SCADAPack E Target 5
Modbus Communication
Interfaces

Documentation

Table of Contents

I SCADAPack E Target 5 Modbus Communication Interfaces

Schneider Electric

Documentation

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All pertinent state, regional, and local safety regulations must be observed when installing and using this product. For reasons of safety and to help ensure compliance with documented system data, only the manufacturer should perform repairs to components.

When devices are used for applications with technical safety requirements, the relevant instructions must be followed. Failure to use Schneider Electric software or approved software with our hardware products may result in injury, harm, or improper operating results.

Failure to observe this information can result in injury or equipment damage.

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2 Safety Information

Read these instructions carefully, and look at the equipment to become familiar with the device before trying to install, operate, or maintain it. The following special messages may appear throughout this documentation or on the equipment to warn of potential hazards or to call attention to information that clarifies or simplifies a procedure.

	The addition of this symbol to a Danger or Warning safety label indicates that an electrical hazard exists, which will result in personal injury if the instructions are not followed.
	This is the safety alert symbol. It is used to alert you to potential personal injury hazards. Obey all safety messages that follow this symbol to avoid possible injury or death.

⚠DANGER

DANGER indicates an imminently hazardous situation which, if not avoided, **will result in** death or serious injury.

⚠WARNING

WARNING indicates a potentially hazardous situation which, if not avoided, **can result** in death or serious injury.

⚠CAUTION

CAUTION indicates a potentially hazardous situation which, if not avoided, **can result** in minor or moderate injury.

CAUTION

CAUTION used without the safety alert symbol, indicates a potentially hazardous situation which, if not avoided, **can result in** equipment damage..

PLEASE NOTE

Electrical equipment should be installed, operated, serviced, and maintained only by qualified personnel. No responsibility is assumed by Schneider Electric for any consequences arising out of the use of this material.

A qualified person is one who has skills and knowledge related to the construction and operation of electrical equipment and the installation, and has received safety training to recognize and avoid the hazards involved.

BEFORE YOU BEGIN

SCADAPack Workbench and SCADAPack E Smart RTU are not suitable for controlling safety-critical systems. SCADAPack Workbench and SCADAPack E Smart RTU are not tested for, nor have approval for use in, the control of safety-critical systems. Safety-critical systems should be controlled by an approved safety-critical platform that is independent of SCADAPack Workbench and SCADAPack E Smart RTU.

⚠WARNING

UNINTENDED EQUIPMENT OPERATION

Do not control safety-critical systems with SCADAPack Workbench and SCADAPack E Smart RTU.

Failure to follow these instructions can result in death, serious injury or equipment damage.

Do not use this product on machinery lacking effective point-of-operation guarding. Lack of effective point-of-operation guarding on a machine can result in serious injury to the operator of that machine.

⚠CAUTION

EQUIPMENT OPERATION HAZARD

- Verify that all installation and set up procedures have been completed.
- Before operational tests are performed, remove all blocks or other temporary holding means used for shipment from all component devices.
- Remove tools, meters, and debris from equipment.

Failure to follow these instructions can result in injury or equipment damage.

Follow all start-up tests recommended in the equipment documentation. Store all equipment documentation for future references.

Software testing must be done in both simulated and real environments.

Verify that the completed system is free from all short circuits and grounds, except those grounds installed according to local regulations (according to the National Electrical Code in the U.S.A, for instance). If high-potential voltage testing is necessary, follow recommendations in equipment documentation to prevent accidental equipment damage.

Before energizing equipment:

- Remove tools, meters, and debris from equipment.
- Close the equipment enclosure door.
- Remove ground from incoming power lines.
- Perform all start-up tests recommended by the manufacturer.

OPERATION AND ADJUSTMENTS

The following precautions are from the NEMA Standards Publication ICS 7.1-1995 (English version prevails):

- Regardless of the care exercised in the design and manufacture of equipment or in the selection and ratings of components, there are hazards that can be encountered if such equipment is improperly operated.
- It is sometimes possible to misadjust the equipment and thus produce unsatisfactory or unsafe operation. Always use the manufacturer's instructions as a guide for functional

adjustments. Personnel who have access to these adjustments should be familiar with the equipment manufacturer's instructions and the machinery used with the electrical equipment.

- Only those operational adjustments actually required by the operator should be accessible to the operator. Access to other controls should be restricted to prevent unauthorized changes in operating characteristics.

3 Overview

This document describes communication with other Modbus devices using Modbus RTU, Modbus/TCP, or Modbus RTU in TCP protocols.

Master/Slave and Client/Server Terminology

A Modbus Master or Modbus Client sends commands to another device. The Modbus Slave or Modbus Server device responds to the commands.

- The Modbus RTU and Modbus RTU protocols call the device sending the commands a Modbus Master. The device responding to the commands is called a Modbus Slave.
- The Modbus/TCP protocol calls the device sending the commands a Modbus Client. The device responding to the commands is called a Modbus Server.

The SCADAPack E Smart RTU can operate as a Modbus Master or Modbus Client; and as a Modbus Slave or Modbus/TCP Server. It supports simultaneous communication using supported protocols. It does not support Modbus ASCII protocol.

Assumed Knowledge

Familiarity with Modbus RTU, Modbus/TCP, or Modbus RTU in TCP protocols.

Target Audience

- Systems Engineers
- Commissioning Engineers
- Maintenance Technicians

References

- SCADAPack E Target 5 I/O Device Reference Manual
- SCADAPack E Configurator User Manual
- SCADAPack E Technical Reference Manuals.

- Workbench Help
- Protocol documentation for various Modbus PLC devices
- Open Modbus/TCP Specification Revision 1.0, March 1999

4 Modbus Master/Client Operation

A Modbus Master or Modbus Client sends commands to another device.

- The Modbus RTU and Modbus RTU protocols call the device sending the commands a Modbus Master.
- The Modbus/TCP protocol calls the device sending the commands a Modbus Client.

These sections describe operation as a Master/Client.

4.1 I/O Device Types and Modbus Addressing Terminology

The SCADAPack E Smart RTU controller provides three groups of Modbus I/O Devices. See the SCADAPack E Target 5 I/O Device Manual for details.

A maximum of 200 PLC Device I/O Devices (total of every PLC type) may be configured in total per Resource.

Modbus RTU Protocol

I/O Devices beginning with MBUS... communicate using the Modbus RTU protocol.

Modbus RTU operates on serial ports. One or more serial ports must be configured as a *PLC Device*. The RTU communication port data rate and parity format are used. RS232, RS422 and RS485 communications are supported.

Modbus/TCP Protocol

I/O Devices beginning with MTCP... communicate using the Modbus/TCP protocol.

Modbus/TCP operates on TCP/IP networks. The *Modbus/IP (Client)* service must be enabled. The protocol connects TCP sockets between the Modbus client and server. TCP/IP over Ethernet and PPP communications are supported.

Modbus RTU in TCP Protocol

I/O Devices beginning with MRTUTCP... communicate using the Modbus RTU in TCP protocol.

Modbus RTU in TCP operates on TCP/IP networks. The *Modbus/IP (Client)* service must be enabled. The protocol connects TCP sockets between the Modbus client and server. TCP/IP over Ethernet and PPP communications are supported.

Modbus Addressing Terminology

The SCADAPack E Smart RTU uses 5-digit Modbus address numbering, where the leading digit generally represents the register data type. In addition, the numbering within each register data type adheres to the classical Modicon PLC numbering convention, commencing at register 1. For example: A register read by the SCADAPack E Smart RTU specifying Modbus register 40010 is represented by Modbus protocol function code 3, protocol register address 0x0009.

Some Modbus systems use 6-digit addressing, as opposed to the 5-digit Modbus register addressing described above. 6-digit addressing is designed to enable access to additional registers in each register range. A 6 digit address is made up of a single digit numeric prefix and a 5-digit Modbus register number. For example: Registers 300001 – 309999 are equivalent to 5-digit Modbus register addresses 30001 – 39999. However, input registers 310000 – 365536 in a remote PLC device are not addressable with the SCADAPack E Smart RTU 5-digit register address.

In the 5-digit addressing regime, HOLDING REGISTERS are extended beyond register 49999. RTU Modbus register addresses 50000 – 65535 can be addressed in a remote PLC device, and are the equivalent to 6-digit holding register numbers 450000 – 465535. So the SCADAPack E RTU can access remote PLC device holding registers equivalent to the (6-digit) range 400001-409999 & 450000-465535.

4.2 Serial Modbus I/O Devices

I/O Devices beginning with MBUS... communicate using the Modbus RTU protocol using serial ports configured as *PLC Device*.

Each I/O device can access different PLC register data within the same PLC device, or in different PLCs. For example, multi-drop RS485 permits many uniquely addressed Modbus

PLCs to be connected to a serial port. In addition, multiple I/O Devices may be configured to use different RTU serial ports configured as a *PLC Device*.

Each I/O device uses a separate Modbus request to read or write its data. Improved communication efficiency can be achieved by grouping Modbus registers together and using fewer I/O Devices with a larger number of channels, rather than more I/O Devices with a smaller number of channels.

A maximum of 200 PLC Device I/O Devices (total of every PLC type) may be configured in total per IEC 61131-3 Resource.

Communication status is available on the first 60 I/O Devices for IEC 61131-3 Resource 1, and 14 I/O Devices for IEC 61131-3 Resource 2. See Section System Points 48 for more information.

- Modbus Input devices 11
- Modbus Output devices 12

4.2.1 Modbus Input Devices

Modbus input device variables are updated at the start of the IEC 61131-3 Resource scan. The value presented to the IEC 61131-3 variables is the value returned by the PLC to the previous read request. This read may have occurred during previous resource scans.

The *data update rate* parameter on the I/O device sets the scan rate of the PLC data. The PLC communication status is updated if there is a status code returned from the PLC, or no response from the PLC after a data request by the RTU (see Section Modbus Status Values 30). The status is cleared upon successful communications. To catch transient status codes, you can use IEC 61131-3 logic to store non-zero values.

Input Device Parameters

***first_register*:** specifies the Modbus data registers to access when reading PLC data into IEC 61131-3 variables. The PLC data type accessed is specific to the PLC Device I/O device type and device address.

***register_format*:** specifies the Modbus PLC data register type. Various PLC data types are supported. See Modbus PLC Data Types 20.

***data_update_rate*:** specifies the rate in milliseconds (ms) at which the data for the input device is extracted from the PLC. Individual I/O Devices may have different data update rates allowing prioritization of data extracted from a PLC. The SCADAPack E Smart RTU may not be able to read requested PLC data within the time set by the data update rate depending on the quantity of data to be read, rate of write requests and PLC communication speed. In this case the update rates will be slower.

***plc_device_addr*:** specifies the PLC device address. Modbus PLC devices on the same communication channel need to have unique device addresses. Logic may access data from multiple PLCs via the same communication interface. In this case a separate I/O device will

be required for each PLC device. Values for this parameter are usually in the range 1-254.

***timeout*:** specifies the communications timeout on an individual I/O device. The timeout applies to communications associated with that device. Where this value is "0", the PLC device driver will use the default timeout (1200ms). Units for this field are the millisecond (ms).

***port*:** specifies which serial port will be used to communicate with the PLC. The port must be configured as a *PLC Device*. If only one *PLC Device* port is configured, this field is ignored.

Controlling PLC Device Communications

Communication using these I/O Devices can be controlled by the function block mbusctrl using the En_RD parameter. See *SCADAPack E Target 5 Function Block Reference* for details.

