open Select or Close Select must be followed by an EXECUTE COMMAND to effectuate the control operation. Note that the Override Interlock Switch Control state is determined by the value written to the bit for operation. For the OVERRIDE INTERLOCK SWITCH command, the coil must be set to a 0 or a 1 as illustrated in the table.

All other commands in this discrete block write are executed by writing a value of 1 to the bit. A value of 0 need not be written to the coil to reset the function. The REM will automatically reset the bit state to 0 upon receiving the command. The address list for each of the functions is listed in Table 5-9.

Note: A delay must occur between the select and operate sequence for a coil breaker control operation. The minimum time between a select operate sequence is 400 milliseconds. Multiple bit coil operations are not allowed within the REM even though Command 05 (Single Coil Operate) or 0F (Multiple Coil Operate) commands may be used to effectuate breaker operation.

Table 5-9. Coil Control Operation

Modbus Address	ANSI Description	REM Protection Function Description	Comments
08192	Reserved	Reserved	
08193	Reserved	Reserved	
08194	Wear Alarm Reset	CMBWEAR1 Alarm ACK	1 = Ack Alarm
08195	Breaker Trip Select	COCB1 Open Select	1 = Trip
08196	Breaker Close Select	COCB1 Close Select	1 = Close
08197	Cancel Trip/Close Command	COCB1 Cancel	1 = Cancel
08198	Execute Trip/Close Command	COCB1 Execute	1 = Execute
08199	Override Interlock Switch	COSW2 ON State	1 = Override On 0 = Override Off
08200	Operation Time Counter Alarm Ack	CMTIME1 Alarm Ack	1 = Ack Alarm
08201	Schedule Maintenance Alarm Ack	CMSCHED Alarm Ack	1 = Ack Alarm
08202	Reset Latched Bits	CH001 Reset Output Glovar	1 = Reset Latched Bits

Three examples are given in Figures 5-22, 5-23 and 5-24 illustrating the three types of control methods for performing a Trip, Reset Latched Bits, and Turn ON/OFF Interlock Switch.

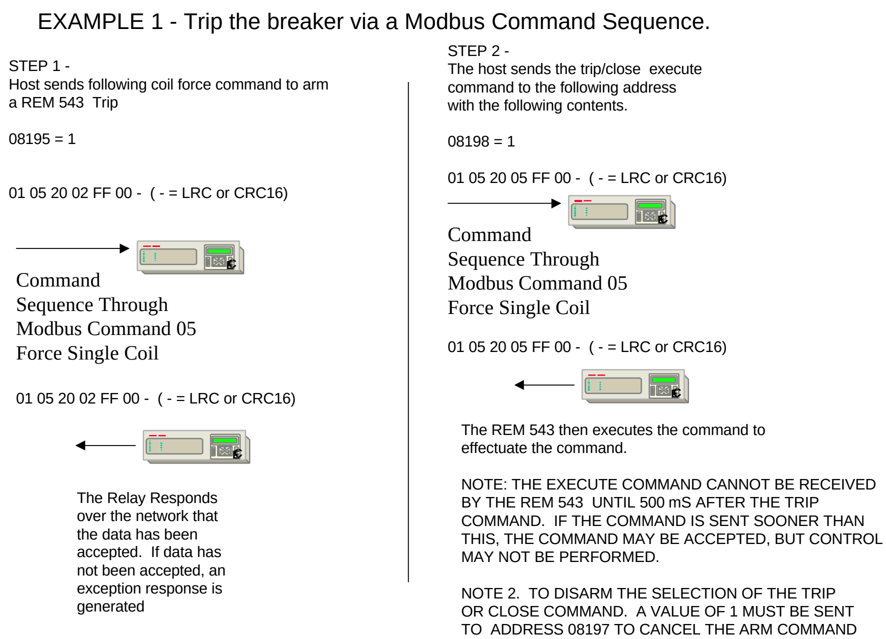


Figure 5-22. Breaker Trip Control Example

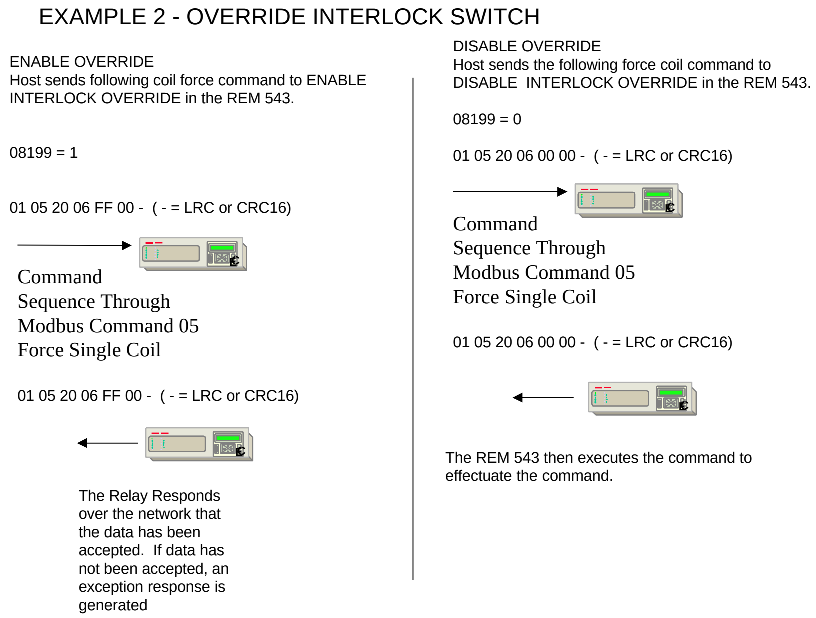


Figure 5-23. Enable/Disable Interlock Override Switch Example

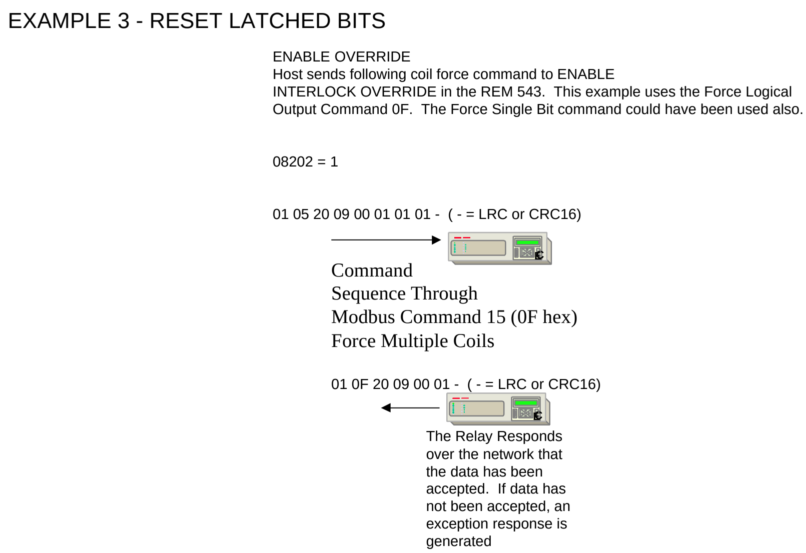


Figure 5-24. Reset Latched Bit Example

Register Function Control

If password based function control is required, the REM 543 has the capability to do so. Using the following write commands available in Modbus, control may be performed:

