GRID AUTOMATION PRODUCTS

MicroSCADA X SYS600 10.2

Modbus Slave Protocol

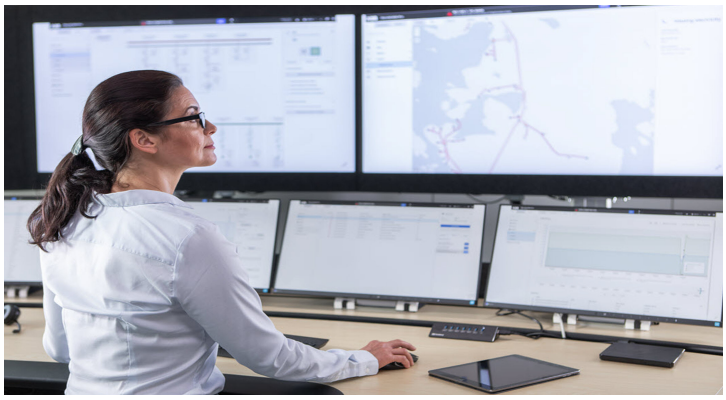

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Table of contents

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Section 2 Introduction

2.1 This manual

This manual provides thorough information on the Modbus slave protocol and information related to it. It describes how to configure the base system and the Modbus slave application for communication between them and with the Modbus master.

In addition to this configuration, the base system needs to be configured for the process communication. For information about this subject, see other manuals, for example SYS600 Application Objects or SYS600 COM500*i* User's Guide. The Modbus master needs to be configured as well.

2.1.1 Modbus slave

The Modbus slave protocol is mainly used for upper level communication between SYS600 and a network control system as illustrated by Figure 1. In MicroSCADA, the Modbus slave protocol is implemented using the CPI protocol development environment.

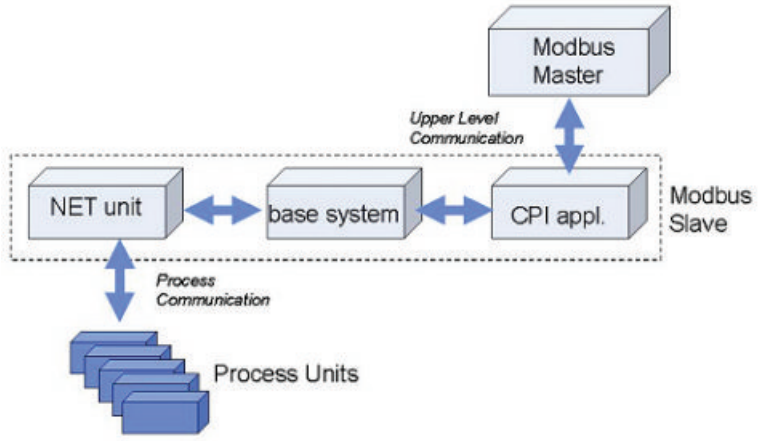

Figure 1: The Modbus master sees the NET unit and the process behind it as a slave

The data from the process activates a certain event channel and command procedure in the base system. This command procedure sends the information forward to the Modbus slave CPI application program and the Modbus master.

When COM500*i* is used, all protocol specific objects are created automatically (for example, command procedure and event channels). This is recommended since otherwise the user has to create an application, which forwards the data between the process device and the Modbus protocol.

In TCP mode, Modbus slave protocol operates as TCP server and is thus exposed to attacks from the network. For more information, see SYS600 Cyber Security Deployment Guideline, which collects instructions to harden the system as a whole.

2.2 Related documents

The following MicroSCADA manuals should be available for reference during the use of this manual:

Name of the manual	Document ID
SYS600 10.2 System Configuration	1MRK 511 481-UEN
SYS600 10.2 System Objects	1MRK 511 482-UEN
SYS600 10.2 Application Objects	1MRK 511 467-UEN
SYS600 10.2 Cyber Security Deployment Guideline	1MRK 511 485-UEN

2.3 Document revisions

Revision	Version number	Date	History
A	10.2	31.3.2021	New document for SYS600 10.2

Section 3 Safety information

This chapter gives information about the prevention of hazards.

3.1 Backup copies

We suggest that taking backup copies before making any changes, especially ones that might have side effects. Software and data need to be copied to another place, usually to a CD or a backup tape. A writable CD and DAT tape are commonly used.

Backup copies make it easier to restore application software in case of a disk crash or any other serious failure resulting in the loss of stored data. Therefore, it is recommended that backup copies are taken regularly.

There should be at least two system backup copies and two application copies. A new backup is copied over the oldest backup. This way the latest version is always available, even if the backup procedure fails.

Detailed information on how to take backup copies should be delivered to the customer with the application.

3.1.1 System backup

Usually, a system backup is taken after the application is made. A backup should be taken every time changes are made to the SYS600 system. For example, if the driver configuration or the network set-up is changed.

3.1.2 Application backup

An application backup is taken simultaneously with the system backup after the application is made. A backup should be taken every time changes are made to the application. For example, if pictures or databases are edited or new pictures are added.

3.2 Fatal errors

A fatal error is an error that causes a break-down or a locked situation in the SYS600 program execution.

3.2.1 Handling

In case of a fatal error:

1. Write down the possible SYS600 error messages.
2. Shut down the SYS600 main program. If this cannot be done in the SYS600 Control Panel, try to end the task in Windows Task Manager.

Shutting down the base system computers by switching off the power may damage files.

3. In Windows, the data kept in the main memory at the time of a fatal error is placed in the drwtsn32.log file. It is placed in a system folder, for example, WINNT. Analyze and copy the data in this file.
4. Restart the system.

Report the program break-down together with the possible SYS600 error messages and the information from the drwtsn32.log file to the SYS600 supplier.

3.2.2 Status codes

Error messages in SCIL are called status codes. A list of status codes and short explanations can be found in SYS600 Status Codes.