4.2.2 Modbus Output Devices

Modbus output device variables are updated at the end of the IEC 61131-3 Resource scan.

Output variables are written to the PLC:

- When the value of a variable attached to the output device changes. They are sent to the PLC after this occurs, but the scan continues executing while the PLC communications are in progress. In order words, communications to the PLC is occurs asynchronously to the program scan.
- When the IEC 61131-3 Resource starts.
- When the PLC does not respond to a command, it is re-sent until the PLC responds.
- When the data update rate configured for the output device is reached.

Output Device Parameters

***first_register*:** specifies the Modbus data registers to access when reading PLC data into IEC 61131-3 variables. The PLC data type accessed is specific to the PLC Device I/O device type and device address.

***register_format*:** specifies the Modbus PLC data register type. Various PLC data types are supported. See Modbus PLC Data Types 20.

***data_update_rate*:** specifies the rate in milliseconds (ms) at which the data for the output device is written to the PLC. Between *data_update_rate* periods, data is written to the PLC only when the output variable values change. Individual I/O Devices may have different data update rates allowing prioritization of data sent to a PLC Device. Setting this parameter to 0 disables the time-based writing of output data. Data is written at IEC 61131-3 Resource startup and thereafter only when individual output variables change. See PLC Output device Default Background Update Rate 31.

***plc_device_addr*:** specifies the PLC device address. Modbus PLC devices on the same communication channel need to have unique device addresses. Logic may access data from multiple PLCs via the same communication interface. In this case a separate I/O device will be required for each PLC device. Values for this parameter are usually in the range 1-254.

***timeout*:** specifies the communications timeout on an individual I/O device. The timeout applies to communications associated with that device. Where this value is "0", the PLC device driver will use the default timeout (1200ms). Units for this field are the millisecond (ms).

***port*:** specifies which serial port will be used to communicate with the PLC. The port must be configured as a *PLC Device*. If only one *PLC Device* port is configured, this field is ignored.

Controlling PLC Device Communications

Communication using these I/O Devices can be controlled by the function block mbusctrl using the En_WR parameter. See *SCADAPack E Target 5 Function Block Reference* for details.

Remote Device Requirements

The device to which Modbus Output commands are sent needs to provide Modbus register addresses for each of the channels on the output device, regardless of whether variables are attached to the channels, or not. For example, for a 16-channel device, 16 contiguous Modbus registers need to be present in the remote device.

4.3 Modbus TCP I/O Device Interface

I/O Devices beginning with MTCP... communicate using the Modbus/TCP protocol.

Each I/O device uses a separate Modbus/TCP request to read or write its data. Improved communication efficiency can be achieved by grouping Modbus registers together and using fewer I/O Devices with a larger number of channels, rather than more I/O Devices with a smaller number of channels.

A maximum of 200 PLC Device I/O Devices (total of every PLC type) may be configured in total per IEC 61131-3 Resource.

A corresponding pair of system points relates to each PLC Slave I/O device as described in Section System Points 48.

Communication using these I/O Devices can be controlled by an function block: mtcpctrl.

- Modbus/TCP Input devices 14
- Modbus/TCP Output devices 15
- Open Modbus/TCP Conformance Classes 16

4.3.1 Modbus/TCP Input Devices

Modbus/TCP input device variables are updated at the start of the IEC 61131-3 Resource scan. The value presented to the IEC 61131-3 variables is the value returned by the PLC to the previous read request. This read may have occurred during previous resource scans.

The *data update rate* parameter on the I/O device sets the scan rate of the PLC data. The PLC communication status is updated if there is a status code returned from the PLC, or no response from the PLC after a data request by the RTU (see Section Modbus Status Values 30). The status is cleared upon successful communications. To catch transient status codes, you can use IEC 61131-3 logic to store non-zero values.

Input Device Parameters

***first_register*:** specifies the Modbus data registers to access when reading PLC data into IEC 61131-3 variables. The PLC data type accessed is specific to the PLC Device I/O device type and device address.

***register_format*:** specifies the Modbus PLC data register type. Various PLC data types are supported. See Modbus PLC Data Types 20.

***data_update_rate*:** specifies the rate in milliseconds (ms) at which the data for the input device is extracted from the PLC. Individual I/O Devices may have different data update rates allowing prioritization of data extracted from a PLC. The SCADAPack E Smart RTU may not be able to read requested PLC data within the time set by the data update rate depending on the quantity of data to be read, rate of write requests and PLC communication speed. In this case the update rates will be slower.

***plc_device_addr*:** specifies the PLC device address. Modbus PLC devices on the same communication channel need to have unique device addresses. Logic may access data from multiple PLCs via the same communication interface. In this case a separate I/O device will be required for each PLC device. Values for this parameter are usually in the range 1-254.

***timeout*:** specifies the communications timeout on an individual I/O device. The timeout applies to communications associated with that device. Where this value is “0”, the PLC device driver will use the default timeout (1200ms). Units for this field are the millisecond (ms).

TCP_port: This parameter specifies the port number of the Modbus/TCP server. Default is 502.

IP_address: This parameter specifies the IP network address that the SCADAPack E Smart RTU connects to for communication with the PLC for this I/O device. Enter the IP address of the Modbus/TCP PLC, or Modbus bridge if applicable.

Controlling PLC Device Communications

Communication using these I/O Devices can be controlled by the function block mtcpctrl using the En_RD parameter. See *SCADAPack E Target 5 Function Block Reference* for

details.

4.3.2 Modbus/TCP Output Devices

Modbus/TCP output device variables are updated at the end of the IEC 61131-3 Resource scan.

Output variables are written to the PLC:

- When the value of a variable attached to the output device changes.
- When the IEC 61131-3 Resource starts.
- When the PLC does not respond to a command, it is re-sent until the PLC responds.
- When the data update rate configured for the output device is reached.

Output Device Parameters

***first_register*:** specifies the Modbus data registers to access when reading PLC data into IEC 61131-3 variables. The PLC data type accessed is specific to the PLC Device I/O device type and device address.

***register_format*:** specifies the Modbus PLC data register type. Various PLC data types are supported. See Modbus PLC Data Types 20.

***data_update_rate*:** specifies the rate in milliseconds (ms) at which the data for the output device is written to the PLC. Between *data_update_rate* periods, data is written to the PLC only when the output variable values change. Individual I/O Devices may have different data update rates allowing prioritization of data sent to a PLC Device. Setting this parameter to 0 disables the time-based writing of output data. Data is written at IEC 61131-3 Resource startup and thereafter only when individual output variables change. See PLC Output device Default Background Update Rate 31.

***plc_device_addr*:** specifies the PLC device address. Modbus PLC devices accessed at the same IP address (e.g. via a Modbus bridge) need to have a unique unit address in order to be identified. Logic may access data from different units on the same IP address or at different IP addresses. In these cases a separate I/O device will be required for each device.

***timeout*:** specifies the communications timeout on an individual I/O device. The timeout applies to communications associated with that device. Where this value is “0”, the PLC device driver will use the default timeout (1200ms). Units for this field are the millisecond (ms).

TCP_port: This parameter specifies the port number of the Modbus/TCP server. Default is 502.

IP_address: This parameter specifies the IP network address that the SCADAPack E Smart RTU connects to for communication with the PLC for this I/O device. Enter the IP address of the Modbus/TCP PLC, or Modbus bridge if applicable.

Controlling PLC Device Communications

Communication using these I/O Devices can be controlled by the function block mbusctrl using the En_WR parameter. See *SCADAPack E Target 5 Function Block Reference* for details.

Remote Device Requirements

The device to which Modbus Output commands are sent needs to provide Modbus register addresses for each of the channels on the output device, regardless of whether variables are attached to the channels, or not. For example, for a 16-channel device, 16 contiguous Modbus registers need to be present in the remote device.

4.3.3 Open Modbus/TCP Conformance Classes

The Open Modbus/TCP standard defines conformance classes for Master & Slave (Client & Server) devices.

When using the PLC I/O Devices in the following way, the SCADAPack E RTU conforms to the requirements for Open Modbus/TCP Conformance CLASS 0 devices:

MTCP_BOOL_READ	device address: 40001-65535 plc data type: IEC DISCRETE uses Modbus function code 3 – read multiple registers
MTCP_BOOL_WRITE	device address: 40001-65535 plc data type: IEC DISCRETE uses Modbus function code 16 – write multiple registers
MTCP_INT_READ MTCP_DINT_READ MTCP_UINT_READ MTCP_REAL_READ	device address: 40001-65535 plc data type: IEC INT, IEC UINT, IEC DINT, IEC REAL uses Modbus function code 3 – read multiple registers
MTCP_INT_WRITE MTCP_DINT_WRITE	device address: 40001-65535 plc data type: IEC INT, IEC UINT, IEC DINT, IEC REAL uses Modbus function code 16 – write multiple registers

MTCP_UINT_WRITE

MTCP_REAL_WRITE

Use of the PLC I/O Devices in the following ways requires the PLC slave device (Open Modbus/TCP server) to be at least an Open Modbus/TCP Conformance CLASS 1 device:

MTCP_BOOL_READ	device address: 1-9999 plc data type: IEC DISCRETE uses Modbus function code 1 – read coils
MTCP_BOOL_WRITE	device address: 10001-19999 plc data type: IEC DISCRETE uses Modbus function code 2 – read input discrete (status)
MTCP_INT_READ MTCP_DINT_READ MTCP_UINT_READ MTCP_REAL_READ	device address: 30001-39999 plc data type: IEC INT, IEC UINT, IEC DINT, IEC REAL uses Modbus function code 4 – read input registers
MTCP_INT_WRITE MTCP_DINT_WRITE MTCP_UINT_WRITE MTCP_REAL_WRITE	device address: 1-9999 plc data type: IEC INT, IEC UINT, IEC DINT, IEC REAL uses Modbus function code 5 – write coil

PLC data type options additional to those listed here are available. The above types are a selection of those defined in the Open Modbus/TCP Conformance Classes. Refer to Modbus PLC Data Types 20 for a complete listing of supported data types.

4.4 Modbus RTU in TCP I/O Device Interface

I/O Devices beginning with MRTUTCP... communicate using the Modbus RTU in TCP protocol.

Each I/O device uses a separate Modbus RTU in TCP request to read or write its data. Improved communication efficiency can be achieved by grouping Modbus registers together and using fewer I/O Devices with a larger number of channels, rather than more I/O Devices with a smaller number of channels.

A maximum of 200 PLC Device I/O Devices (total of every PLC type) may be configured in total per IEC 61131-3 Resource.

A corresponding pair of system points relates to each PLC Slave I/O device as described in Section System Points 48.

Communication using these I/O Devices can be controlled by the function block: mtcpctrl.

4.4.1 Modbus RTU in TCP Input Devices

Modbus RTU in TCP input device variables are updated at the start of the IEC 61131-3 Resource scan. The value presented to the IEC 61131-3 variables is the value returned by the PLC to the previous read request. This read may have occurred during previous resource scans.

The *data update rate* parameter on the I/O device sets the scan rate of the PLC data. The PLC communication status is updated if there is a status code returned from the PLC, or no response from the PLC after a data request by the RTU (see Section Modbus Status Values 30). The status is cleared upon successful communications. To catch transient status codes, you can use IEC 61131-3 logic to store non-zero values.

Input Device Parameters

***first_register*:** specifies the Modbus data registers to access when reading PLC data into IEC 61131-3 variables. The PLC data type accessed is specific to the PLC Device I/O device type and device address.