- Function 16 (10 hex) Preset Multiple Registers
- Function 23 (17 hex) Read/Write 4X Registers
- Function 06 Preset Single Register

Figures 5-25, 5-26 and 5-27 illustrate the method to perform commands using password register command write commands. The assigned 4X registers are listed in Tables 5-10 and 5-11 as follows. It should be noted that the same commands as illustrated in coil control commands in Table 5-9 are available as register control commands.

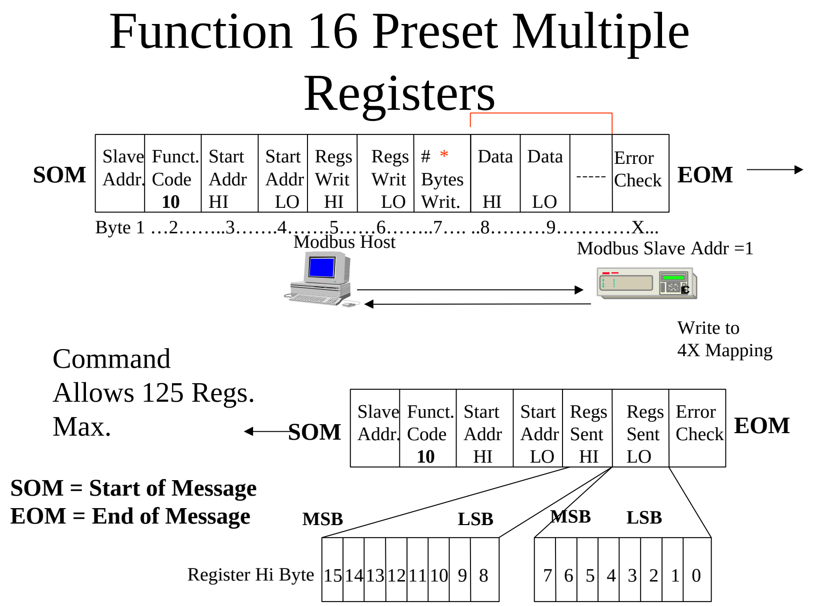


Figure 5-25. Modbus Write Command 16 (10 HEX) Allowing Writes to the REM 543

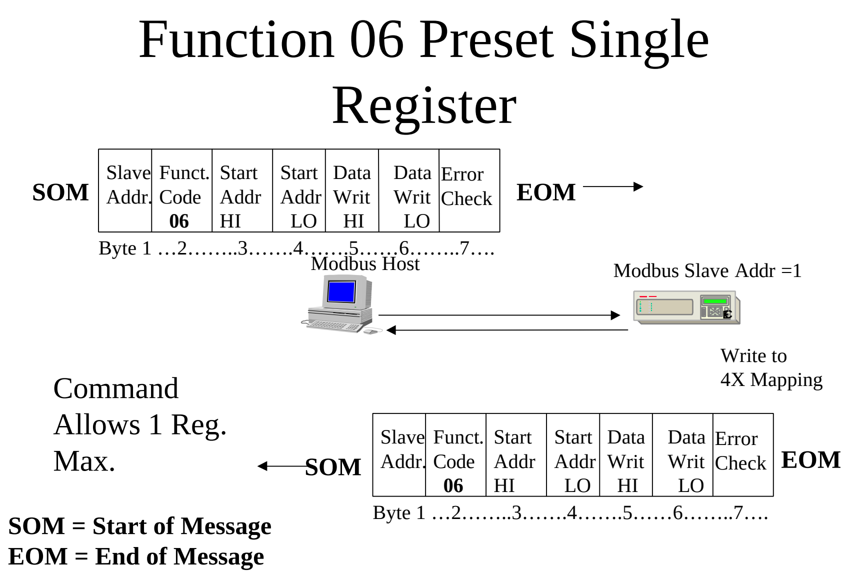


Figure 5-26. Modbus Write Command 06 Allowing Single Register Writes to Effectuate Control

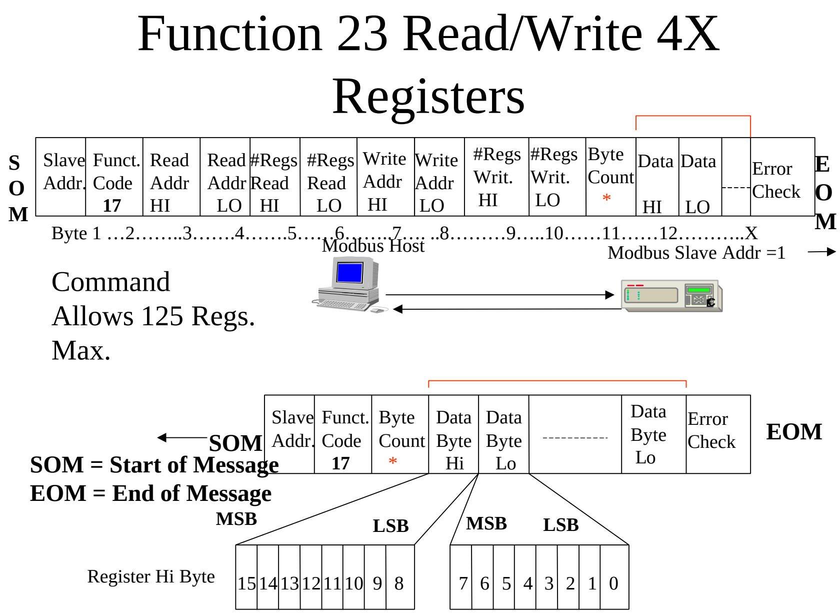


Figure 5-27. Read/Write Function 23 (HEX 17) Command

Another format command which allows for a simultaneous read/write is command 23 (17HEX). Figure 5-27 illustrates the read/write 4X register command format. The 23 command is used when the user wishes to write registers and read other registers in a single request.

Control Blocks 1 and 2 allows for access of protective device function state. If a user wished to read the status of each function within the relay, a Function Read/Write Register Command would be the most desirable command to be issued. Read/Write register data commands are also useful in accessing the Operation and Fault record blocks.