Section 4 Instructions

4.1 General

4.1.1 CPI application program

A program that has been made by using the Communication Programming Interface (CPI) software is called a CPI application program. This program is a separate executable file, Modbus_Slave.exe, which locates in the \prog\Modbus_Slave directory. A CPI application program is connected to the SYS600 base system through the TCP-IP network. The Modbus slave CPI application program communicates with the Modbus masters via the serial ports or the TCP/IP ports of the computer running it. Modbus slave supports the use of two serial and two TCP communications, which can all be used simultaneously. The used communication channels can be defined in the config.ini configuration file. With each serial port the Modbus slave can only be connected to one Modbus master at a time. With the TCP/IP communications, multiple masters can communicate with the slave simultaneously.

4.1.2 Requirements

The following software is required:

- SYS600
- Windows operation system
- Modbus slave executable
- MDDebugWin.exe (debug window executable)

The Modbus slave application can be installed either on the same computer as the SYS600 base system or on a separate computer. The most common and recommended setup is that the modbus slave instances are connected to the same computer as the SYS600 base system and the COM500*i* application.

4.1.3 Installation

Modbus Slave software is installed when SYS600 is installed. modbus_slave.exe and the configuration file config.ini are installed to the /sc/prog/modbus_slave directory. If an older config.ini file is found, it is not overwritten but a config$ini file is created from the new installation file. The new file can be taken into use by renaming it to 'config.ini'. It is recommended to use the newest config.ini file.

4.2 Configuration

4.2.1 General

The configuration can be divided into following parts:

- Base system configuration
- Communication system configuration
- COM500*i* configuration

The base system configuration can be done by using SCIL statements. The communication system configuration is done by configuring the Modbus slave CPI application program. When

COM500*i* is used, the station objects configured to a Modbus slave node should be defined on the NCC page of the Signal X-reference tool.

4.2.2 Base system configuration

4.2.2.1 General

Each base system has a set of objects that specify the base system and its environment, hardware and software, as well as the physical and logical connections of the base system and its applications.

The base system objects are defined with SCIL commands in the SYS_BASCON.COM file, which is executed every time the base system is started. With a few limitations, the definition and modification of the base system objects is possible at any time when SYS600 is running. During the operation, the base system objects are in the primary memory of the base system computer.

The Modbus slave CPI application program emulates an RTU type station, which means that the interface towards the base system is similar as with an RTU station. The CPI application program requires a node of its own. Communication between this node and the base system takes place via a LAN link.

4.2.2.2 Configuration steps

To configure SYS_BASCON.COM:

1. Define the base system.
2. Define a LAN link.
3. Define an application.
4. Define nodes for the Modbus slave instances
5. Define the RTU stations. The number of RTU stations can be the same as the number of the connected process units. This way the information related to a certain process unit can be routed to the corresponding station in the NET unit. This way, the Modbus master can differentiate between the information from different process units. In the COM500*i* configuration, it is possible to use a maximum of 8 NCC stations.

The definitions are made in the example below. For more information on the system objects, see SYS600 System Objects. Steps 1..3 are necessary, but they are configured using the standard SYS_BASCON.COM template. Steps 4..5 are necessary for the Modbus slave.

4.2.2.3 Example

The following is an example of the SYS_BASCON.COM file for communication with the Modbus slave protocol. An application CPI_TEST is defined. In this example, 1 node and 2 stations are configured.

```
;*************************************************************************
;
; SYS_BASCON.COM
; BASE SYSTEM CONFIGURATION TEMPLATE
;
;*************************************************************************

  #CREATE SYS:B = LIST(-
     SA = 209,-                          ;STATION ADDRESS OF BASE SYSTEM
     ND = 9,-                            ;NODE NUMBER OF BASE SYSTEM
```

Table continues on next page

```
   DN = 3,-                          ;DEFAULT NET NODE NUMBER
   DS = "RTU",-                      ;STA TYPES: E.G. STA,RTU,SPA,REX
   FS = "NEVER")                     ;FILE SYNCH CRITERIA


 ;*********************************************************************
 ;
 ;            COMMUNICATION LINKS
 #CREATE LIN:V = LIST(-            ;REQUIRES TCP/IP
             LT = "LAN")           ;FOR SYS-SYS AND LAN FRONTEND
 #CREATE LIN1:B = %LIN


 ;*********************************************************************
 ;
 ;            COMMUNICATION NODES


#CREATE NOD3:B = LIST(-
    LI = 1,-
    SA = 203)
;*************************************************************************
    ;


 ;            PRINTERS
 ;*********************************************************************
 ;
 ;            MONITORS


#LOOP_WITH I = 1..5
   #CREATE MON'I':B = LIST(-
         TT = "LOCAL",-  ;TRANSLATION TYPE
         DT = "X")       ;X MONITOR
   @MON_MAP(%I) = -1
#LOOP_END

#LOOP_WITH I = 6..10
   #CREATE MON'I':B = LIST(-
         TT = "LOCAL",-        ;TRANSLATION TYPE
         DT = "VS")            ;VISUAL SCIL MONITOR
   @MON_MAP(%I) = -1
#LOOP_END
;*************************************************************************
;

 ;            APPLICATIONS
```

```
#CREATE APL:V = LIST(-
TT = "LOCAL",-                  ;TRANSLATION TYPE
NA = "CPI_TEST",-               ;NAME OF APPLICATION DIRECTORY
AS = "HOT",-                    ;APPLICATION STATE: COLD,WARM,HOT
HB = 2000,-

      RC = VECTOR("FILE_FUNCTIONS_CREATE_DIRECTORIES"),-

AP = (1,2),-                    ;HISTORY BUFFER SIZE)
MO = %MON_MAP,-                 ;MONITOR MAPPING
PR = (1,2,3))                   ;PRINTER MAPPING
#CREATE APL1:B = %APL

;*********************************************************************


;            STATIONS


#CREATE STA1:B = LIST(-
       TT = "EXTERNAL",-
       ST = "RTU",-
       ND = 3,-
       TN = 1)

#CREATE STA2:B = LIST(-
       TT = "EXTERNAL",-
       ST = "RTU",-
       ND = 3,-
       TN = 2)

;*********************************************************************
```

4.2.3 Communication system configuration

4.2.3.1 General

Unlike configuring a protocol implemented in PC-NET, configuring the communication system for the Modbus slave protocol is done by configuring the CPI application program. This can be done by setting the configuration parameters of the file config.ini located in the sc\prog \modbus_slave directory. Config.ini can be edited by using a text editor, such as Notepad. The parameters should be set before the Modbus slave CPI application program instances are started.