***register_format*:** specifies the Modbus PLC data register type. Various PLC data types are supported. See Modbus PLC Data Types 20.

***data_update_rate*:** specifies the rate in milliseconds (ms) at which the data for the input device is extracted from the PLC. Individual I/O Devices may have different data update rates allowing prioritization of data extracted from a PLC. The SCADAPack E Smart RTU may not be able to read requested PLC data within the time set by the data update rate depending on the quantity of data to be read, rate of write requests and PLC communication speed. In this case the update rates will be slower.

***plc_device_addr*:** specifies the PLC device address. Modbus PLC devices on the same communication channel need to have unique device addresses. Logic may access data from multiple PLCs via the same communication interface. In this case a separate I/O device will be required for each PLC device. Values for this parameter are usually in the range 1-254.

***timeout*:** specifies the communications timeout on an individual I/O device. The timeout applies to communications associated with that device. Where this value is "0", the PLC device driver will use the default timeout (1200ms). Units for this field are the millisecond (ms).

TCP_port: This parameter specifies the port number of the Modbus RTU in TCP server.

IP_address: This parameter specifies the IP network address that the SCADAPack E Smart RTU connects to for communication with the PLC for this I/O device. Enter the IP address of the Modbus/TCP PLC, or Modbus bridge if applicable.

Controlling PLC Device Communications

Communication using these I/O Devices can be controlled by the function block mtcpctrl using the En_RD parameter. See *SCADAPack E Target 5 Function Block Reference* for details.

4.4.2 Modbus RTU in TCP Output Devices

Modbus RTU in TCP output device variables are updated at the end of the IEC 61131-3 Resource scan.

Output variables are written to the PLC:

- When the value of a variable attached to the output device changes.
- When the IEC 61131-3 Resource starts.
- When the PLC does not respond to a command, it is re-sent until the PLC responds.
- When the data update rate configured for the output device is reached.

Output Device Parameters

***first_register*:** specifies the Modbus data registers to access when reading PLC data into IEC 61131-3 variables. The PLC data type accessed is specific to the PLC Device I/O device type and device address.

***register_format*:** specifies the Modbus PLC data register type. Various PLC data types are supported. See Modbus PLC Data Types 20.

***data_update_rate*:** specifies the rate in milliseconds (ms) at which the data for the output device is written to the PLC. Between *data_update_rate* periods, data is written to the PLC only when the output variable values change. Individual I/O Devices may have different data update rates allowing prioritization of data sent to a PLC Device. Setting this parameter to 0 disables the time-based writing of output data. Data is written at IEC 61131-3 Resource startup and thereafter only when individual output variables change. See PLC Output device Default Background Update Rate 31.

***plc_device_addr*:** specifies the PLC device address. Modbus PLC devices accessed at the

same IP address (e.g. via a Modbus bridge) need to have a unique unit address in order to be identified. Logic may access data from different units on the same IP address or at different IP addresses. In these cases a separate I/O device will be required for each device.

***timeout*:** specifies the communications timeout on an individual I/O device. The timeout applies to communications associated with that device. Where this value is "0", the PLC device driver will use the default timeout (1200ms). Units for this field are the millisecond (ms).

TCP_port: This parameter specifies the port number of the Modbus RTU in TCP server.

IP_address: This parameter specifies the IP network address that the SCADAPack E Smart RTU connects to for communication with the PLC for this I/O device. Enter the IP address of the Modbus/TCP PLC, or Modbus bridge if applicable.

Controlling PLC Device Communications

Communication using these I/O Devices can be controlled by the function block mbusctrl using the En_WR parameter. See *SCADAPack E Target 5 Function Block Reference* for details.

Remote Device Requirements

The device to which Modbus Output commands are sent needs to provide Modbus register addresses for each of the channels on the output device, regardless of whether variables are attached to the channels, or not. For example, for a 16-channel device, 16 contiguous Modbus registers need to be present in the remote device.

4.5 Modbus PLC Data Types

The following data types are supported.

IEC DISCRETE

Binary (discrete) data packed into an 8-bit value where the least significant bit of the value represents the low discrete bit number. For a protocol message that contains 16 discrete coils at addresses 11-26 for example, coil 11 is represented by the least significant bit of the first byte in the protocol, and coil 26 is represented by the most significant bit of the second byte in the protocol. This data type can be used to access PLC inputs, coils or holding register bits.

984 DISCRETE

Binary (discrete) data usually packed into a 16-bit value where the least significant bits of the 16-bit value represent the high discrete bit numbers. For a protocol message that contains 16 discrete coils at addresses 30-45 for instance, coil 30 is represented by the most

significant bit of the 16-bit value, and coil 45 is represented by the least significant bit of the 16-bit value. This data type can be used to access PLC inputs, coils or holding register bits.

IEC UINT

Unsigned 16-bit integer value. Valid values are 0 ~ 65535. This is the default data type used by the RTU for Modbus PLC register data. This data type can be used to access PLC input registers or holding registers.

IEC INT

Signed 16-bit integer value. Valid values are –32768 ~ 32767. This data type can be used to access PLC input registers or holding registers.

IEC DINT

Signed 32-bit double integer value, organized as two words in the protocol in Little Endian format (least significant word first). Valid values are –2^31 ~ 2^31-1. I/O Devices utilizing this data type will automatically select between IEC DINT data format for integer analog variables, and IEC REAL data format for real analog variables on the I/O device. This data type generally accesses a consecutive pair of 16-bit holding registers.

IEC REAL

IEEE-754 format 32-bit floating point real value, organized as two words in the protocol in Little Endian register format (least significant word in first register). This data type generally accesses a consecutive pair of 16-bit holding registers.

SWAP REAL

IEEC-754 format 32-bit floating point real value, organized as two words in the protocol in swapped (Big Endian) register format (most significant word in first register). This data type generally accesses a consecutive pair of 16-bit holding registers.

IEC UDINT

Unsigned 32-bit double integer value, organized as two words in the protocol in Little Endian format (least significant word first). Valid values are 0 ~ 2^32-1. This data type is not supported in I/O Devices. This data type is supported by Modbus Slave and Modbus/TCP Server interfaces. See Modbus Slave / Server Analog Addresses 39. This data type generally accesses a consecutive pair of 16-bit holding registers.

4.6 Communication Interfaces

These communication interfaces are provided by the SCADAPack E Smart RTU.

4.6.1 Serial Modbus Communications

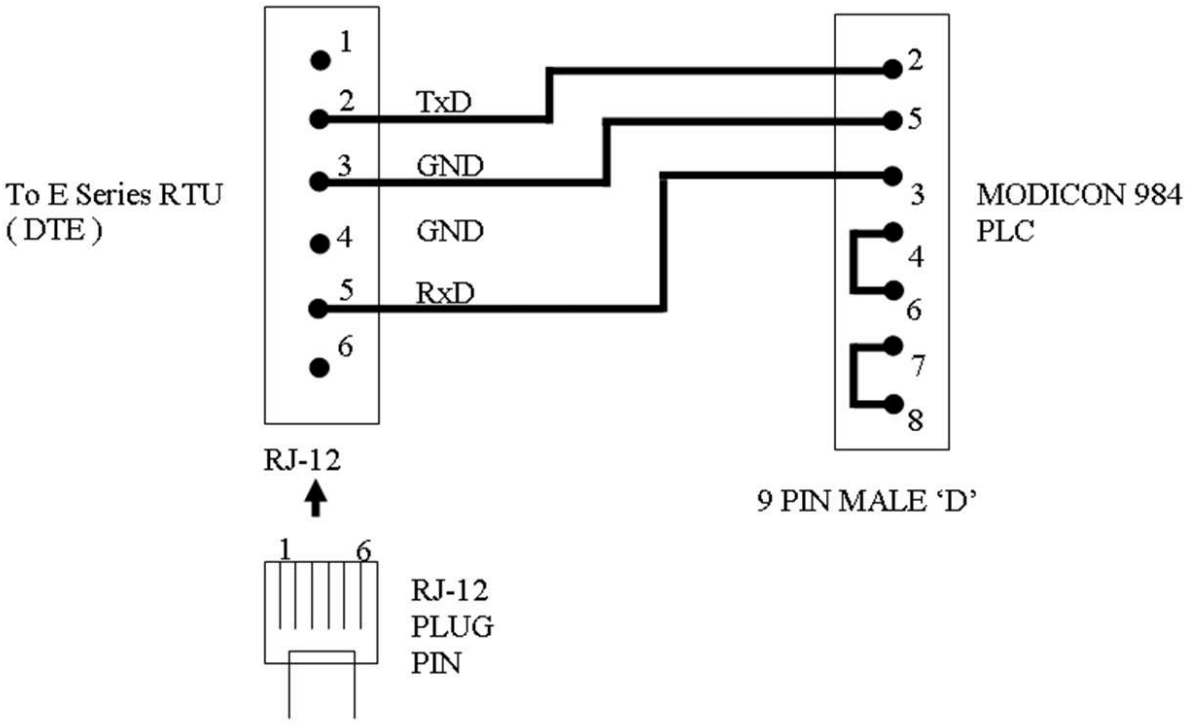
When using serial Modbus master communications, the SCADAPack E Smart RTU communicates with the PLC or peripheral devices using serial ports configured as *PLC Device*.

Each port needs to be configured to communicate at the same rate and in the same format as the peripheral devices. For example 9600 bps, 8 data bits, 1 stop bit, and no parity.

The SCADAPack E Smart RTU will not assert any hardware handshaking lines when communicating using RS232, RS422 or 4-wire RS485 with its Modbus PLC device driver. If the Modbus PLC requires hardware handshaking (e.g. CTS asserted), it needs to be provided in the cabling to the PLC (as shown above).

When 2-wire RS485 communications is used, the SCADAPack E Smart RTU provides RS485 transmitter/receiver control internally.

A sample cable configuration for connecting a PLC to a SCADAPack ES RTU RS232 port is shown below.



4.6.2 Modbus/TCP Client Communications

When using Modbus/TCP communications, the SCADAPack E Smart RTU communicates with the PLC or peripheral devices using a TCP/IP interface. This may be an Ethernet interface configured as “TCP/IP Enable” or "TCP/IP + RemIO" (depending on the RTU model), or a serial port configured as ‘PPP-TCP/IP’.

In addition, the “IP Services” configuration needs to have “Modbus/TCP Client” service enabled for operation of Modbus/TCP protocol. This configuration can be made on the SCADAPack E Configurator “TCP/IP” page. For more information see the SCADAPack E TCP/IP Technical Reference manual.

Enabling Modbus/IP Client service requires the SCADAPack E Smart RTU to be restarted in order to start the PLC Cache task.

The SCADAPack E Smart RTU may connect to any Open Modbus/TCP protocol device including PLCs, I/O modules and Modbus Bridges.

Each Modbus/TCP I/O device specifies an “IP_address” parameter that needs to be configured with the address of the Modbus/TCP device that the RTU is communicating with (for that I/O device). It is assumed that the SCADAPack E Smart RTU and the Modbus/TCP device(s) have fixed IP address which are unique on the IP network to which they are connected.

The SCADAPack E Smart RTU Modbus/TCP client attaches to TCP port number 502 in each target Modbus/TCP server device. This can be changed by advanced users if required.