Review of the Modbus 23 command allows for write and read of data if the total amount of read and write registers do not exceed over 125 words. An advantage of using a combined read/write command is that of speed. If conventional commands were to be used, a 16 Write 4X Register Command would be issued and thereafter, within 15 seconds, a 03 Modbus (Read 4X Register Command) would then be issued to extract the data from the relay. Using Modbus command 23 allows for decreasing of the overhead associated with multiple register reads and writes.

Figure 5-28 illustrates the Group Blocks within the REM 543 and its associated typical control register mapping.

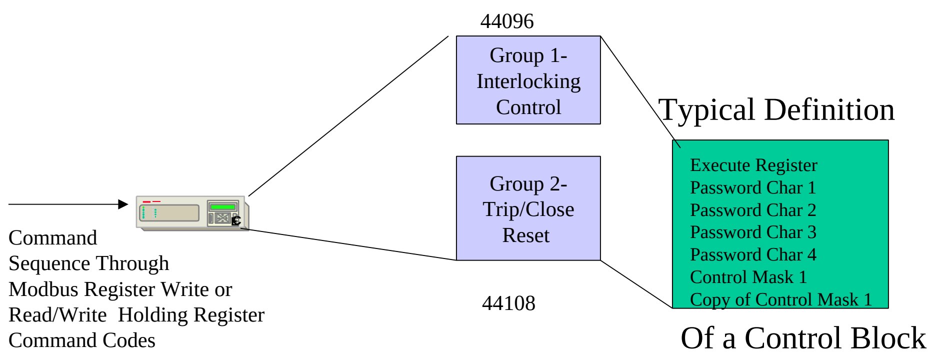


Figure 5-28. Control Register Address Mapping

The REM 543 supports in addition to the bit control operations, a method to include password control for a select before operate scenario. The following table lists the address mapping for the associated functions.

Group 1

Table 5-10. Group 1 Register Control Functionality

Modbus Register	Address	ANSI Function	REM Description	Description
44096		Execute Register		1 to Execute Any other number will not effectuate execution
44097		Password Hi		
44098		Password Lo		
44099		Reserved		
44100		Select Control Word		
	Bit 15 (leftmost bit)	Reserved	Reserved	
	Bit 14	Reserved	Reserved	
	Bit 13	Reserved	Reserved	
	Bit 12	Reserved	Reserved	
	Bit 11	Reserved	Reserved	
	Bit 10	Reserved	Reserved	
	Bit 9	Reserved	Reserved	
	Bit 8	Reserved	Reserved	
	Bit 7	Reserved	Reserved	
	Bit 6	Reserved	Reserved	
	Bit 5	Reserved	Reserved	
	Bit 4	Reserved	Reserved	
	Bit 3	Reserved	Reserved	
	Bit 2	Reserved	Reserved	
	Bit 1	Reserved	Reserved	
	Bit 0	Interlock Control Select	COSW2 on State	Interlocking Switch Over Ride Control Select
44101		Force Control Select		
	Bit 15 (leftmost bit)	Reserved	Reserved	
	Bit 14	Reserved	Reserved	
	Bit 13	Reserved	Reserved	
	Bit 12	Reserved	Reserved	
	Bit 11	Reserved	Reserved	
	Bit 10	Reserved	Reserved	
	Bit 9	Reserved	Reserved	
	Bit 8	Reserved	Reserved	
	Bit 7	Reserved	Reserved	
	Bit 6	Reserved	Reserved	
	Bit 5	Reserved	Reserved	
	Bit 4	Reserved	Reserved	
	Bit 3	Reserved	Reserved	
	Bit 2	Reserved	Reserved	
	Bit 1	Reserved	Reserved	
	Bit 0 Right most bit	Interlock Control State	COSW2 on State	Interlocking Switch Over Ride Control State 1 = override 0 = inhibit override
44102		Force State		Force State when Selected.

				1 = Force Hi 0 = Force Low
	Bit 15 (leftmost bit)	Reserved	Reserved	
	Bit 14	Reserved	Reserved	
	Bit 13	Reserved	Reserved	
	Bit 12	Reserved	Reserved	
	Bit 11	Reserved	Reserved	
	Bit 10	Reserved	Reserved	
	Bit 9	Reserved	Reserved	
	Bit 8	Reserved	Reserved	
	Bit 7	Reserved	Reserved	
	Bit 6	Reserved	Reserved	
	Bit 5	Reserved	Reserved	
	Bit 4	Reserved	Reserved	
	Bit 3	Reserved	Reserved	
	Bit 2	Reserved	Reserved	
	Bit 1	Reserved	Reserved	
	Bit 0 Right most bit	Interlock Control State	COSW2 on State	Interlocking Switch Over Ride Control State 1 = override 0 = inhibit override

Group 1 control only effectuates control of the INTERLOCK CONTROL SWITCH operation.

Group 2 Control

Table 5-11. Group 2 Register Address Mapping

Modbus Register	Address	ANSI Function	REM Description	Description
44102		Execute Register		1 to Execute Any other number will not effectuate execution
44103		Password Hi		
44104		Password Lo		
44105		Reserved		
44106		Select Control Word		
	Bit 15 (leftmost bit)	Reserved	Reserved	
	Bit 14	Reserved	Reserved	
	Bit 13	Reserved	Reserved	
	Bit 12	Reserved	Reserved	
	Bit 11	Reserved	Reserved	
	Bit 10	Reserved	Reserved	
	Bit 9	Reserved	Reserved	
	Bit 8	Reserved	Reserved	
	Bit 7	Reset Latched Elements	CH001 Latch Reset Glovar	1 = Reset Latched Elements
	Bit 6	Scheduled Maintenance Alarm Reset	CMSCHED Alarm Ack	1 = Reset Alarm
	Bit 5	Run Time Alarm Reset	CMTIME1 Alarm Ack	1 = Reset Alarm
	Bit 4	Wear Alarm	CMWEAR1 Alarm	1 = Wear Alarm Reset Alarm

		Reset	Ack	
	Bit 3	Trip Motor Breaker	COCB1 Direct Open	1 = Trip Motor Breaker
	Bit 2	Close Motor Breaker	COCB1 Direct Close	1 = Close Motor Breaker
	Bit 1	Reserved	CMTRAV	
	Bit 0	Reserved	CMTRAV	
44107	100B hex	Confirm Control Select		
	Bit 15 (leftmost bit)			
	Bit 14	Reserved	Reserved	
	Bit 13	Reserved	Reserved	
	Bit 12	Reserved	Reserved	
	Bit 11	Reserved	Reserved	
	Bit 10	Reserved	Reserved	
	Bit 9	Reserved	Reserved	
	Bit 8	Reserved	Reserved	
	Bit 7	Reset Latched Elements	CH001 Latch Reset Glovar	1 = Reset Latched Elements
	Bit 6	Scheduled Maintenance Alarm Reset	CMSCHED Alarm Ack	1 = Reset Alarm
	Bit 5	Run Time Alarm Reset	CMTIME1 Alarm Ack	1 = Reset Alarm
	Bit 4	Wear Alarm Reset	CMWEAR1 Alarm Ack	1 = Wear Alarm Reset Alarm
	Bit 3	Trip Motor Breaker	COCB1 Direct Open	1 = Trip Motor Breaker
	Bit 2	Close Motor Breaker	COCB1 Direct Close	1 = Close Motor Breaker
	Bit 1	Reserved	CMTRAV	
	Bit 0 Right most bit	Reserved	CMTRAV	

Typical examples to perform control through the Control Block is as follows:

- Write all registers other than the register associated with the “Execute Register”
- Write a “1” to execute the control command.