The communication parameters of a Modbus slave CPI application program can be divided into six groups:

- Own Node Parameters
- Base System Parameters
- Serial Port Communication Parameters
- TCP/IP Communication Parameters
- Modbus Slave Parameters
- Debug Parameters

The parameters are grouped into sections in the configuration file, which are separated by section headers written inside square brackets. For example, the serial port communication parameters are listed below the section header [SerialPortCommPar]. The names of the sections and parameters should not be modified. If these names are modified, the program will use default values.

4.2.3.2 Own node parameters

The following parameters describe the node and communication channels of the Modbus slave application program:

own_node_no

The number of the node of the CPI application program.

Data type: Integer

Default value: 3

own_station_no

The station address of the node of the CPI application program.

Data type: Integer

Default value: 203

serial_port_in_use

Sets whether or not the serial port communication 1 is used.

Data type: Integer

Values: 0 – not in use
1 – in use

Default value: 1

If all of the communication channels are configured as not to be used, Serial port 1 is opened as default.

serial_port_2_in_use

Sets whether or not the serial port communication 2 is used.

Data type: Integer

Values: 0 – not in use
1 – in use

Default value: 0

tcpip_1_in_use

Sets whether or not the TCP/IP communication 1 is used.

Data type: Integer

Values: 0 – not in use
1 – in use

Default value: 0

tcpip_2_in_use

Sets whether or not the TCP/IP communication 2 is used.

Data type: Integer

Values: 0 – not in use
1 – in use

Default value: 0

4.2.3.3 Base system parameters

The following parameters describe the connection to the base system:

basesystem_node_no

The number of the base system node (the ND attribute of the SYS:B object). Value range: 1...250.

Data type:	Integer
Value range:	1 .. 250
Default value:	9

basesystem_station_no

The station address of the node of the base system. (the SA attribute of the SYS:B object).

Data type:	Integer
Default value:	209

tcp_ipadd

The TCP/IP address of the base system computer.

Data type:	Integer
Default value:	empty string

If the Modbus slave and base system exist on the same computer, IP-address 127.0.0.1 should be used.

application_number

The number of the SYS600 application the CPI application program communicates with.

Data type:	Integer
Default value:	1

basesystem_diagnostics_interval

Diagnostic interval from modbus slave to base system. In case modbus slave is started from WD (Watchdog) application, the value of this parameter have to be increased to 20 seconds or 2xnode diagnostic interval for the modbus slave node in question, which one is bigger. See description basesystem NOD attribute DI from SYS600 System Objects manual. If basesystem_diagnostics_interval is not defined, the default value is used; this configuration is valid when modbus slave is started from the main application. Diagnostic timer is started when an attribute of Modbus slave is accessed across CPI. If basesystem diagnostics indicate that main application has gone to COLD state, modbus slave disconnects the connection to the basesystem.

Data type:	Integer
Value range:	1..65535
Unit:	Seconds
Default value:	1

4.2.3.4 Serial port communication parameters

The following parameters describe the properties of the serial port communications. Both serial communications have the same configurations, but they can be configured separately. The configurations are separated with sections [SerialPortCommPar] and [SerialPortCommPar2]. The configurations are:

port_name

Name of the Serial port, for example "COM1".

Data type:	string
Default value:	empty string

baud_rate

Depends on the hardware. Normally a value of at least 9600 bits/s is supported

Data type: Integer

Default value: 9600

parity

Parity value.

Data type: Integer

Values: 0 - none1 - odd
2 - even
3 - mark
4 - space

Default value: 0

stop_bit

Defines the number of stop bits.

Data type: Integer

Values: 0 - 1 stop bit is used
1 - 1,5 stop bits are used
2 - 2 stop bits are used

Default value: 0

The stop_bit parameter value is not the actual amount of stop bits.

data_bits

Defines the number of data bits.

Data type: Integer

Valid value: 8 (RTU mode of Modbus protocol is used)

Default value: 8

flow_control

Data type: Integer

Valid values: Parameter not used. CTS (clear-to-send) signal is always monitored for output flow control.
If CTS is non-signaled, data is not sent until CTS is signaled again.

Default value: 0

dtr_control

For more information see Section 4.5.2, section DI Database Initialized.

Data type: Integer

Valid values: 0 - DTR signal is not controlled
1 - DTR signal is controlled

Default value: 1

config_delay_msecs

Delay between COM port opening and its configuration. In case the debug output indicates that the parameter setting using WinAPI calls SetCommState or SetCommTimeouts fail or do not become activated, using this parameter it is possible to add a delay between port opening and configuration. In case of problems, values >0 are worth to try especially with virtual serial ports. If parameter is not specified in configuration file, no delay is added.