Some Modbus/TCP devices expect to obtain their IP addresses from another device on their network rather than being configured with their address, locally. For this purpose, the

SCADAPack E Smart RTU supports BOOTP Server capability. BOOTP Server needs to also be enabled in the “IP Services” configuration to support this capability. See Section BOOTP Server Configuration 25 for more information.

For further information on connecting to the SCADAPack E Smart RTU to TCP/IP networks, refer to the SCADAPack E TCP/IP Reference manual.

4.6.3 Modbus/TCP Server Communications

When using Modbus/TCP Server communications, the SCADAPack E Smart RTU communicates with Modbus/TCP clients using one of its TCP/IP interfaces. This may be the Ethernet interface configured as “TCP/IP Enabled” or "TCP/IP + RemIO" (depending on the RTU model), or a serial port configured as ‘PPP-TCP/IP’.

In addition, the “IP Services” configuration needs to have “Modbus/TCP Server” service enabled for operation of Modbus/TCP protocol. This configuration can be made on SCADAPack E Configurator’s “TCP/IP” or "Slave / Modbus" page. For more information see the SCADAPack E TCP/IP Technical Reference manual.

Enabling Modbus/TCP Server service requires the SCADAPack E Smart RTU to be restarted in order to start the Modbus/TCP Server listening task.

The Modbus/TCP Server ‘listens’ on TCP port number “502” for any Modbus/TCP client devices attempting to connect.

The Modbus/TCP server supports a maximum of concurrent clients depending on the controller type.

- For the SCADAPack ER and SCADAPack ES controllers the Open Modbus/TCP server supports a maximum of 20 concurrent client connections.
- For the SCADAPack 300E controllers the Open Modbus/TCP server supports a maximum of 5 concurrent client connections.

An open socket will be closed if there is no activity detected for 120 seconds (see Section TCP / Operating System Issues 51 for more information regarding the inactivity disconnect timeout).

For further information on connecting the SCADAPack E Smart RTU to TCP/IP networks, refer to the SCADAPack E TCP/IP Reference manual.

4.6.4 Modbus RTU in TCP Client Communications

When using Modbus RTU in TCP communications, the SCADAPack E Smart RTU communicates with the PLC or peripheral devices using a TCP/IP interface. This may be the Ethernet interface configured as “TCP/IP Enable” or "TCP/IP + RemIO" (depending on the RTU model).

In addition, the “IP Services” configuration needs to have “Modbus/IP (Client)” service enabled for operation of Modbus RTU in TCP protocol. This configuration can be made on the

SCADAPack E Configurator “TCP/IP” page. For more information see the SCADAPack E TCP/IP Technical Reference manual.

Enabling Modbus/IP (Client) service requires the SCADAPack E Smart RTU to be restarted in order to start the PLC Cache task.

The SCADAPack E Smart RTU may connect to any Modbus RTU in TCP protocol device including PLCs, I/O modules and Modbus Bridges.

Each Modbus RTU in TCP I/O device specifies an “IP_address” parameter that needs to be configured with the address of the Modbus RTU in TCP device that the RTU is communicating with (for that I/O device). It is assumed that the SCADAPack E Smart RTU and the Modbus RTU in TCP device(s) have fixed IP address which are unique on the IP network to which they are connected.

The Modbus RTU in TCP client attaches to TCP port number “49152" in each target Modbus RTU in TCP server device. (Can be changed by advanced users if required).

Some Modbus RTU in TCP devices expect to obtain their IP addresses from another device on their network rather than being configured with their address, locally. For this purpose, the SCADAPack E RTU supports BOOTP Server capability. BOOTP Server needs to also be enabled in the RTU’s “IP Services” configuration to support this capability. See Section BOOTP Server Configuration 25 for more information.

For further information on connecting to the the SCADAPack E Smart RTU to TCP/IP networks, refer to the SCADAPack E TCP/IP Reference manual.

4.6.5 BOOTP Server Configuration

BOOTP is a TCP/IP application protocol that utilizes UDP socket communications.

The SCADAPack E Smart RTU may be configured to start a BOOTP server by selecting it from the SCADAPack E Configurator “TCP/IP Services” configuration.

The BOOTP server (SCADAPack E Smart RTU) listens for requests from a BOOTP client (typically an IP device on a LAN).

Typically, the BOOTP client uses its Ethernet MAC address to identify itself, and via broadcast IP messages, requests a BOOTP server to configure its parameters.

The SCADAPack E Smart RTU is capable of configuring a BOOTP client’s “your-ip” address. However, the SCADAPack E Smart RTU will not configure any of the other BOOTP standard or extended fields. (see RFC 951 and later).

SCADAPack E Configurator provides a configuration interface for the BOOTP server. The user enters an Ethernet-MAC / IP address pair for each node requiring BOOTP configuration of its IP address.

The SCADAPack E Smart RTU will not answer a BOOTP request from a client node unless there is a corresponding entry in the Ethernet-MAC / IP address table.

Devices refer to their Ethernet-MAC address in different ways, such as “IEEE Global Address”. In each case, the Ethernet-MAC address will contain a 12 digit hexadecimal number.

Ethernet-MAC address entry in the SCADAPack E Smart RTU, for BOOTP, may be in any of the following formats (12 hexadecimal digits, case insensitive):

00:1A:2B:3C:4D:5E

00-1A-2B-3C-4D-5E

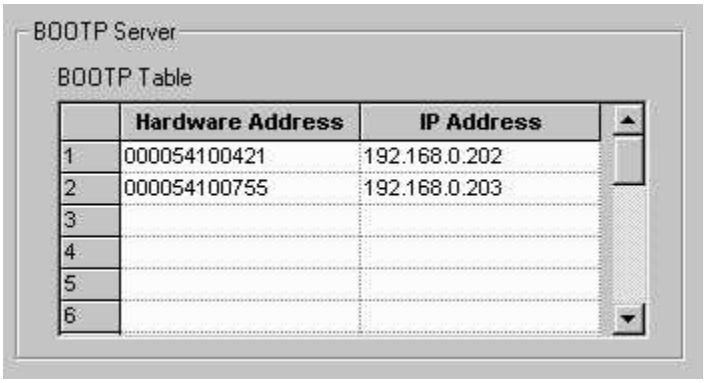
001A2B3C4D5E

IP address entry needs to be in the following format (leading zeroes not required):
192.168.1.97

- Configuring BOOTP with SCADAPack E Configurator 26
- Configuring BOOTP from the Command Line 27

4.6.5.1 Configuring BOOTP with SCADAPack E Configurator

The following figure shows the configuration of the BOOTP table. This is found on the “Advance TCP/IP” page of SCADAPack E Configurator.



Enter the BOOTP client details in the table, in the same format as described above.

The “Hardware Address” field is the Ethernet-MAC address in one of the three formats described.

The configured “IP Address” is dowloaded to the peripheral device that has the matching

hardware address.

Changes to the BOOTP Table in SCADAPack E Configurator should be followed by “Write RTU Configuration”.

BOOTP Table changes become active in the SCADAPack E RTU immediately (i.e. no need to restart the RTU).

4.6.5.2 Configuring BOOTP from the Command Line

In addition to configuring the BOOTP table via SCADAPack E Configurator, the SCADAPack E Smart RTU command line provides a management command to manipulate the BOOTP server configuration table.

```
C:\> bootp /?
BOOTP protocol loads IP address to remote Ethernet devices
BOOTP command manipulates configuration table
(changes ARE permanent)
Usage:
BOOTP PRINT
BOOTP ADD remote-MAC remote-IP
BOOTP DELETE [remote-MAC]
             [remote-IP]
```

For example, the following command prints the BOOTP configuration table:

```
C:\> bootp print
```

BOOTP entries:

Ethernet MAC Addr	IP Addr Loaded	Load Count
00-01-02-03-04-05	192.168.0.242	1
01-02-03-04-05-06	158.234.186.168	2

This indicates the configured BOOTP server entries (what IP Address will be loaded to which Ethernet MAC address), and indicates how many times the BOOTP server has sent BOOTP response commands to the appropriate BOOTP client.

The following command ADDS or REPLACES an entry in the BOOTP configuration table:

```
C:\> bootp add 01-02-03-04-AA-BB 158.234.186.168
```

An existing entry with a matching Ethernet MAC address OR matching IP address will be replaced by the new entry. This is typically used if an existing Modbus/TCP or Modbus RTU

in TCP device is replaced by another device with a different Ethernet MAC Addr, for example.

The following command REMOVES an entry in the BOOTP configuration table:

```
C:\> bootp del 01-02-03-04-AA-BB
```

Either the Ethernet-MAC address or IP address may be used to specify which BOOTP entry to remove, but the string used in the “del” command needs to exactly match the string in the BOOTP entry in order for the entry to be removed successfully.

Changes made to the BOOTP configuration table via SCADAPack E Configurator or command line are retained in NON-VOLATILE MEMORY not requiring the SCADAPack E Smart RTU to be restarted in order to take effect. However, remember to make a record of the configuration after they are modified.

When BOOTP diagnostics are enabled (via TCPDIAG command), the SCADAPack E Smart RTU diagnostic stream indicates when a remote device is configured via BOOTP by the RTU. E.g.

BOOTP>>loaded IP: 158.234.186.168 to MAC: 01-02-03-04-AA-BB

4.7 System Points

System points are provided to indicate the status of some I/O Devices that are used for Slave I/O communications with peripheral devices such as PLCs.

Where multiple Slave I/O Devices are present in an IEC 61131-3 Resource , consecutive, sequential system point pairs are used for the next Slave I/O device, regardless of what PLC port the devices are connected to. Each Resource is allocated a separate set of system points for Slave I/O Devices.

The status for the Slave I/O Devices reported (according to the above rules) has two system points associated with it. The communications status, and the data cache time.

The communication status indicates the status of the communication with the PLC for the data on the I/O device. For more information see Section Modbus Status Values 30.

The age of the cached data for a slave Input devices is stored in the cache time system point for that device. For more information see Section Data Cache Time 49.

A separate RTU system point is provided to set the background update rate of PLC Output devices. For more information see Section PLC Output device Default Background Update Rate 31.

The RTU Slave I/O device status system points for a user application loaded for Resource 1 are as follows:

System Point Description	Point Number	Point Type

Resource 1 Slave I/O device 1 communication status	53300	16-bit unsigned integer (read-only)
Resource 1 Slave I/O device 1 data cache time	53301	16-bit unsigned integer (read-only)
Resource 1 Slave I/O device 2 communication status	53302	16-bit unsigned integer (read-only)
Resource 1 Slave I/O device 2 data cache time	53303	16-bit unsigned integer (read-only)
…		
Resource 1 Slave I/O device 60 communication status	53418	16-bit unsigned integer (read-only)
Resource 1 Slave I/O device 60 data cache time	53419	16-bit unsigned integer (read-only)

The RTU Slave I/O device status system points for a user application loaded for Resource 2 are as follows:

System Point Description	Point Number	Point Type
Resource 2 Slave I/O device 1 communication status	53422	16-bit unsigned integer (read-only)
Resource 2 Slave I/O device 1 data cache time	53423	16-bit unsigned integer (read-only)
Resource 2 Slave I/O device 2 communication status	53424	16-bit unsigned integer (read-only)
Resource 2 Slave I/O device 2 data cache time	53425	16-bit unsigned integer (read-only)
…		
Resource 2 Slave I/O device 14 communication status	53448	16-bit unsigned integer (read-only)
Resource 2 Slave I/O device 14 data cache time	53449	16-bit unsigned integer (read-only)

4.7.1 Modbus Status Values

The Modbus I/O device communication status system point values are updated by the Modbus PLC driver as follows. See System Points 48 for the system points updated with this status.