If an execute command is not written to the register block within 15 seconds after parameters have been configured in the block, the block will be reset and the entire configuration sequence must be re-initiated.

Another method to perform control through the Control Block is to write individual registers to the desired control Group block and then write “1” to the execute register within 15 seconds after all the writes have been completed.

Yet another method to perform control through the Control Block is to write all registers in addition to the ARM register

IMPLEMENTATION TIP – If control does not occur after intiation through the network, verify that the REM 543 is in remote mode. There is a L/R (Local/Remote Switch) on the front panel interface. If the REM 543 is place in local mode, the control command will be accepted, however control will not occur.

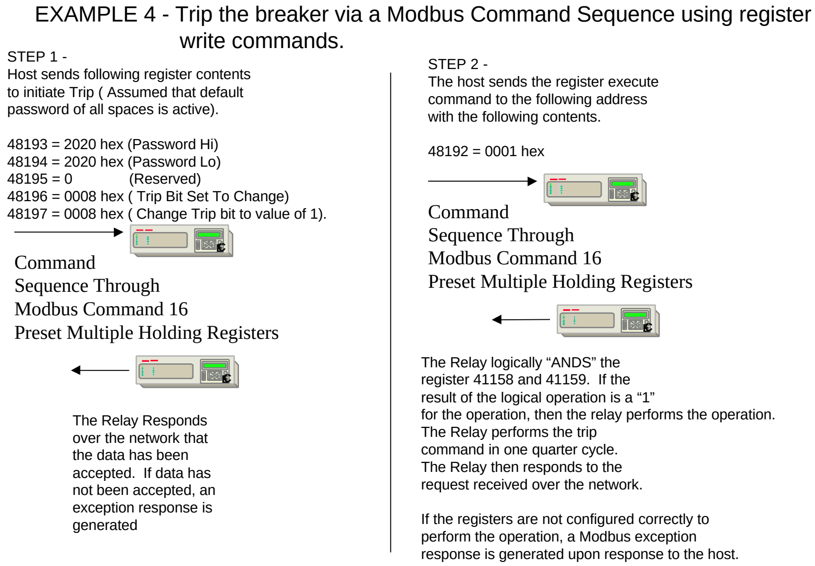


Figure 5-29. Circuit Breaker Trip Operation Via Modbus Network Control

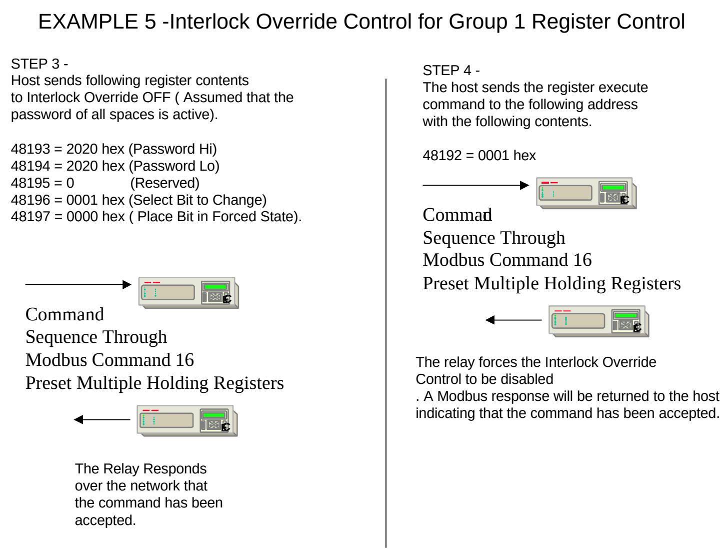


Figure 5-30. Force Physical Input Example (Continued)

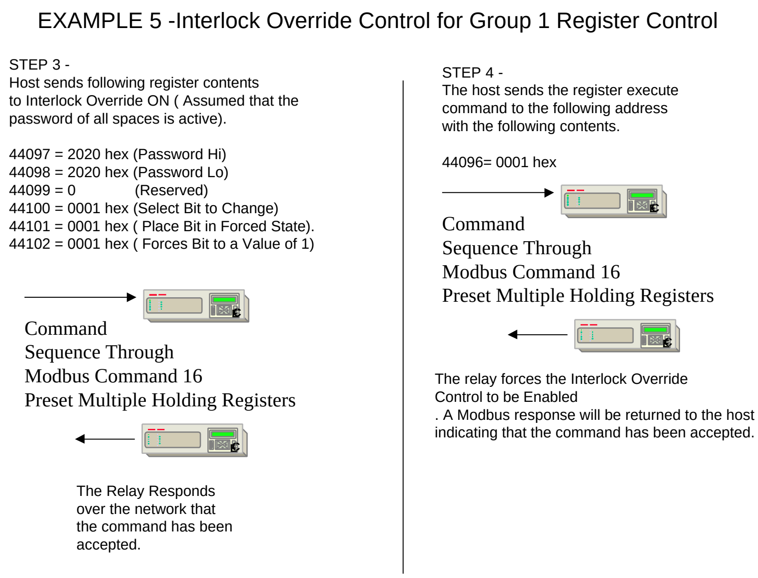


Figure 5-31. Force Physical Input Example (Continued)

IMPLEMENTATION TIP – As is common practice with any control, after a control task has been completed via the network, the host should query the device to assure that control has been executed.

Section 6 - Modbus ASCII Communication Test Example

The easiest method to initiate communications in the MODBUS protocol is to read known discrete and register data. A list of the register definitions of the REM 543 is presented and explained in the next section. A Read Holding Register Modbus Command is explained. Documentation is available from Groupe Schneider further describing the Modbus ASCII emulation characteristics. The explanation contained within this document is intended to be a quick start guide to communication initiation.