Data type:	Integer
Valid values:	0..65535 (milliseconds)
Default value:	0

If there are problems with the COM port, try to set the COM port configuration of Windows to be the same as in the Initialization file.

poll_listen_cold

When this parameter is set to 1, incoming polls are listened by the modbus slave line while DI (Database initialized) is 0. Latest poll is always stored. This configuration is used when the modbus slaves of a hot-standby pair is connected to the same serial line as multidrop and NCC is not sending retries for modbus polls. When DI changes to 1, usually because of a HSB switch-over, the stored poll is immediately responded with current data values, without waiting for a new poll. In order to use this feature, modbus slave must be started from WD (Watchdog) application. When 'poll_listen_cold' is 0 or it is not defined, polls are not listened while DI=0. This the default behaviour.

Data type:	Integer
Valid values:	0, (disabled), 1 (enabled)
Default value:	0

poll_listen_expiration

This parameter is used with setting poll_listen_cold = 1. It defines the maximum age of the poll stored when DI=0. If the stored poll is older than the time defined with this parameter, the poll is not responded thought DI is set to 1. This parameter is meaningless if poll_listen_cold is 0 or if it is not defined.

Data type:	Integer
Valid values:	1..255
Default:	20
Unit:	Seconds

4.2.3.5 TCP/IP communication parameters

The following parameters describe the properties of the TCP/IP communications. Both TCP communications have the same configurations but they can be configured separately. The configurations are separated with sections [TCPIPCommPar1] and [TCPIPCommPar2]. The configurations are:

slave_ip_addr

Defines the local IP address of the Modbus slave server.

Data type:	String
Default value:	empty string

The IP addresses must be given in the form xxx.xxx.xxx.xxx (for example, slave_ip_addr_1 = 127.0.0.1).

tcp_ip_port

Defines the local TCP port of the Modbus slave server.

Data type: Integer

Default value: 502

Both Modbus Slave TCP communications need to have either separate IP address or separate TCP port number. If both are configured with same IP and TCP port numbers, neither of the communications can be opened.

no_of_masters

The allowed number of simultaneously connected master.

Data type: Integer

Valid values: 1 .. 16

Default value: 1

This value determines also the number of connections from a single master. The maximum number of connections for one TCP communication is 16. Number of connections per master is set by the Modbus slave so that each master has the same amount of connections within the 16 connections. For example if the no_of_masters is 3 the number of connections for one master is set to 5 (in this case one connection slot is not used). The recommended number of masters is 2, 4 or 8, which allows for the best use of available connections.

no_of_ips

The number of allowed IP addresses.

Data type: Integer

Valid values: 1 .. 32

Default value: 1

allowed_ip_addr_x

Allowed IP address. The "x" is the number of the IP address.

Data type: String

Default value: empty string

The IP addresses must be given in the form xxx.xxx.xxx.xxx (for example, allowed_ip_addr_1 = 127.0.0.1). Only IP addresses listed in this configuration are allowed to make a connection to the Modbus server. Connections from other IP addresses are discarded.

connection_watchdog

defines the time a connection waits for a request from a master before the connection is closed as unused. The watchdog time is given in seconds.

Data type: Integer

Default value: 20

4.2.3.6 Modbus slave parameters

The following general parameters are in the Initialization file. They have default values, which can be used in normal cases. However, these values can be edited if there is a need to create some special features.

address_offset

Defines how the Modbus master address is mapped in the slave device. According to the Modbus protocol standards, all the addressing is with reference to zero. For more information about the usage of the Address_offset parameter, see Section 5.2.4.

Data type:	Integer
Default value:	0

Example 1:

Read analog value from register 40001 (set in Modbus master) is read from the address 0000 of the slave device. In this case the value of offset is 1.

For the SYS600 Modbus master there is no shifting of addresses as above.

Example 2:

Read analog value from register 40001 (set in master) is read from address 0001 of the slave device. In this case the value of offset is 0.

change_bit_offset

This configuration indicates if change bits are used and what is the offset in memory address between a process object value and its change bit. A change bit indicates if the state of a binary process object has changed more than once between read requests.
Change bit value 0 means that the process objects state has not changed or that the changed state can be seen in the objects current value.
Value 1 means that the process objects state has changed more than once between the last polled state and the current state.
The actual process objects and their memory bits are stored in the same container, so the change bits can be read the same way, and in the same poll as the process object. A change bit is created only for binary process objects when they are written. Each binary process object in Modbus slave has only one change bit. When creating and cross-referencing binary process objects, the user should be cautious not to assign addresses that overlap with other objects change bits. When a change bit is read, the bit is cleared. If the change bit is not read at all, the value of the change bit stays unchanged. The change bit functionality can only be used with one master due to clearing of a change bit after it is read. Figure 2 below shows the functionality of a change bit when a process objects value changes and when a read message (dashed line) occurs.
Recommended offset values are 1 and 16, in which the change_bit is always the next bit or the same bit in the next word/byte.

Data type:	Integer
Valid values:	0 – not in use 1 .. 32767 – change bit is used, and this is also the number of offset in bits
Default value:	0

Examples:

If the change_bit_offset is 1, a binary process object in address: block 2 bit 0 has its change bit in address to block 2 bit 1.

If the change_bit_offset is 16, a binary process object in address: block 3 bit 1 has its change bit in address to block 4 bit 1.

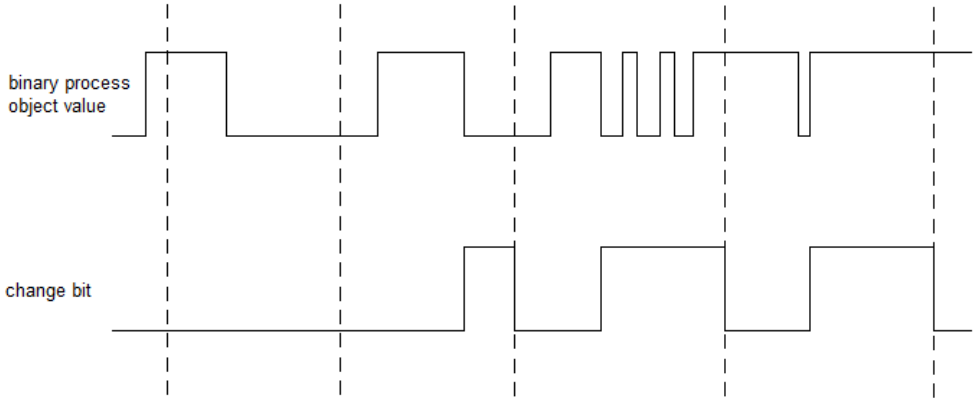

Figure 2: Change detection bit

modbus_master

Type of the Modbus master.