Modbus Exception Code	Status	Comment	RTU Status
-	Success	Normal	0
0x01	Illegal Function	Slave device does not support requested Modbus function code	103
0x02	Illegal Data Address	Reading or Writing an invalid register address was attempted. This may be returned by RTU's device driver, or by Modbus device	103
0x03	Data Value out of Range	Reported by the Modbus device if register value was outside supported value range and could not be written	108
0x04	Illegal Response Length	A request was rejected by the Modbus device as it would have resulted in a response exceed the maximum allowed size (256 bytes)	102
0x0B	Gateway Target No Response	Gateway reported Modbus device did not respond	104
-	Timeout	The Modbus device did not respond	104
-	Socket connect Unsuccessful	Could not connect the TCP socket to a server at the configured IP address	104
-	Invalid Message	The message from the Modbus device was not understood by the RTU	106
other	Generic Status Code	A generic response was received	101

4.7.2 Data Cache Time

The age of the data in the RTU cache for Modbus PLC and Modbus/TCP Input device data is presented in data 'Cache Time' system points. The cache time is initialized to zero when the IEC 61131-3 Resource starts and increases until a successful read occurs, after which time the value is reset to zero.

The system point corresponding to a PLC Device input device may be used by the Resource to determine the suitability of using the input data from the input device. (I.e. if the value is too high, then the data is stale and the Resource may choose not to use it).

Each Input device has its own data cache time system point. The data cache time system points for Output devices will indicate zero.

4.7.3 PLC Output Device Default Background Update Rate

The following system point controls the default background update rate of PLC Device Output devices on the RTU. Where an I/O device's "data update rate" parameter is zero, or if the older style PLC I/O Devices (that don't have a data update rate) are in use, the SCADAPack E Smart RTU writes PLC output device variables to the appropriate PLC at this rate. This occurs regardless of whether changes are occurring on the output variable, or not. The purpose of the "data update" is so RTU output variable values are updated in the PLC.

For example, if the PLC is initialized or replaced, then the output values are re-written by the RTU. Similarly, a Modbus/TCP device may clear its outputs upon no communications unless a periodic write is made to its outputs.

The default value of the background update rate is 60 seconds. It may be adjusted by the user or specified in an RTU configuration, and is a non-volatile RTU system point that is retained by the RTU.

Changes in the background update rate take effect when an IEC 61131-3 Resource is loaded and started, or re-started.

System Point Description	Point Number	Point Type
PLC Output device Background Update Rate (seconds)	53420	32-bit unsigned integer

The background updates are disabled by setting the system point value to 0 (zero). This may be used to optimize the PLC Device communications bandwidth where background writes are not appropriate or necessary.

4.8 Replacing a Modbus/TCP or Modbus RTU in TCP Device that uses BOOTP

Modbus/TCP devices using BOOTP may require SCADAPack E Smart RTU re-configuration if they are replaced. This will be necessary if the Modbus/TCP device has a different Ethernet hardware address.

See Sections:

- Change a Modbus/TCP Device Using SCADAPack E Configurator 32
- Change a Modbus/TCP Device Using COMMAND LINE 33.

If the device does not use BOOTP to configure its own IP address, it needs to be reconfigured with the correct IP address by following the procedure detailed in the device's user manual.

⚠WARNING

Having two or more devices with the same IP address can cause unpredictable operation of your network. Before removing any adapter from service, or adding any adapter, check that there is no possibility of a duplicate address appearing on your network. Failure to observe this precaution can result in injury or equipment damage.

REMEMBER: After changing the configuration of an RTU, make a permanent record of the RTU's new configuration

4.8.1 Change a Modbus/TCP or Modbus RTU in TCP Device Using SCADAPack E Configurator

Establish communication with the RTU using SCADAPack E Configurator either locally, or remotely.

To replace an existing device:

- Find the BOOTP table in SCADAPack E Configurator's Advanced TCP/IP page.
- Identify the relevant BOOTP entry in the SCADAPack E Configurator's BOOTP Configuration Table.
- Change the entry's Ethernet-MAC address to that of the new device. Use one of the following formats:

  000054A12104 or 00-00-54-A1-21-04 or 00:00:54:A1:21:04

- Write the configuration to the RTU. The BOOTP entry is now active.
- Connect the new device to the network & power it up.

To add a new device:

- Choose the first free BOOTP entry in the SCADAPack E Configurator's BOOTP Configuration Table.
- Add the new device's Ethernet-MAC address to the table. Use one of the following formats:

  000054A12104 or 00-00-54-A1-21-04 or 00:00:54:A1:21:04
- Add the desired IP address for the entry.
- Write the configuration to the RTU. The BOOTP entry is now active.
- Connect the new device to the network & power it up.

4.8.2 Change a Modbus/TCP or Modbus RTU in TCP Device Using COMMAND LINE

Change a Modbus/TCP Device Using COMMAND LINE

The SCADAPack E Smart RTU command line is available:

- Using Telnet, when enabled on the RTU
- Using a terminal program plugged into an RTU (e.g. the DIAG port)
- Using a terminal program plugged into an RTU's port, and by pressing <Enter><Enter><Enter>

The command line can be use to replace an existing Modbus/TCP device BOOTP entry, or add a new Modbus/TCP device BOOTP entry. This is only applicable for devices that use BOOTP as a means of configuring their IP addresses.

If you are replacing an existing device you will need to know the IP address being used by the old device. You will also need to know the new device's Ethernet-MAC address (12-digit hexadecimal number).

If you are adding a new BOOTP entry, you will need to know the desired IP address for the new device as well as its Ethernet-MAC address.

You can check configured BOOTP entries by using the command:

```
bootp print
```

From the SCADAPack E RTU command line, enter the following command to add or change a BOOTP entry:

```
bootp add Ethernet-MAC-addr  IP-address
```

For example: `bootp add 01020304AABB 158.234.186.168`

You can re-check the changed BOOTP entries by using:

```
bootp print
```

Check BOOTP Diagnostics

You can check BOOTP operation with a new device by performing the following procedures:

Enable BOOTP diagnostics & enter diagnostic mode with the commands:

```
tcpdiag enable BOOTP  <enter>
diag
```

Connect the new device to the network & power it up. When the new device sends a BOOTP request for

```
BOOTP>>loaded IP: 158.234.186.168  to MAC: 01020304AABB
```

Communication may also be verified by issuing a PING command. For example:

```
ping 158.234.186.168
```

5 Modbus Slave/Server Operation

The following sections detail SCADAPack E Smart RTU communication where the RTU is a Modbus Slave and Modbus/TCP Server.

5.1 Setting up Modbus Slave / Server

The following sections document the conditions specific to the native Modbus Slave / Server driver.

Conditions common to the Modbus/TCP Server and the Modbus serial Slave such as conformance classes, mapping of Modbus addresses to the RTU point address space, and the circumstances under which specific response exception codes are generated, are detailed in Section Modbus/TCP Server and Modbus Slave Implementation Conditions 35.

The SCADAPack E Smart RTU supports a native Modbus Slave driver which responds to

Modbus requests by accessing RTU point data directly.

The Modbus Slave driver is only operational if at least one serial port function is set to Modbus Slave or if Modbus/TCP (Server) is enabled as part of the RTU TCP/IP Services selection. The RTU needs to be restarted to activate a port mode or TCP Services change.

Modbus Slave communications can be independently enabled on multiple serial ports, though the single Slave Address is applied to each instance of the Modbus Slave driver (see Section Modbus Slave Address 49 for details regarding Modbus Slave configuration system points).

Multiple Modbus/TCP server communications sessions are supported (up to 5), though the single Modbus Unit Identifier is applied to each Modbus/TCP connection. Also see section Modbus/TCP Server Unit Identifier 49.

5.2 Modbus Slave and Modbus /TCP Server Implementation Conditions

This following sections detail implementation conditions that are common to both the Modbus/TCP Server and the native Modbus Slave:

- Conformance Classes and Function Codes 7 & 8 35
- Modbus Address Mapping to RTU Point Address Space 36
- Exception Codes 47

Open Modbus/TCP Server

The SCADAPack E Smart RTU Modbus/TCP server is only operational if the “IP Services” configuration has the “Modbus/TCP Server” service enabled.

This configuration can be made from the SCADAPack E Configurator “TCP/IP” page or "Slave / Modbus" page.

5.2.1 Conformance Classes & Supported Function Codes

Conformance Classes

The following Modbus conformance classes (and function codes) are supported by the Modbus/TCP Server and the native Modbus Slave.

- Class 0 (function codes 3 and 16)
- Class 1 (function codes 1, 2, 4, 5, 6, and 7)
- Class 2 (function code 15 only).

Function Code 7

This function code allows a client to request the Modbus server/slave to return an exception status that is stored in a pre-determined range of 8 coils. RTU binary system (scratchpad) points 50000 to 50007 are allocated for this purpose.

- RTU binary point 50000 will map to the least significant bit of the response byte.
- RTU binary point 50007 will map to the most significant bit of the response byte.

Function Code 8

This function code allows a client to request the Modbus slave to return a response to a "Return Query Data" request. The following functionality is provided:

- Function Code 8 is supported on Modbus Slave serial connections only
- A Function Code 8 request on a Modbus/TCP connection returns Exception response with exception code 1 (Illegal function)
- Sub function 00 00 is the only sub function supported for a Modbus function code 8 request
- A response will only be generated to a FC8 Sub-function 00 00 request when the data field size is 2
- The Response to a FC8 Sub-function 00 00 (data field size 2) request is an echo of the request
- A request for Sub functions other than 00 00 returns an Exception response with exception code 3 (Illegal Data Value)
- There will be no response to a FC8 Sub-function 00 00 request if the data field size is not 2

5.2.2 Modbus Address Mapping to RTU Point Address Space

This section identifies how the binary and analog Modbus addresses are mapped to the RTU point address space.

The “Modbus address” referenced in this section refers to the Modicon PLC equivalent register address i.e. "protocol address" + 1. The "protocol address" is also referred to as the "reference address".

- Modbus Slave / Server register addresses are mapped directly to the SCADAPack E Smart RTU database point number in a one to one relationship
- Modbus input register types map to RTU Physical Input point types and RTU Derived point types
- Modbus output register types map to RTU Physical Output point types and RTU Derived

point types

- The points used by the DATA CONCENTRATOR are converted to Physical point types automatically, according to their protocol data type (e.g. DNP3 Static Object Type). Modbus register types map to Data Concentrator points using the same rules as RTU Physical point types. Take care to use the appropriate Modbus request to access the appropriate physical point type.
- For more information see Binary Addresses 38 and Analog Addresses 39 sections
- The data format presented to Modbus is dependent on the DNP3 Static Object Type attribute of the RTU point configuration

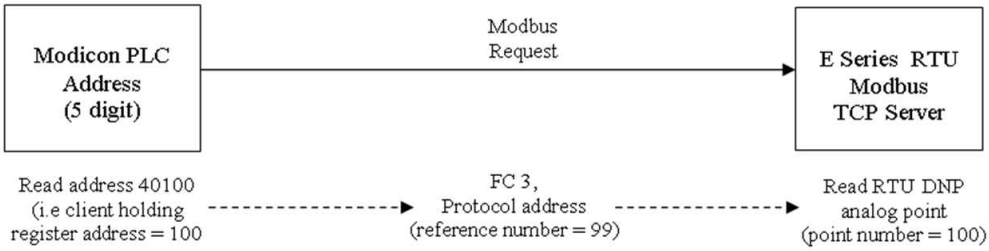
For analog multiple read/writes, this mapping is relevant for the start address only. The mapping of subsequent registers to RTU points is dependent on the RTU configuration point DNP static object types (e.g 16-bit, 32-bit and floating point object types).