The length of the catalog number is 12 characters or 6 registers. The following command string format, when sent will retrieve the catalog number from the unit.

: 01 03 00 00 00 06 73 lf cr

The above string in MODBUS ASCII format should be sent:

3A 30 31 30 33 30 30 30 36 30 30 30 36 37 33 0D 0A

The string is translated as such:

Colon (in HEX) , unit address = 01 (in HEX) , Read Holding Registers (Code 3 in HEX), data memory desired address –1 = 0000 decimal (0000 in HEX), number of registers read = 6 (0006 in HEX), message calculated LRC code 72 (37 32), and line feed (0D) and (0A).

A typical response shall include the following:

: Address number (01), Read Holding Registers Command (Code 3 in HEX), Byte Count Returned in decimal (0C in HEX 12 bytes in decimal) , Data Register 40001 = 0000 hex – 587A, Data Register 40002 = 3743 hex, Data Register 40003 = 3034, Data Register 40004 = 3132 hex, Data Register 40005 = 3631 HEX, Data Register 40006 = 3131HEX, , and calculated LRC =79 (HEX) and line feed with carriage return (0D 0A).

The aforementioned response would be returned as such:

3A 30 31 30 33 30 43 35 38 37 43 30 34 31 32 36 31 31 31 37 39 0A 0D.

Calculation of the LRC (Longitudinal Redundancy Code)

Modbus ASCII protocol uses a Longitudinal Redundancy Code to verify correct reception of the command. This error check is used in addition to the parity option (used by the UART in the PC) and other data such as the byte count which verifies data returned. The process for calculation of the checksum is described as such:

1. Add all bytes in the message except for the colon, line feed, and carriage return. Exclude the LRC checksum which in included in the message structure.
2. Invert all bits in the word after the addition.
3. Add 1 to the inverted result. This is the checksum.

An example is as follows:
Command sent:

3A 30 31 30 33 30 30 38 33 30 30 30 36 37 33 0D 0A

Decode of the data from ASCII to HEX yields.

: 01 03 00 83 00 06 73 lf cr

The decoded LRC checksum is 73. The calculation of the checksum is as such:

1. Neglect the colon (3A) and the lf (Line Feed 0A) and cr (Carriage Return OD). This decreases the string to the LRC checksum 73 (37 33 in ASCII) should also be saved for comparison to the original data string. The string for LRC calculation is 01 03 00 83 00 06.
2. The byte data should be added thus 01 + 03 + 00 + 83 + 00 + 06 = 8D in HEX. Notice that the bytes have been decoded from ASCII before performing the addition.
3. A Two's compliment must be performed on the number to determine the LRC Checksum. Inversion of the number 8D hex yields 72 hex.
4. To complete the Two's compliment addition for accurate compilation of the checksum 1 hex must be added to the inverted bits to yield 72 + 1 = 73 HEX. Thus the two calculated values agree.

Please reference the Modicon Modbus Documentation for additional command configuration on each data type (0X, 1X, and 4X data access capabilities).

Modbus CRC-16 Calculation

The CRC-16 error check is much more robust than that of the LRC error check. It is however, a more complex algorithm to compute. It's computation is started by setting a word of 16 bits to a value of FFFF hex. A byte of the message is logically OR'ed with the register word and then shifted in a predictable method. What follows is a reprint from the protocol manufacturer's manual MODICON MODBUS PROTOCOL REFERENCE GUIDE – PI-MBUS-300 Revision J Dated June 1996 published by Modicon Inc. Industrial Automation Systems, One High Street, North Andover, MA 01845.

"The Cyclical Redundancy Check (CRC) field is two bytes, containing a 16 – bit binary value. The CRC value is calculated by the transmitting device which appends the CRC to the message. The receiving device, recalculates a CRC during the receipt of the message, and compares the calculated value to the value it received in the CRC field. If the two values are not equal, an error results"

The CRC is started by first preloading a 16 bit register register to all 1's. Then a process begins of applying successive 8 – bit bytes of the message to the current contents of the register. Only the eight bits of data in each character are used for generating the CRC. Start and stop bits and the parity bit do not apply to the CRC.

During the generation of the CRC, each 8-bit character is exclusive Ored with the register contents. Then the reslult is shifted in the direction of the least significant bit (LSB), with a zero filled into the most significant bit (MSB) position. The LSB is extracted and examined. If the LSB was a 1, the register is then exclusive Ored with a preset, fixed value. If the LSB was A0, no exclusive OR takes place.

The process is repeated until eight shifts have been performed. After the last eighth shift, the next 8-bit character is exclusive OR'ed with the register's current value and the process repeats for eight more shifts as described above. The final contents of the register,after all the characters of the message have been applied, is the CRC value.

A procedure for generating a CRC is

1. Load a 16 Bit Register with FFFF hex (all 1's) Call this the CRC register.
2. Exclusive OR the first 8-bit byte of the message with the low-order byte of the 16 – bit CRC register, putting the result in the CRC register.
3. Shift the CRC register one bit to the right (Toward the LSB), zero-filling the MSB. Extract and examine the LSB.
4. (If the LSB was 0): Repeat Step 3 (Another Shift)
5. (If the LSB was 1): Exclusive OR the CRC register with the polynomial value A001 hex (1010 0000 0000 0001)
6. Repeat Steps 3 and 4 until 8 shifts have been performed. When this is done, a complete 8-bit byte will have been processed
7. Repeat Steps 2 through 5 for the next 8 bit byte of the message. Continue doing this until all bytes have been processed.
8. The final contents of this CRC register is the CRC value.
9. When the CRC is placed into the message, its upper and lower bytes must be swapped as described below."

The CRC-16 message generation capability is best done by a hardware chip or using a software algorithm. Within the aforementioned manual, the protocol's inventor supplies a C language program to calculate the CRC-16 code. It is advised that the text be referenced for those wishing to calculate such a code.

REM 543 Modbus Exception Response Analysis

If the REM 543 does not understand the command sent to the device or if the command is sent in the wrong format, the REM 543 shall generate an exception response. A Modbus exception response is in the format of that shown in Figure 6-1. As illustrated, the function code is "ANDed" with 80 HEX. Following the modified function code, an exception code byte will follow. The customary LRC and terminator of a Carriage Return and Line feed will terminate the communication string.

Table 6-1 shall list the REM 543 exception codes as the device reports them.