Data type:	Integer
Valid values:	0 - other system than SYS600 is used as Modbus master 1 - SYS600 is used as Modbus master
Default value:	1

no_of_stns

Number of Modbus stations configured in the system.

Data type:	Integer
Valid values:	1 .. 8
Default value:	1

stn_no_x

Station numbers of the Modbus stations. The "x" is a running number. Station numbers needs to be given as a separate value for each station. For example in the case of two stations, stn_no_1 determines the station number of a one station and stn_no_2 the number of another station. The station numbers do not need to be sequential. See also parameters stn_address_x and stn_alt_address_x. In case stn_address_ parameter is not defined, the given station number is also the modbus address used to access the data.

Data type:	Integer
Valid values:	1 .. 255
Default value:	1 .. 255 (running number)

stn_address_x

Modbus address of the Modbus station. The "x" is a running number. This is an optional parameter which should be used when modbus address of the station object is different from the station number. If used, a unique value must be given for each station. If parameter is not defined, modbus address is the same as the station number.

Data type:	Integer
Valid values:	1 .. 255
Default value:	1 .. 255 (running number)

stn_alt_address_x

Alternative modbus address of the Modbus stations. The "x" is a running number. This is an optional parameter which may be used when there is a need to access the same data using two different modbus addresses. This situation may be present if e.g. redundant lines are using different modbus addresses in master configuration. If used, a unique value must be given for each station and given value should not overlap with values given to stn_address_

Data type:	Integer
Valid values:	1 .. 255
Default value:	1 .. 255 (running number)

format_analog

The format of analog values.

Data type:	Integer
Valid values:	5 - Format WORD. Integer value, two bytes long (Unsigned if SYS600 is used as Modbus master and Signed for any other Modbus master). 6 - Format LONG. Signed 32 bit value, four bytes long in msb-lsb order* 7 - Format MSB_LONG. Signed 32 bit value, four bytes long in lsb-msb order* * The most significant byte - the least significant byte order (and vice versa).
Default value:	5

respond_also_if_invalid

This parameter defines whether or not an exception message is sent the master if the status of data in the requested station is not ok.

Data type:	Integer
Valid values:	0 - Modbus requests are responded to with exception 0xB if data is invalid 1 - Modbus requests are responded to even if data is invalid
Default value:	1

se_applevent_used

This parameter sets the Modbus slaves' SE attribute, which is related to system and node status messages and use of the Self System Supervision (SSS). If the SSS is used, the status of the node and stations are updated to the SSS process objects. Information about the SSS process objects is presented in Section 4.4.2. For more information about the SSS, see Application design manual chapter 16.

Data type:	Integer
Valid values:	1 - SSS is not used 4 - SSS is used
Default value:	1

4.2.3.7 Debug parameters

The following parameters describe the properties of the debug functionality. The debug functionality affects the whole Modbus slave regardless of the used communications.

Debug prints slow down the serial and TCP communications to some extent. It is recommended to turn off the debug prints, if the highest communication speed is desired.

debug_info

This parameter defines if the debug messaging is activated. It is recommended to use the debug mode only temporarily.

Data type:	Integer
Valid values:	0 - debug messaging is not activated 20714 - debug messaging is activated
Default value:	0

debug_window

Defines whether or not a separate debug window is used. The debug window is started from a separate executable MDDebugWin.exe. This feature should be used if debug messages are needed and the Modbus slave is started from the APL_INIT procedure, as explained in Section 4.4.

Data type:	Integer
Valid values:	0 – not used 1 – is used
Default value:	0

The start-up of the separate debug window is explained at the end of chapter 4.4.

namedpipe_name

Defines the name of the Namedpipe, which is used to communicate between the Modbus slave and the separate debug window. The name given here needs to be used as a startup parameter when starting the debug window. The maximum length of the namedpipe_name is 10 characters. It can consist of letters and numbers.

Data type:	String
Maximum length:	10 characters. It can consist of letters and numbers
Default value:	empty string

error_debugs_only

Defines if only error messages are printed into the used debug window.

Data type:	Integer
Valid values:	0 - both error and communication related messages are printed 1 - only error messages are printed
Default value:	0