As a result of these mapping rules, it is possible to reference a different 32-bit analog point in the RTU with the same Modbus register, based on different reference numbers and word counts of separate Modbus requests.

Section Modbus Register / 32-bit Analog Point Mapping Configuration 43 discusses the required configurations for consistent and deterministic mapping of Modbus registers to 32-bit analog points.

See Sections Reading Analog Registers 40 and Writing Analog Registers 42 for more information on function codes that reference analog points.

This standard mapping is illustrated in the following example using 5 digit addressing



For clients using 5 digit addressing, the addressable range of both the client register address and the RTU point numbers are from 1 to 9999, and this corresponds to a protocol address (reference number) range from 0 – 9998.

For clients using 6 digit addressing, the addressable range of both the client register address and the RTU point numbers are from 1 to 65535, and this corresponds to a protocol address (reference number) range from 0 – 65534.

The following sections describe how each function code is affected by point mapping.

See Section Exception Codes 47 for information on how multiple read / write requests are handled when some of the requested addresses are invalid.

- Binary Addresses 38
- Analog Addresses 39

5.2.2.1 Binary Addresses

RTU database binary point data is provided to the Modbus serial Slave and Modbus/TCP server in IEC_DISCRETE format. For more information refer to Modbus PLC Data Types 20.

The following information is applicable to the next sections for Function Code 1 and 2 reads and Function Code 5 and 15 writes:

- when "x" is referenced it means Modbus Address = x
- NONE of the requested points exist if for every modbus address x referenced in the request, no RTU configuration point x exists.

Function Code 1: Read Discrete Coils

FC 1 will invoke point reads for every Modbus address x referenced in the request, described as follows …

- if NONE of the requested points exist then return ILLEGAL FUNCTION (01)
- if x exists as a Physical Out binary point or a Derived binary point then the current value of point x will be read
- The Data Concentrator converts Derived binary points that present as DNP3 binary output objects into Physical Out binary points
- if at least one of the points in the Modbus request does exist, and point x does NOT exist, then a zero value will be returned in the response for Modbus register x

Function Code 2: Read Discrete Inputs

FC 2 will invoke point reads for every modbus address x referenced in the request, described as follows …

- if NONE of the requested points exist then this returns ILLEGAL FUNCTION (01)
- if x exists as a Physical In binary point or a Derived binary point then the current value of point x will be read
- The Data Concentrator converts Derived binary points that present as DNP3 binary input objects into Physical In binary points
- if at least one of the points in the Modbus request does exist, and point x does NOT exist,

then a zero value will be returned in the response for Modbus register x

Function Code 5: Preset Discrete Coil

FC 5 will invoke point writes, described as follows …

- if x exists as a Physical Out binary point or a Derived binary point then point x will be controlled
- The Data Concentrator converts Derived binary points that present as DNP3 binary output objects into Physical Out binary points
- if point x does NOT exist then this returns ILLEGAL FUNCTION (01)

Function Code 15: Write Multiple Coils

FC 15 will invoke point writes for every modbus address x referenced in the request, described as follows …

- if x exists as a Physical Out binary point or a Derived binary point then point x will be controlled
- The Data Concentrator converts Derived binary points that present as DNP3 binary output objects into Physical Out binary points
- if x does NOT exist as a binary output point then stop processing request and return ILLEGAL FUNCTION (01)

5.2.2.2 Analog Addresses

This section details the specific mapping for function codes that reference analog addresses.

As noted earlier, it is possible for mixed 16-bit and 32-bit Modbus data value's register mapping to be inconsistent where Modbus registers map to RTU points configured in 32-bit value format. Section Modbus Register / 32-bit Analog Point Mapping Configuration 43 demonstrates the configurations required for consistent mapping of Modbus registers to 32-bit analog points.

The data types returned in Modbus responses are influenced by the configuration of the DNP Static Object Type in each database analog point configuration.

Analog Point Configuration: DNP3 Static Object Type	Modbus Response: Number of Registers	 Modbus data type
g30 v1 32-bit Analog In g30 v3 32-bit Analog In No Flags	2	IEC DINT (signed 32-bit integer)

g20 v1 32-bit Counter g20 v5 32-bit Counter No Flags	2	IEC UDINT (unsigned 32-bit integer)
g30 v5 Short Floating Point (Engineering value)	2	IEC REAL (32-bit floating point)
g30 v2 16-bit Analog In g30 v4 16-bit Analog In No Flags	1	IEC INT (signed 16-bit integer)
g20 v2 16-bit Counter g20 v6 16-bit Counter No Flags	1	IEC UINT (unsigned 16-bit integer)

For more information refer to Modbus PLC Data Types 20.

The following information is applicable to the next sections for Function Code 3 and 4 reads and Function Code 6 and 16 writes:

- when "x" is referenced it means modbus address = x
- corresponding analog database point = y (depends on DNP static object type of point. If points referenced are “16 bit analogs” then y = x)
- "NONE of the requested points exist" means that for every modbus address x referenced in the request, no RTU configuration point y exists.

See the following sections for descriptions of individual Modbus function codes and how Modbus register requests map to point types:

- Reading Analog Registers 40
- Writing Analog Registers 42

5.2.2.2.1 Reading Analog Registers

Function Code 3: Read Holding Registers

FC 3 will invoke point reads for every modbus address x referenced in the request, described as follows …

- if NONE of the requested points exist then return ILLEGAL FUNCTION (01)
- if y exists as a Physical Out analog point or a Derived analog point then the current value of

point y will be read

- The Data Concentrator converts Derived analogs points that present as DNP3 analog output objects into Physical Out analog points
- if at least one of the points in the Modbus request does exist, and point y does NOT exist, then a zero value will be returned in the response for Modbus register x

Function Code 4: Read Input Registers

FC 4 will invoke point reads for every modbus address x referenced in the request, described as follows …

- if NONE of the requested points exist then return ILLEGAL FUNCTION (01)
- if y exists as a Physical In analog point or a Derived analog point then the current value of point y will be read
- The Data Concentrator converts Derived analogs points that present as DNP3 analog input objects into Physical In analog points
- if at least one of the points in the Modbus request does exist, and point y does NOT exist, then a zero value will be returned in the response for Modbus register x

Reading Multiple Registers

The register address to RTU database point mapping described in this section relates primarily to the start register address specified in the Modbus request.

The word count included in the request, in conjunction with the DNP static object type of the mapped points, will affect the number of RTU database points included in the response.

The following example illustrates this mapping for function code 3:

Consider the Modbus request as follows (starting from the function code)

… 03 03 e8 00 03

which translates to …"read 3 holding registers at protocol reference number 1000" (41001 in Modicon style register addressing).

The protocol reference number 1000 would therefore map to RTU point number 1001.

Consider the following RTU points configurations:

RTU Analog Point 1001 : DNP static object type ➔ 16 bit analog

RTU Analog Point 1002 : DNP static object type ➔ 32 bit analog

RTU Analog Point 1003 : DNP static object type ➔ 16 bit analog …

This would map RTU analog points to Modbus client holding register addresses as follows

RTU Analog point 1001 maps to client holding register address 1001

RTU Analog point 1002 maps to client holding register addresses 1002 and 1003.

RTU Analog point 1003 would not be included in the response as it exceeds the register length requested.

The same functionality applies for function code 3 and 4.

See Modbus Register / 32-bit Analog Point Mapping Configuration 43 for more information on handling more complex combinations of 16 and 32 bit registers.

5.2.2.2.2 Writing Analog Registers

Function Code 6: Write Single Register

FC 6 and FC 16 will invoke point writes for every modbus address x referenced in the request, described as follows …

- if y exists in the SCADAPack E RTU as a Physical Out analog point or a Derived analog point then point y will be controlled
- if point y does NOT exist as a Physical Out analog point or a Derived analog point then processing is stopped ILLEGAL FUNCTION (01) is returned

Function Code 16: Write Multiple Registers

- if y exists in the SCADAPack E RTU as a Physical Out analog point or a Derived analog point then point y will be controlled
- if point y does NOT exist as a Physical Out analog point or a Derived analog point then processing is stopped ILLEGAL FUNCTION (01) is returned

Writing Multiple Registers

The register address point mapping described above for function code 16, relates primarily to the start register address specified in the modbus request. The word count included in the request, in conjunction with the DNP static object type of the mapped points, will affect the

number of RTU points controlled by the request. The following example illustrates this mapping.

Consider the modbus request as follows (starting from the function code)

… 10 03 e8 00 03 06 00 08 00 04 00 00

which translates to …"write 3 holding registers at protocol reference number 1000" (41001 in Modicon style register addressing).

The protocol reference number 1000 would therefore map to RTU point number 1001. Consider the following RTU points configurations:

RTU Analog point 1001 : DNP static object type ➔ 16 bit analog

RTU Analog point 1002 : DNP static object type ➔ 32 bit analog

RTU Analog point 1003 : DNP static object type ➔ 16 bit analog …

The Modbus request would result in the following controls :

RTU Analog point 1001 is assigned the integer value 8

RTU Analog point 1002 is assigned the integer value 4.

RTU Analog point 1003 is not controlled as the point is outside the register range of the Modbus write request.

See Modbus Register / 32-bit Analog Point Mapping Configuration 43 for more information on handling more complex combinations of 16 and 32 bit registers.

5.2.2.3 Modbus Register / 32-bit Analog Point Mapping Configuration

As noted earlier, it is possible to reference a different 32-bit analog point in the RTU with the same modbus register, based on different reference numbers and word counts of separate modbus requests.

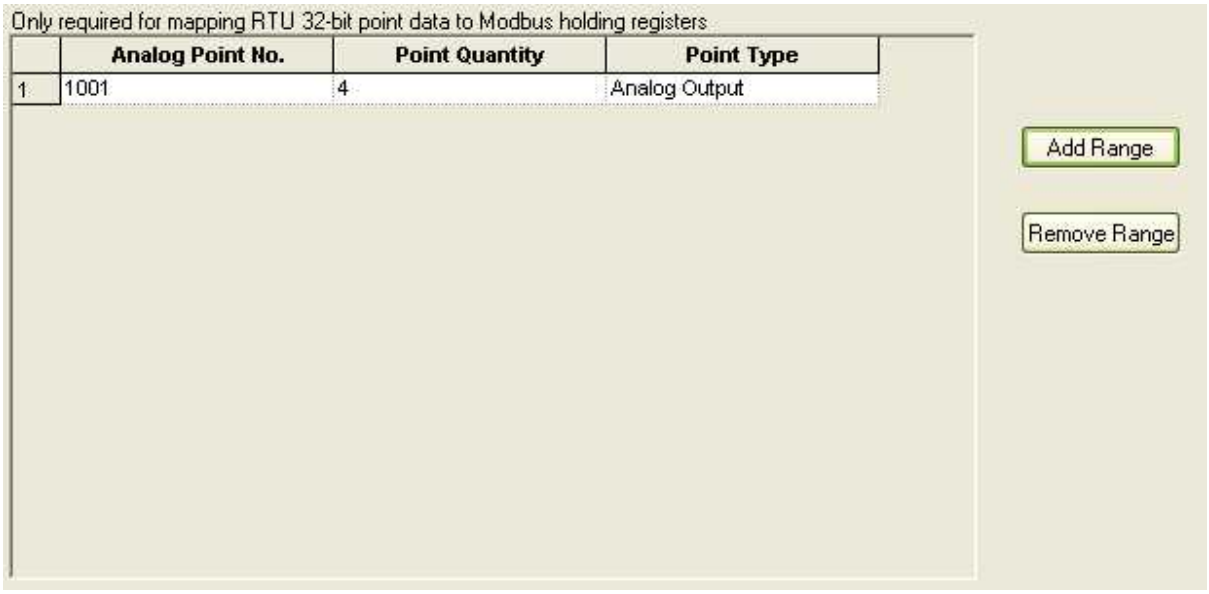
For a consistent and deterministic mapping for 32-bit values point values to Modbus registers for the Modbus/TCP Server and the native Modbus Slave, use the Modbus Register / 32-bit Analog Point Map table on the SCADAPack E Configurator Slave | Modbus page.