Table 6-1. Modbus Standard Exception Codes

Code	Name
01	Illegal Function
02	Illegal Data Address
03	Illegal Data Value
05	Acknowledge
06	Slave Device Busy

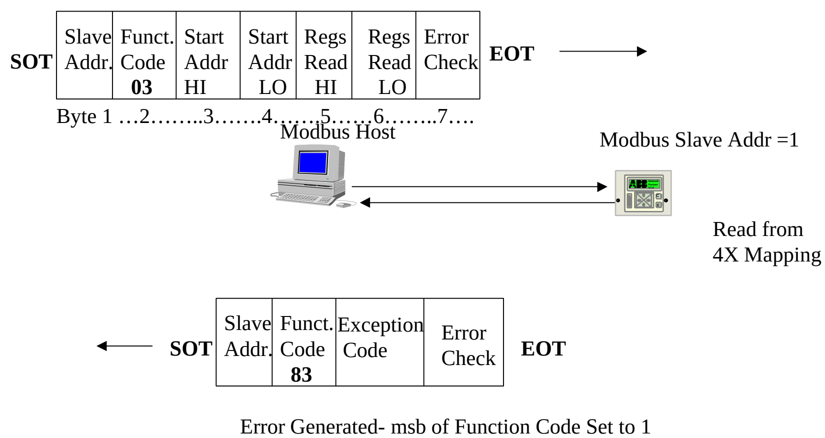


Figure 6-1. Exception Code Example for Holding Register Read

Modbus Troubleshooting Tips

The Modbus Protocol contains a set of commands intended to assist with network troubleshooting. Those commands are:

- 08 – Diagnostic Functions
- 0B – Fetch Communication Event Counter

Function 0B - Fetch Comm Event Counter

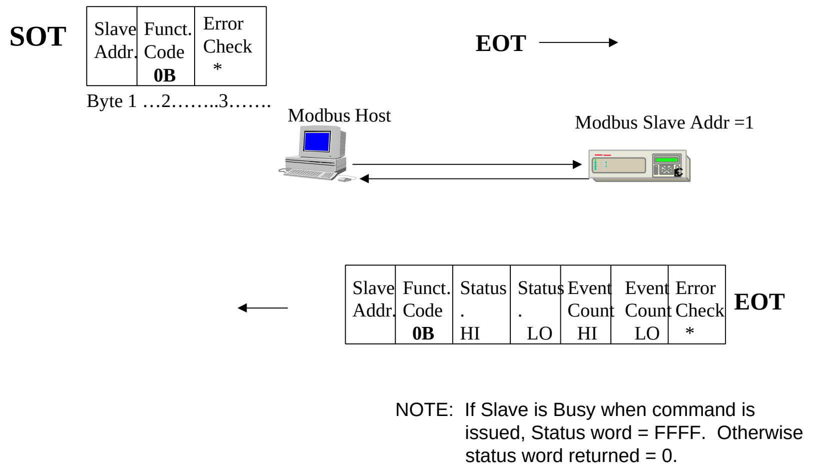


Figure 6-2. Event Counter 0B Format

Reading the communication event counter periodically can determine if the correct format of the Modbus commands have been received.

The REM 543 does support many 08 Diagnostic Sub Function codes. Modbus Commands 0C is not supported. Modbus Command 0B is supported.

Figure 6-2 lists the 08 Diagnostic Function Format.

Function 08 - Diagnostic Function

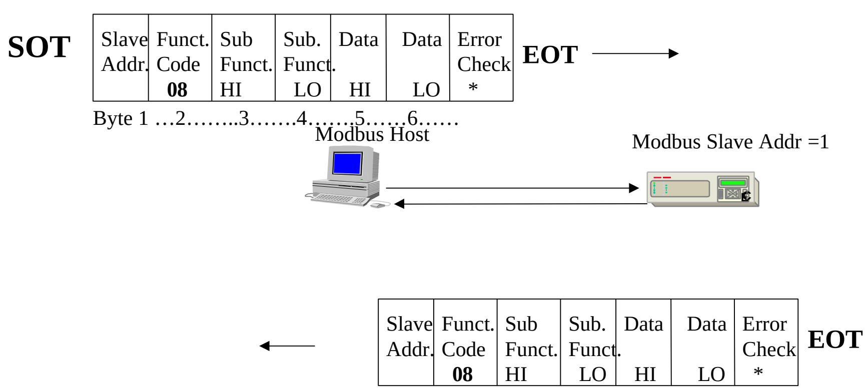


Figure 6-3. Diagnostic Function Code

Many sub functions are supported.

- 00 – Return Query Data – Echo's back data sent in transmission.
- 01 – Restart Communication Option – Re-initialize the communication port.
- 02 – Return Diagnostic Register –Returns Comm Port Diagnostic Failure Code

- 04 – Force Listen Only Mode – Disables response from slave device. Subfunction 01 enables communications.
- 0A – Clear Counter and Diagnostic Register – Clear All Counters and Diagnostic Register.
- 0B – Return Bus Message Count - Number of communications on network slave since last power up, Subfunction 01 Communication Restart, or Clear Counter Operation, Subfunction 0A.
- 0C – Return Bus Communication Error Count - Number of CRC communication errors on network slave since last power up, Subfunction 01 Communication Restart, or Clear Counter Operation, Subfunction 0A.
- 0D – Return Bus Exception Error Count - Number of communication exception errors on network slave since last power up, Subfunction 01 Communication Restart, or Clear Counter Operation, Subfunction 0A.
- 0E – Return Slave Message Count - Number of communications to slave since last power up, Subfunction 01 Communication Restart, or Clear Counter Operation, Subfunction 0A.
- 0F – Return Slave No Response Count - Number of no replies this network slave had since last power up, Subfunction 01 Communication Restart, or Clear Counter Operation, Subfunction 0A.
- 11 – Return Slave Busy Count - Number of BUSY communications responses generated by the network slave since last power up, Subfunction 01 Communication Restart, or Clear Counter Operation, Subfunction 0A.

Another method to troubleshoot the REM 543 is to use the 0B (Fetch Comm Event Counter) command and access the communication status registers.

Finally, it is always advantageous to use a datascope or a communication analyzer when troubleshooting a Modbus Network. Such devices allow the implementers to view the data strings between the host and IED. Modicon's parent company Schneider Electric has designed many utilities and products to assist the network professional with troubleshooting. Such tools are inexpensive when compared to the person-hours spent guessing as to what is sent between a host and IED. Such tools available are at a modest cost, such as Modlink, or at no cost MTS. Many of these tools are available on the website www.modicon.com.

REM 543 Modbus ASCII Communication Timing Analysis

Perhaps the most common error in implementing a Modbus ASCII network is timing setup for communication. Modbus ASCII protocol operates according to the following timing rules:

- If the REM 543 **receives** a command without a communication error (LRC, PARITY, FRAMING, OVERRUN … errors), a normal response occurs.
- If the REM 543 **does not receive** a command without a communication error (LRC, PARITY, FRAMING, OVERRUN …. Errors), no response is returned. The host (master) device will sense a timeout according to its timeout parameter. The host could then send a new command or retry sending the original command.
- Modbus ASCII allows for internals up to 1 second between characters are acceptable gaps. The REM 543 will not timeout. Character send gaps in excess of 1 second will result in REM 543 Modbus port timeouts.