4.2.3.8 Examples

This is an example of the Modbus slaves' config.ini file with the configuration parameters explained above. Modbus slave with two stations and all four communication channels are configured in this example. Used modbus addresses are 11 and 21 (STA1) and 12 and 22 (STA2). Both serial lines are listening polls while DI=0 (parameter 'poll_listen_cold').

```
[OwnNodeParameters]
own_node_no = 3
own_station_no = 203
serial_port_in_use = 1
serial_port_2_in_use = 1
tcpip_1_in_use = 1
tcpip_2_in_use = 1
[BaseSystem1]
basesystem_node_no = 9
basesystem_station_no = 209
tcp_ipadd = 127.0.0.1
application_number = 1
```

```
basesystem_diagnostics_interval = 20
[SerialPortCommPar]
port_name = COM1
baud_rate = 1200
parity = 0
stop_bit = 0
data_bits = 8
flow_control = 0
dtr_control = 1
poll_listen_cold = 1
poll_listen_expiration = 30
[SerialPortCommPar2]
port_name = COM1
baud_rate = 1200
parity = 0
stop_bit = 0
data_bits = 8
flow_control = 0
dtr_control = 1
poll_listen_cold = 1
poll_listen_expiration = 30
[TCPIPCommPar1]
slave_ip_addr = 10.0.1.1
tcp_ip_port = 502
no_of_masters = 4
no_of_ips = 3
allowed_ip_addr_1 = 10.0.12.1
allowed_ip_addr_2 = 10.0.12.2
allowed_ip_addr_3 = 10.0.12.3
connection_watchdog = 20
[TCPIPCommPar2]
slave_ip_addr = 10.0.1.2
tcp_ip_port = 502
no_of_masters = 4
no_of_ips = 2
allowed_ip_addr_1 = 10.0.12.1
allowed_ip_addr_2 = 10.0.10.1
connection_watchdog = 20
[ModbusSlavePar]
address_offset = 0
change_bit_offset = 0
modbus_master = 1
no_of_stns = 2
stn_no_1 = 1
stn_no_2 = 2
stn_address_1 = 11
stn_address_2 = 12
stn_alt_address = 21
stn_alt_address = 22
format_analog = 5
respond_also_if_invalid = 0
se_applevent_used = 1
[Debug]
debug_info = 0
debug_window = 0
namedpipe_name = namedpipe
error_debugs_only = 0
```

In order to add one more station with address 10 under the Modbus slave parameter, add the following information:

```
no_of_stns = 3
stn_no_1 = 1
stn_no_2 = 2
stn_no_3 = 10
```

4.3 After configuration

For each input signal from the process devices, the process database should contain a process object whose value changes after the process data is received. The change activates an event channel, which in turn starts a command procedure. The command procedure sends the value to the CPI application program from which the data is transferred to the Modbus master through the communication media.

In addition to the configuration of the base and communication systems, following steps are needed:

1. Configure the Modbus master in NCC.
2. Configure the base system for process communication.
3. Configure the process units.
4. Create and define input and output process objects for the process communication. This is usually done when creating the station picture by using standard functions from an application library.
5. Define the COM500*i* cross-references for signals. For more information, see SYS600 COM500*i* User's Guide

If COM500*i* is used, the cross-references between the process objects and the Modbus slave are made in the Signal X-references Tool. COM500*i* creates the required event channels and command procedures automatically. For more information, see SYS600 COM500*i* User's Guide.

If COM500*i* is not used, for more information on how to program the command procedures and values of the attributes, see Section 5 in this document.

4.4 Start-up

The Modbus slave protocol runs in an external executable program and must be started separately. The basic idea of the start-up is similar to stand-alone and HSB systems. The configuration of the HSB system is described in the System Configuration manual, chapter Configuring redundancy.

As mentioned earlier in chapter 4.1, a Modbus slave can have two serial and two TCP communication channels running simultaneously. Both TCP communications can communicate with multiple masters, but serial port communications can only have a single master. If different Modbus slave IP addresses or more master connections than one slave can co-operate with are needed, separate Modbus slave instances must be configured.

This example must be applied to the required amount of Modbus slave lines, i.e. NCC connections from COM500*i*. The following steps are required to configure 3 Modbus slave instances:

1. Create the following directories:
   * `\sc\prog\modbus_slave\s1`
   * `\sc\prog\modbus_slave\s2`
   * `\sc\prog\modbus_slave\s3`
2. Copy the modbus_slave.exe and config.ini to each of the created directories.
3. Rename the modbus_slave.exe to Mds1.exe, Mds2.exe and Mds3.exe.
   The renaming is needed to shut down the instances in a controlled way. If there is only one instance of the modbus slave, renaming it is not necessary and the shutting down (step 6) can be done using the name modbus_slave.exe.
4. Edit the config.ini configurations in each directory for that specific Modbus slave instance and make the corresponding configuration to the base system as instructed in Section

4.2.2 in this manual. The number of the main application should be given to the configuration item "application_number".

A unique node must be created for each Modbus slave instance.

5. Create a .bat file Mds1.bat into the modbus_slave\s1 directory, with the following example content:

```
cd C:\sc\prog\modbus_slave\s1
mds1
```

Create a similar .bat file for each instance in their own subdirectory. A .bat file can be created with, for example, Windows Notepad.

6. Add the following script to a command procedure executed from the event channels APL_INIT_1 and APL_INIT_H (only in HSB systems) of the main application.

```
;MD_SLAVE_START:C
@MDS1_STATUS = OPS_CALL("C:\sc\prog\modbus_slave\s1\MDS1.BAT",0)
@MDS2_STATUS = OPS_CALL("C:\sc\prog\modbus_slave\s2\MDS2.BAT",0)
@MDS3_STATUS = OPS_CALL("C:\sc\prog\modbus_slave\s3\MDS3.BAT",0)
```

7. Add the following script in a command procedure executed from the event channel APL_CLOSE of the main application.

```
;MD_SLAVE_STOP:C
@MDS1_STATUS = OPS_CALL("taskkill /IM mds1.exe /F",0)
@MDS2_STATUS = OPS_CALL("taskkill /IM mds2.exe /F",0)
@MDS3_STATUS = OPS_CALL("taskkill /IM mds3.exe /F",0)
```

8. Define the NCC connections to the Signal X-reference tool in the base system.
The entered RTU station numbers should be equal to the values entered in config.ini files, item stn_no_*. COM500*i* initializes the Modbus databases in the order NCC1, NCC2, and so on. If some of the Modbus slaves require a faster communication start-up after a takeover, they should be configured into a lower NCC number compared to the others.