TIP: Add RTU points to this table when you want to access them as 32-bit Modbus registers. (e.g. Long Integers, Short Floating Point values, etc.)

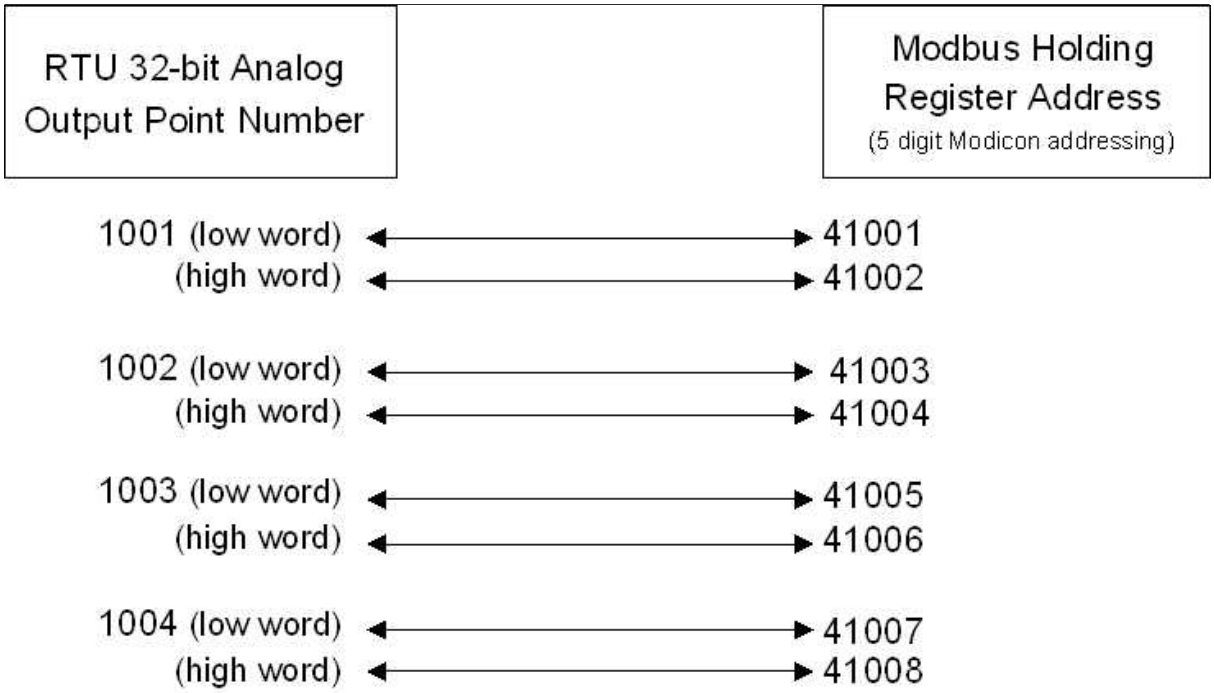
It is strongly recommended that points are allocated consecutively so that the register mapping is grouped together in a single entry in the table. The Point Quantity field indicates how many consecutive points will be read or written as 32-bit Modbus registers.

Points accessed as 16-bit Modbus registers should NOT be added to this table.

The following image displays the SCADAPack E Configurator interface, which show an example for RTU analog points 1001-1004 as writeable 32-bit Modbus holding registers.



This configuration would result in the consistent register / point mapping as shown in the following diagram, irrespective of the protocol reference number (register address) and the word count specified in a Modbus request.



Example: a Modbus request to write to the holding register pair 41005/41006 would result in controlling RTU analog point 1003. Without the additional mapping configuration shown above, this control would have otherwise mapped to analog point 1005.

An attempt to control single holding register 41006 would result in an exception response, as this register maps to the high word of analog point 1003. In general, multiple register requests whose start reference number is the high word of a designated 32-bit analog register pair will be considered invalid and return an exception response.

This configuration can also be directly manipulated in a configuration file using the MR table format. Consult the SCADAPack E Configuration File Format document for more information regarding the MR table format.

5.2.2.4 Supported Data Types

The SCADAPack E Smart RTU Modbus/TCP Server and the native Modbus Slave shall support the IEC61131 data types as described in the Open Modbus/TCP specification.

The following table lists the IEC61131 data type interpreted for function codes 3, 4 and 16.

The interpreted data type is dependant on the DNP static object type of the RTU configuration point (configurable on a per point basis).

Refer to the SCADAPack E RTU Configuration Technical Reference manual for more information.

Mapped Point's DNP Static Object Type	IEC61131 Data Type (returned in Modbus response)
DNP object Group 1 Var 1 (binary input no status) DNP object Group 1 Var 2 (binary input with status) DNP object Group 10 Var 2 (binary output status)	DISCRETE Binary (discrete) data packed into 8-bit values where least significant bit represents low discrete bit numbers.
DNP object Group 30 Var 1 (32-bit analog with status) DNP object Group 30 Var 3 (32-bit analog no status) DNP object Group 40 Var 1 (32-bit analog output status)	DINT (signed 32-bit integer value) Bits 15 - 0 of 1st register = bits 15 - 0 of DINT Bits 15 – 0 of 2nd register = bits 31 - 16 of DINT
DNP object Group 30 Var 2 (16-bit analog with status) DNP object Group 30 Var 4 (16-bit analog no status) DNP object Group 40 Var 2 (16-bit analog output status)	INT (signed 16-bit integer value) Bits 15 – 0 of register = bits 15 - 0 of INT
DNP object Group 30 Var 5 (short float point with status) DNP object Group 40 Var 3 (short float point output status)	REAL (32-bit Intel single precision real) Bits 15 – 0 of first register = bits 15 – 0 of REAL (bits 15 - 0 of significance) Bits 15 – 0 of second register = bits 31 - 16 of REAL (exponent + bits 23-16 of significance)
DNP object Group 20 Var 1 (32-bit counter with status) DNP object Group 20 Var 5 (32-bit counter no status)	UDINT (unsigned 32-bit integer value) Bits 15 – 0 of first register = bits 15 - 0 of UDINT Bits 15 – 0 of second register = bits 31-16 of UDINT
DNP object Group 20 Var 2 (16-bit counter with status) DNP object Group 20 Var 6 (16-bit counter	UINT (unsigned 16-bit integer value) Bits 15 - 0 of register = bits 15 - 0 of INT

no status)	

5.2.3 Exception Codes

This section lists some specific circumstances under which response exception codes may be generated. Refer to the Open Modbus/TCP Specification for the full list of exception codes and their descriptions:

- Read & Write Multiple Coils/Register Exceptions 47
- Writes to RTU Point under Control & Invalid Addresses 48

Useful Exception Codes are listed in the following table:

Exception Code	Code Description	Comment
0x01	Illegal Function	slave doesn't support function in request
0x02	Illegal Data Address	slave doesn't have register specified in request
0x03	Illegal Data Value	value in request out of range for register in slave
0x04	Illegal Response Length	request would cause response to exceed 256 bytes
0x0A	No Response From Gateway Target Device	returned by Gateway when no response from remote device

5.2.3.1 Read & Write Multiple Coils / Register Exceptions

Read Multiple Coils/Register Exceptions

Requests to read multiple coils/registers will generate a successful response, if at least one of the requested addresses is valid, and the invalid data addresses shall be returned with a zero value. If requested addresses are invalid, the response exception code shall be set to ILLEGAL FUNCTION (01).

Write Multiple Coils/Register Exceptions

Requests to write to multiple coils/registers may generate a successful response only if the requested addresses are valid and controls succeed. If at least one of the requested addresses is invalid or a control does not succeed then the remaining controls in the request are ignored and an exception response is returned with exception code ILLEGAL FUNCTION (01).

5.2.3.2 Exceptions Writing to RTU Points

Writes to RTU Points under Control

Any requests to write to coils / registers that may be under the exclusive control of the RTU sequencer (ISaGRAF), will generate the response exception code ILLEGAL FUNCTION (01) even if previous controls in the same multiple write request have been successful. Read requests to points under control will be successful.

Invalid Addresses

Any requests that reference RTU point numbers outside of the range 0-65535 will generate the response exception code ILLEGAL DATA ADDRESS (02). See Section Modbus Address Mapping to RTU Point Address Space 36 for details on how Modbus addresses map to RTU point numbers.

Bad Point Quality

Any requests that write to an RTU point that has bad quality (e.g. Point Operation Unsuccessful quality) will update the point in the RTU database, but generate an exception response with exception code ILLEGAL FUNCTION (01).

5.3 System Points

RTU system points are provided for configuration of Modbus communication parameters.

- Modbus/TCP Server Unit Identifier 49
- Modbus Slave Address 49

5.3.1 Modbus/TCP Server Unit Identifier

Data Cache Time

The age of the data in the RTU cache for Modbus PLC and Modbus/TCP Input device data is presented in data 'Cache Time' system points. The cache time is initialized to zero when the IEC 61131-3 Resource starts and increases until a successful read occurs, after which time the value is reset to zero.

The system point corresponding to a PLC Device input device may be used by the IEC 61131-3 Resource to determine the suitability of using the input data from the input device. (I. e. if the value is too high, then the data is stale and the IEC 61131-3 Resource may choose not to use it).

Each Input device has its own data cache time system point. The data cache time system points for Output devices indicate zero.

Modbus/TCP Server Unit Identifier

The following SCADAPack E Smart RTU system point determines the configuration value of the Modbus/TCP Server Unit Identifier. Responses are sent to Open Modbus/TCP requests that include a unit identifier that matches this configuration value. If the unit identifier included in the request differs from the configuration value, the request is therefore determined to invalid for this RTU, and the socket is closed.

The default value of the Unit Identifier is 1. It may be adjusted by the user or specified in an RTU configuration, and is a non-volatile RTU system point that is retained by the RTU. Changes in the Unit Identifier take effect when the RTU is restarted.

System Point Description	Point Number	Point Type
Open Modbus/TCP Server Unit Identifier	54038	32-bit unsigned integer

5.3.2 Modbus Slave Address

The following SCADAPack E Smart RTU system point determines the configuration value of the Modbus Slave Address. This applies only to the native Modbus Slave driver. The slave address of the Modbus Slave is detailed in the SCADAPack E Target 5 Technical Reference.