REM 543 Modbus network implementers will usually notice communication errors in the form of excessive communication retries, errors, or non-responses. Understanding communication timing is a subject rarely covered in protocol manuals, but an important topic in network implementation.

Network timing is predicated upon the following factors:

Host Latency (How long does it take a host device to generate a command, receive the response and interpret the data).
Intermediate Device Latency (If a Modem, data concentrator or other device is between the end device required for data retrieval, how long does it take for each device to receive the command and process it downline to the next device).
REM 543 Device Latency (How long does it take for an REM 543 to receive a command, and return a response to the network).
Baud Rate (How fast is each data bit propagated on the medium. One cannot get around the laws of physics)
Protocol Efficiency [Network Bandwidth Utilization] (Does the protocol utilized allow for the issuance of another command before a response is received from an outstanding communication request).

The common question to a network system engineer is usually " How fast can I get my relay alarm data to appear on the screen?". An analysis of the amount of data and the above 5 areas is required.

Host latency varies widely by manufacturer or the PC or host computer. Software speed and port access varies widely. Most manufacturers of these hardware and software platforms have general benchmarks to supply to the users for processing time once the device acquires the data from the communication port.

Intermediate Device Latency also varies from the type of device used. Some modems have a device turnaround of 5 mS per transactions whereas, a radio modem may require hundreds of mS to obtain an open frequency from which to transmit.

This section shall illustrate and explain a simple network transaction based upon a simple point to point communication from a single REM 543 to a host device as illustrated in Figure 6-4 of this document. **This example shall exclude SCADA Master host latency**.

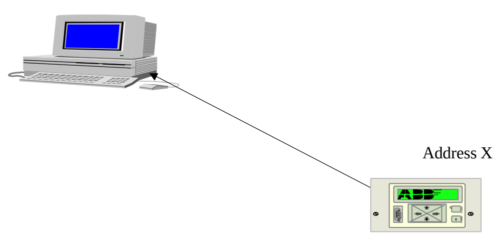


Figure 6-4. Example Communication Timing Topology

Modbus Baud Rate Analysis

If Section 5 **MODBUS ASCII PROTOCOL** is re-examined, the Modbus frame is illustrated in Figure 5-8. The frame is a standard 10 bit frame. One character (7 data bits) is transmitted as 10 bits per frame.

The rate of the data transfer is determined by the selected baud rate. The faster the baud rate, the faster the communication. The REM 543 supports baud rates of 1200, 2400, 4800, 9600 and 19200. The effect of transfer time is shown in Table 6-2. Each bit has specific transfer time which correlates to a specific character transfer time.

Table 6-2. Character Transfer Time vs Baud Rate

Baud Rate	Transfer Time Per Bit	Transfer Time Per Character
300	3.33 mS	3.33 mS
1200	0.833 mS	8.333 mS
2400	0.4167 mS	4.167 mS
4800	0.2083 mS	2.083 mS
9600	0.1041 mS	1.041 mS
19200	0.0521 mS	0.521 mS

These are fixed times determined by the laws of physics, and are standard for asynchronous bit stream transfers ASCII.

Each Modbus transfer varies in the amount of bytes transmitted and requested. Table 6-2 lists the amount of fixed data per some of the common Modbus Commands. For example, each data transmission contains the following characters as per Figure 5-8:

- Colon (:)[3A Hex]
- Slave Address (Two Characters)
- Function (Two Characters)
- Error Check (Two Characters)
- Line Feed (One Character)
- Carriage Return (One Character)

Each base transmitted and received command has at least 9 characters for transmission. The transmission time, depending upon baud rate can range from 74.97 mS (at 1200 baud) to 4.689 mS (at 19200 baud). For example Figure 6-5 illustrates the Function 01 Read Coil Status format. Figure 6-6 illustrates the transaction request for four coils. Analysis of the data transmitted and received yields the following:

Transmission Request:
Common characters 9 + 4 address characters + 4 data request characters
Total characters for transmission request = 17 characters.

Returned Response
Common characters 9 + 2 data byte characters + 4 data returned characters.
Total characters returned by REM 543 = 15 characters.
Depending upon the baud rate the total time for the communication characters to propagate along the network could range from:

Transmission Request:
17 characters at 141.61. mS (1200 Baud) to 8.857 mS (19200 Baud)

Returned Response
15 characters at 124.95 mS (1200 Baud) to 7.815 (19200 Baud)

Total network transfer time via the physical medium can range from 265.56 mS at 1200 baud to 16.672 at 19,200 baud.

Baud rate is a major influence at 1200 baud and a lesser influence at 19200 baud. It must be realized that this is only one of three components analyzed for a complete throughput analysis. In this case the Host time to generate the command

REM 543 Throughput Analysis

Communication implementation within a protective relay is a demanding task. In other devices, communications may take first priority. Within an ABB protective relay **PROTECTION IS THE FIRST PRIORITY.** Communication shall not compromise protection capabilities. Thus communication throughput may vary depending upon the demands of the protection. Table 6-3 illustrates the REM 543 average benchmark times for recognition of a Modbus command at the physical port and the time it takes to generate a reply to the respective port. The times listed in the table are average times and do not include the calculated values generated in Section 4.

Table 6-3. REM 543 Modbus Command Throughput (Average Time in mS)

			Reading from REM 543		Write to REM 543	
Modbus Command	**Register Start**	**Num. Refs.**	**Min (ms)**	**Max (ms)**	**Min (ms)**	**Max (ms)**
Real Logical Outs	00001	14	5.023	14.417		
Read Physical Outs	00046	12	1.497	10.688		
Read Physical Inputs	10001	44	1.381	13.726		
Load Metering	42048	46	35.270	78.184		
Test Setup:						
REM 543 COMM Port Settings: 9600, E,7,2, through the RS-232 port						

MODLINK Setup: 500 ms Poll though COM1 on a 486DX100 Notebook Serial Port
REM 543 is "idle", No Current/Voltage applied..
Write Min - Writing to update the Write Link side in ModLink

For the example, the REM 543 generation time for the sample example can range from 1.497 mS to 10.688 mS

Final Throughput Calculation and Analysis

A final calculation of our example throughput is warranted. For this example, the host update time shall now be assumed to be 250 mS. This 250 mS shall be an example estimation or time to generate a command, interpret the received command and update the screen. This is just for this example and varies according to:

- Speed of the host processor (hardware bus structure, # of processors, video card update, RAM memory, microprocessor speed…..)
- Operating system selected (LINUX, UNIX, OS2, WIN NT, WIN 3.1, WIN 98, WIN 95, Windows 2000….)
- MMI Port Driver Efficiency (PRICOM, Power RICH, USDATA)

Two results will be calculated, operation at 1200. The example is described as per Figure 5-8 within this document. The formula used to produce the typical response is:

System Throughput = Host Processing Time + String Transmit Time + REM 543 Processing Time + String Reception Time

At 1200 Baud:
527.248 mS = 250 mS + 141.61 mS + 10.688mS (using worst case)+ 124.95 mS

Figure 6-5 illustrates the individual contributions from each of the components as a percentage of total transaction time.