When running a Modbus slave from version SYS600 9.3FP2 and newer on a Windows XP or Windows 2003 server, it is necessary to start the Modbus slave with a special flag '-closedisable'. This flag disables the possibility to stop the Modbus slave from the upper right corner of the Modbus slave console window. In Windows 7 and on the Windows 2008 server, this flag should not be used, since the Modbus slave is usually running in session 0 (user MicroSCADA).
Starting example for Windows XP or Windows 2003 server:
cd C:\sc\prog\modbus_slave\s1
mds1 -closedisable

If the serial port or TCP port cannot be opened when the Modbus slave is started, or if the sending fails during communication, the opening is reattempted at a regular interval. This feature is useful, if the serial port is virtual or USB-based.

Create a similar .bat file for each instance in their own subdirectory. A .bat file can be created with, for example, Windows Notepad.

4.4.1 Debug window start-up

The separate debug window is started from a standalone executable MDDebugWin.exe file. The debug window does not require any configurations, except the name of the namedpipe defined in the Modbus slaves' config.ini file. The exact same name must be given as a start-up parameter to the debug window, for example, by using a .bat file.

Example of the debug window start-up command with an example pipename parameter:

```
MDDebugWin.exe mdncc1
```

For the debug printing to work, also the debug_window must be set to 1 and the debug_info set to 20714 in the Modbus slave config.ini file.

4.4.2 System Self Supervision

The status of the Modbus slave can be supervised with the System Self Supervision (SSS). The use of the supervision functionality is controlled with the SE (System Messages Enabled) attribute, which can be set in the config.ini configuration file. The SE attribute value can be read in the Test Dialog tool with the SCIL command NETx:SSE, where the "x" is the number of the Modbus slave node. If the value of the SE attribute is not defined, the default value 1 is used.

With the setting SE = 1, the SSS is not used and the system messages are not enabled. The functionality is the same as in SYS600 9.3 FP2. A status update in the process object type ANSI Analog Input (UN=0, OA=8000+STA number) can be used, but this feature is not supported in the current SSS version. The status of a station can also be checked by reading the related Object Status (STAx:SOS) attribute.

With the setting SE = 4, the SSS is used and the system messages are enabled. The supervision information consists of the connection statuses of stations and nodes, which are updated in specific process objects by the SSS. The System Configurations Tool does not have support for the Modbus slave and the SSS stations must be created manually. The station process objects are type ANSI Analog Input (UN=0, OA=1000+STA number) and type ANSI Binary Input (UN=0, O A=1000+1000000hex+STA number). The node process objects are type ANSI Analog Input (UN=0, OA=6000+Node number) and type ANSI Binary Input (UN=0, OA=6000+1000000hex+Node number). In the SE = 4 mode, the Modbus slaves' interface with the SSS is similar to External OPC DA Client with IEC 61850, setting SE = 4.

4.5 How to test the configuration

4.5.1 SYS600 as the Modbus master

The configuration can be tested before the actual Modbus master is connected to the system by using SYS600 as the Modbus master. By using this configuration, it is possible to verify if the communication between the Modbus slave and master is working properly.

The Modbus master protocol is implemented in the PC-NET software. The Modbus master can be configured on the same computer as the Modbus slave or on a separate computer. It is recommended to have the Modbus master on a separate computer.

To configure the base system as the Modbus master, the following base system configuration should be done:

1. Define the base system, monitors and application, if they are not the same as those defined for the Modbus slave.
2. Define a node and a link for the NET unit.
3. Define a PLC station for each station configured in the Modbus slave.

This step is not needed if System Configuration Tool is used.

The following communication system configuration is required:

1. Define a Modbus master line.
2. Define the PLC stations with the same logical address as the RTU stations.

The station addresses (SA attribute) of the PLC stations should be equal to the stn_no_* parameters of the Modbus slave stations. Other attributes of the Modbus master line and PLC stations should also match the configuration of the Modbus slave. For more information on the attributes, see SYS600 System Objects.

Example

Below is an example for defining the station type and two PLC stations.

```
;Define PLC stations. These setting are needed only if System
;Configuration Tool is not used
#CREATE STA1:B = LIST(-
                TT = "EXTERNAL",-
                ST = "PLC",-
                ND = 1,-
                TN = 1)
#CREATE STA2:B = LIST(-
                TT = "EXTERNAL",-
                ST = "PLC",-
                ND = 1,-
                TN = 2)
```

Section 5 Technical description

5.1 Modbus protocol

The Modbus Communications Protocol is an asynchronous, byte packaged protocol used for communication between the master stations and Intelligent Electronic Devices (IEDs) or Remote Terminal Units (RTUs). It supports serial and TCP/IP communications and provides a transport mechanism for the master's requests and RTU response messages. It supports up to 247 RTUs on a multi-drop line.

The Modbus slave application can have two serial and two TCP/IP communications running simultaneously and it supports one master with each serial line communication and up to 16 masters with each TCP/IP communication.

The Modbus protocol has two distinct modes: ASCII Modbus, which uses ASCII-encoded hexadecimal messages and binary Modbus, which uses raw binary messages. The Modbus slave implementation described in this document only supports the binary mode.

All transactions are initiated by transmission of a request from the master station. An RTU may not transmit unsolicited information. Every master station request must be addressed to a specific RTU, and some implementations of Modbus do not support the broadcast message request type. A transaction consists of a single master station request followed by an RTU response, an exception frame or a master station timeout, if no RTU response is generated.

5.2 Communication

5.2.1 CPI application program

The Modbus slave protocol is implemented in SYS600 by using Communication Programming Interface (CPI) software. CPI is a collection of functions written in C language suitable for implementing protocol converters between the internal protocol of SYS600 and other protocols. The internal protocol of SYS600 is used in communication between the SYS600 nodes, for example, between a base system and a NET unit. The communication between the CPI application program and the SYS600 base system is based on the TCP/IP network.

5.2.2 Connection to a SYS600 base system

The CPI application program establishes a connection to the base system with the TCP/IP address as specified in the Modbus slave's configuration file. After establishing the connection, a link is established to the application specified in the configuration file. The CPI application program can access the SYS600 process database using the CPI library functions.