System Point Description	Point Number	Point Type
Modbus Slave Address	52014	16-bit unsigned integer

The rules that determine how the Modbus Slave driver responds to requests according to the

specified slave address are detailed as follows:

- Responses are sent to serial Modbus requests that include a slave address that matches the Modbus Slave Address configured value in the RTU.
- If the slave address included in the request is zero, i.e. broadcast address, the Modbus Slave will respond irrespective of the configuration value of the Modbus Slave Address.
- If the specified slave address is non-zero AND differs from the configuration value, no response is sent for the request.

The default value of the Slave Address is 1. It may be adjusted by the user or specified in an RTU configuration, and is a non-volatile RTU system point that is retained by the RTU. Changes in the Slave Address take effect when the RTU is restarted. Valid Slave Address configuration values are in the range of 1 – 247.

5.4 Diagnostics

The SCADAPack E Smart RTU indicates configuration or communication diagnostics via Diagnostic Display mode from a Command line session.

Configuration diagnostics are indicated via I/O device messages if PLC I/O Devices are not opened. These are displayed when in Diagnostic Display mode (use DIAG command at command prompt).

Communication diagnostics for the Modbus serial and Modbus/TCP drivers are controlled by the PLCDIAG command at the RTU command prompt. The syntax is as follows:

```
PLCDIAG DISABLE filter-name [filter-name…]
PLCDIAG ENABLE  filter-name [filter-name…]
```

Where filter name is one, or more of the following combinations:

*	all Modbus diagnostic messages	
TX	transmit packet bytes display for Modbus Master / Client	
	Indicating transmitted data by	<--Modbus Master-
	Or	<--Modbus/TCP Client -
RX	receive packet bytes display	
	Indicating received data by	– Modbus Master-->
	Or	– Modbus/TCP Client-->
COMMS_ERROR	communication diagnostics	
	Including timeout and TCP socket connection information	
PLC_ERROR	diagnostic messages returned by the PLC	

ISAGRAF	rx/tx packet diagnostics for RTU “ISaGRAF” serial port – not applicable to PLC Cache operation (see the SCADAPack WorkbenchTechnical Reference)
Modbus (ISaGRAF)	rx/tx packet diagnostics for RTU “Modbus” serial port – not applicable to PLC Cache operation (see the SCADAPack WorkbenchTechnical Reference)
MODTCP_SRV	rx/tx packet diagnostics for RTU Open Modbus/TCP Server
MOD_SLAVE	rx/tx packet diagnostics for RTU native Modbus Slave

Multiple filters may be specified at the same time with the PLCDIAG command. Use the command line DIAG command to enter the Diagnostic Display mode after the filters are set. For example:

```
PLCDIAG DISABLE TX RX
PLCDIAG ENABLE COMMS_ERROR PLC_ERROR
DIAG
```

6 Modbus/TCP Operation

Modbus / TCP Operating Constraints

The SCADAPack E Modbus/TCP server listens on port 502 for any incoming connections. On detecting an incoming connection a new task is created to handle the client connection. A new socket will be opened with an inactivity timeout of 120 seconds (2 minutes). The inactivity timer is re-triggered each time a Modbus/TCP request is received.

Conventionally, following a successful transaction, it will be the client that closes the connection, though if the inactivity timer expires with the socket still open, the SERVER in the SCADAPack E RTU will close the connection. On disconnection, the task created to handle this transaction will be destroyed.

If the Modbus/TCP Server receives only part of a message, a shorter inactivity timeout of 30 seconds will be applied.

The SCADAPack E Modbus/TCP server supports a maximum of concurrent clients depending on the controller type.

- For the SCADAPack ER and SCADAPack ES controllers the Open Modbus/TCP server supports a maximum of 20 concurrent client connections.
- For the SCADAPack 300E controllers the Open Modbus/TCP server supports a maximum of 5 concurrent client connections.
- For the 386eNet controllers the Open Modbus/TCP server supports a maximum of 5 concurrent client connections.

Open Modbus/TCP Socket Communication

Open Modbus/TCP communications are initiated by the client (e.g. SCADAPack E RTU, SCADA master station, etc.).

The client opens a TCP socket on a Modbus/TCP Server (e.g. PLC, I/O block, Gateway, Bridge).

The socket is associated with the configured IP address of the server, using assigned TCP port number “502”.

Open Modbus/TCP protocol packets are exchanged between the client and the server across the open TCP socket.

Open Modbus/TCP Client Procedures

An unexpected response causes the socket to be disconnected by the client.

Before the client sends a new request, it attempts to open a new socket at the assigned port number on the server.

Open Modbus/TCP Server Procedures

The Open Modbus/TCP Server may disconnect a connected client (closing the socket) under the following conditions

- error detected - invalid header (i.e. does not conform to Open Modbus/TCP Specification).
- error detected - invalid message (e.g. length differs to that specified in header, etc.).
- requested Unit Identifier differs from RTU configuration value
- inactivity timeout (see Modbus/TCP Operating Constraints 51 for more information regarding inactivity timeout).
- RTU orderly shutdown (e.g. remote RTU restart received) disconnects connected clients and disconnects from servers.

7 Modbus RTU in TCP Operation

Modbus RTU in TCP Socket Communication

Modbus RTU in TCP communications are initiated by the client (e.g. SCADAPack E RTU).

The client opens a TCP socket on a Modbus RTU in TCP Server (e.g. PLC, I/O block, Gateway, Bridge).

The socket is associated with the configured IP address of the server, using assigned TCP

port number “49152”.

Modbus RTU in TCP protocol packets are exchanged between the client and the server across the open TCP socket.

Modbus RTU in TCP Client Procedures

An unexpected response causes the socket to be disconnected by the client.

Before the client sends a new request, it attempts to open a new socket at the assigned port number on the server.

8 Modbus Protocol Technical Information

The following sections detail the framing of the various Modbus data communication protocols used by the RTU:

- Modbus Serial Communication Format 53
- CRC16 Calculation Method 54
- Open Modbus/TCP Communication Format 55

Modbus application layer protocol is used by both serial Modbus, and Open Modbus/TCP.

Details of the application layer protocol may be found in readily available Modbus or Open Modbus/TCP documentation.

8.1 Modbus Serial Communication Format

The basic frame structure for Modbus RTU serial protocol is as follows:

Request

Slave ID	Function Code	Function dependent request data ….	CRC16 (msb)	CRC16 (lsb)

Maximum request frame size 256 bytes.

Response

Slave ID	Function Code	Function dependent response data	CRC16	CRC16 (lsb)

		….	(msb)	

The Slave ID of the request is returned in the Response. The Function Code of the request is returned in the response if the operation was successful. An exception response has the most significant bit of the request function code set on (see Exception Response). Maximum response frame size 256 bytes.

Exception Response

Slave ID	Function Code	Exception Code	CRC16 (msb)	CRC16 (lsb)

The Slave ID of the request is returned in the Response. The Function Code in an exception response has the most significant bit of the request function code set on. I.e. Exception Function Code = Request Function Code + 0x80. Maximum response frame size 256 bytes.

Useful Exception Codes are:

0x01 = Illegal Function	(slave doesn't support function in request)
0x02 = Illegal Data Address	(slave doesn't have register specified in request)
0x03 = Illegal Data Value	(value in request out of range for register in slave)
0x04 = Illegal Response Length	(request would cause response to exceed 256 bytes)

8.2 CRC16 Calculation Method

CRC checking is only performed for Modbus serial communications. Two CRC check codes are appended to the end of both Modbus request and reply messages.

The CRC method used is a standard CRC-16 with the following polynomial:

G(x) = x16 + x15 + x2 + x1

Starting Value = FFFFH

Feedback = A001H

The CRC is calculated using the body and header of the message (i.e. whole message excluding CRC bytes).

8.3 Open Modbus/TCP Communication Format

The basic frame structure for Open Modbus/TCP protocol is as follows. This is the stream data transported via the TCP socket connection and does not include TCP/IP protocol bytes.

Request

Transaction ID (msb) 0*	Transaction ID (lsb) 0*	Protocol ID (msb) 0	Protocol ID (lsb) 0	Length (msb) 0	Length (lsb)	
Unit ID	Function Code	Function dependent request data ….				

*Transaction ID is echoed by the Modbus/TCP server and may be used by a client. The SCADAPack E RTU sets these bytes to 0 in requests.

Protocol ID identifies the message protocol following in the data stream. When both these bytes are 0, it indicates Modbus/TCP protocol.

Length (lsb) indicates the number of bytes following in the rest of the frame. Minimum value is 3, maximum value is 255.

Unit ID uniquely identifies the Modbus device, and is equivalent to Slave ID of serial Modbus.

CRC checking is not used for Open Modbus/TCP communications. Instead it relies on the CRC checking included in the TCP/IP stack layers.

Function Code and following data is equivalent to serial Modbus RTU protocol.

Response

Transaction ID (msb)	Transaction ID (lsb)	Protocol ID (msb) 0	Protocol ID (lsb) 0	Length (msb) 0	Length (lsb)	
Unit ID	Function Code	Function dependent response data ….				

Transaction ID is echoed by the Modbus/TCP server in the response.

Length (lsb) indicates the number of bytes following in the rest of the frame. Minimum value is 3, maximum value is 255.

Unit ID is equivalent to Slave ID of serial Modbus.

Exception Response

Transaction ID (msb)	Transaction ID (lsb)	Protocol ID (msb) 0	Protocol ID (lsb) 0	Length (msb) 0	Length (lsb) 3
Unit ID	Function Code	Exception Code			

Transaction ID is echoed by the Modbus/TCP server in the response

The Unit ID of the request is returned in the Response.

The Function Code in an exception response has the most significant bit of the request function code set on, i.e. Exception Function Code = Request Function Code + 0x80

See Exception Codes 47 for a list of useful Exception Codes.

8.4 Modbus RTU in TCP Communication Format

Modbus RTU in TCP message format is exactly same as that of the Modbus RTU protocol. The main difference is that Modbus RTU in TCP protocol communicates with a device through the Internet and Modbus RTU protocol through the serial port. The Modbus RTU in TCP protocol does not include a six-byte header prefix, as with the Modbus\TCP, but does include the Modbus CRC16 check fields. The Modbus RTU in TCP message format supports Modbus RTU message format.

The basic frame structure for Modbus RTU serial protocol is as follows:

Request

Slave ID	Function Code	Function dependent request data ….	CRC16 (msb)	CRC16 (lsb)

Maximum request frame size 256 bytes.

Response

Slave ID	Function Code	Function dependent response data	CRC16	CRC16 (lsb)

		….	(msb)	

The Slave ID of the request is returned in the Response. The Function Code of the request is returned in the response if the operation was successful. An exception response has the most significant bit of the request function code set on (see Excpetion Response). Maximum response frame size 256 bytes.

Exception Response

Slave ID	Function Code	Exception Code	CRC16 (msb)	CRC16 (lsb)

The Slave ID of the request is returned in the Response. The Function Code in an exception response has the most significant bit of the request function code set on. I.e. Exception Function Code = Request Function Code + 0x80. Maximum response frame size 256 bytes.

Useful Exception Codes are:

0x01 = Illegal Function	(slave doesn't support function in request)
0x02 = Illegal Data Address	(slave doesn't have register specified in request)
0x03 = Illegal Data Value	(value in request out of range for register in slave)
0x04 = Illegal Response Length	(request would cause response to exceed 256 bytes)

Modbus RTU in TCP protocol has some differences from the Modbus/TCP protocol as follows.

1. Modbus RTU in TCP doesn't include a six-byte header.
2. Modbus RTU in TCP includes a two-byte CRC .
3. The message format supports Modbus RTU message.