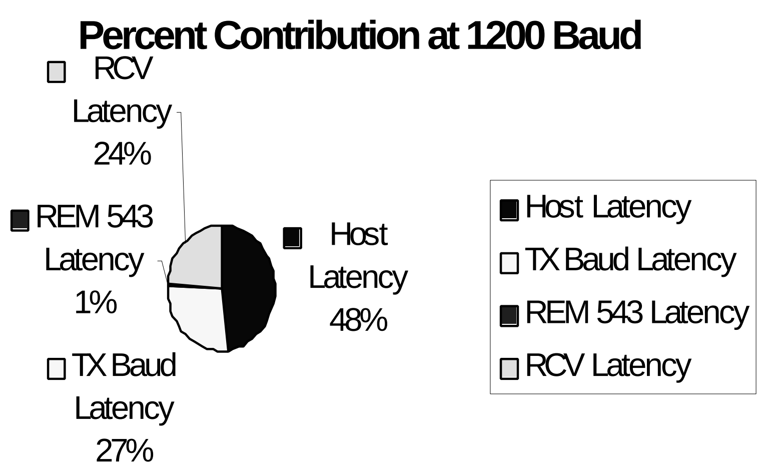


Figure 6-5. Network Throughput Analysis at 1200 Baud

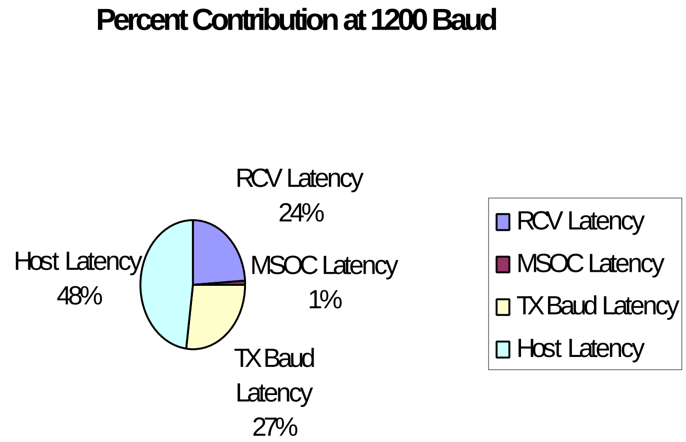


Figure 6-6. Network Throughput Analysis at 19200 Baud

Analysis of the simple example yields a few points to be considered when analyzing system throughput. Each element involved in communication timing contributes significantly to overall throughput. If the host executed and updated faster, overall throughput could be improved. If intermediate devices were inserted within the network, transaction time would increase proportionately. Baud rate is only one of many contributing factors in calculating system throughput. If one network access was required for retrieval of system data, overall network efficiency would be improved. If in a networked system, the protocol utilized would allow for additional data request commands while the slave device is processing a response, Network throughput time would be improved.

Virtual treatises have been written on improving system throughput and data updates. This simple example illustrates and allows the user to calculate system throughput times. This is especially critical so that the system user will not be surprised with overall system response.

ABB has implemented features within the protective relay to maintain system data integrity. Latched bit status, momentary change detect are a few features implemented within the various implementations of the Modbus protocol.

Appendix A - ASCII CODE

Decimal Value	Hexadecimal Value	Control Character	Character
0	00	NUL (CTRL @)	Null
1	01	SOH (CTRL A)	
2	02	STX (CTRL B)	
3	03	ETX (CTRL C)	
4	04	EOT (CTRL D)	
5	05	ENQ (CTRL E)	
6	06	ACK(CTRL F)	
7	07	BEL (CTRL G)	Beep
8	08	BS (CTRL H)	Backspace
9	09	HT (CTRL I)	Tab
10	0A	LF (CTRL J)	Line-feed
11	0B	VT (CTRL K)	Cursor home
12	0C	FF (CTRL M)	Form-feed
13	0D	CR (CTRL N)	Carriage Return (Enter)
14	0E	SO (CTRL O)	Shift Out
15	OF	SI (CTRL P)	Shift In
16	10	DLE	Data Link Escape
17	11	DCI	
18	12	DC2	
19	13	DC3	
20	14	DC4	
21	15	NAK	
22	16	SYN	
23	17	ETB	
24	18	CAN	
25	19	EM	
26	1A	SUB	
27	1B	ESC	
28	1C		Cursor right
29	1D		Cursor left
30	1E		Cursor up
31	1F		Cursor down
32	20		Space
33	21		!
34	22		“
35	23		#
36	24		$
37	25		%
38	26		&
39	27		‘
40	28		(
41	29		(
42	2A		*
43	2B		+
44	2C		,
45	2D		-
46	2E		.
47	2F		/
48	30		0
49	31		1
50	32		2
51	33		3

52	34	4
53	35	5
54	36	6
55	37	7
56	38	8
57	39	9
58	3A	
59	3B	
60	3C	<
61	3D	
62	3E	>
63	3F	?
64	40	@
65	41	A
66	42	B
67	43	C
68	44	D
69	45	E
70	46	F
71	47	G
72	48	H
73	49	I
74	4A	J
75	4B	K
76	4C	L
77	4D	M
78	4E	*N*
79	4F	O
80	50	P
81	51	Q
82	52	R
83	53	S
84	54	T
85	55	U
86	56	V
87	57	W
88	58	X
89	59	Y
90	5A	Z
91	5B	[
92	5C	\
93	5D	]
94	5E	^
95	5F	_
96	60	`
97	61	a
98	62	b
99	63	c
100	64	d
101	65	e
102	66	f
103	67	g
104	68	h
105	69	i
106	6A	j
107	6B	k
108	6C	l
109	6D	m
110	6E	n

111	6F	o
112	70	p
113	71	q
114	72	r
115	73	s
116	74	t
117	75	u
118	76	v
119	77	w
120	78	x
121	79	y
122	7A	z
123	7B	{
124	7C	|
125	7D	}
126	7E	~
127	7F	DEL