SYS600 can have a number of slaves connected to it. The CPI application program acts as a communication front-end and is seen as a node in the SYS600 system. The stations configured in SYS600 can also be logically created in the CPI application program. For Modbus slave emulation, SYS600 is seen as a data collector.

If the TCP/IP connection to SYS600 base system has been established and then lost, Modbus slave sets the data statuses in the Modbus slaves database to 10 and the Database Initialized (DI) attribute to 0. When the TCP/IP connection to the SYS600 base system is re-established again the Modbus slave sends status code 13499 to the base system. When the base system receives the status code it starts the database initialization process, which sets the Modbus slave data statuses to 0 and DI attribute value back to 1.

5.2.3 Data flow

Figure 3 describes the data flow between the process devices and the Modbus master. Both directions are described separately since the data is handled in a different way depending on the direction.

See COM500*i* User's guide for detailed information about the data flow configuration.

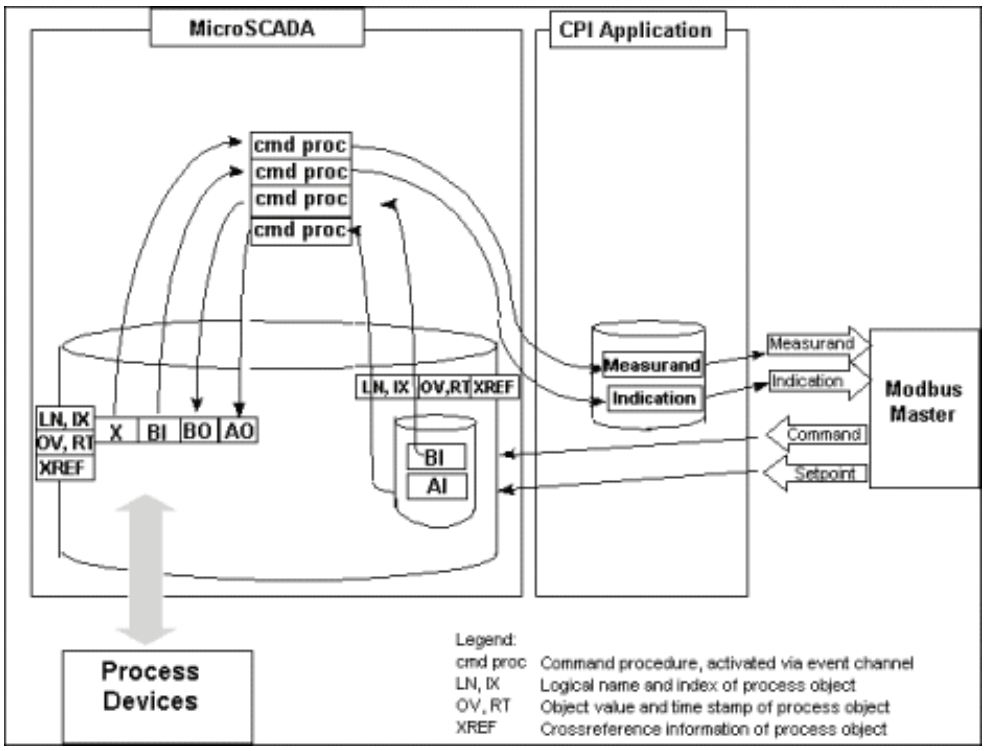

Figure 3: Data flow between the process devices and the Modbus master

5.2.3.1 Input data

When input data, for example, indications and measured values, are sent from the process devices to the Modbus master, the following steps are taken:

1. The process devices send the data to the SYS600 process database.
2. The updated process object activates an event channel.
3. The event channel executes a command procedure. Some of the attributes of the process object are given as arguments to the command procedure.
4. The command procedure sends the data to the database of the CPI application program based on specific cross-reference information.
5. The CPI application program sends the data to the Modbus master.

The cross-reference information is needed to deliver data to the database of the CPI application program, for example, object address and message type. The number of event channels and command procedures needed to deliver data to the master depends on the application. One solution is to have one command procedure for each process object type. Examples of the command procedures are given later in this document. If COM500*i* is used, all the required command procedures and event channels are created automatically.

5.2.3.2 Output data

When output data, for example, object commands and analog setpoints, are sent from the Modbus master to the process devices, the following steps are taken:

1. The command is received by the SYS600 process database. There must be a separate input process object for each Modbus command address. These process objects are created automatically when COM500*i* is used.
2. The updated process object activates an event channel.
3. The event channel executes a command procedure. Some of the attributes of the process object are given as arguments to the command procedure.
4. The command procedure sends commands to the process devices by setting the corresponding output process object(s) and, if required, sends a confirmation to the Modbus master via the CPI application program.

Cross-reference data can also be used with commands. It can contain, for example, information on the logical names and indices of the output process objects. Examples of the command procedures are given later in this document.

5.2.4 Addressing schematics with Modbus protocol

Figure 4 shows the addressing schema with analog values in the Modbus protocol when using the Modbus slave in SYS600 for example with the COM500*i* application and a Modbus type of NCC. Analog values are mapped to address space 4xxxx in the protocol definition. The memory area is not used in protocol queries and responses, and it can be defined from the function type. Protocol addressing is defined in following way:

For example, register 40001 is in query address 0000 and one register is built up of 16 bits (word). If the 3rd party master uses an address offset, the offset parameter must be set to 1, so that the wanted register number and the used block number in the SYS600 application match each other. If the offset parameter is 0 in this case, it must be remembered that the used address is different in the master and the slave.

If SYS600 is also the master system, the offset value should be set to 0. The SYS600 master queries do not use address offsets. The defined register in the master configuration is shown in protocol with the same address number. The SYS600 configuration does not allow register address 0. Therefore, possible block numbers are 1...65535 on the slave's side.

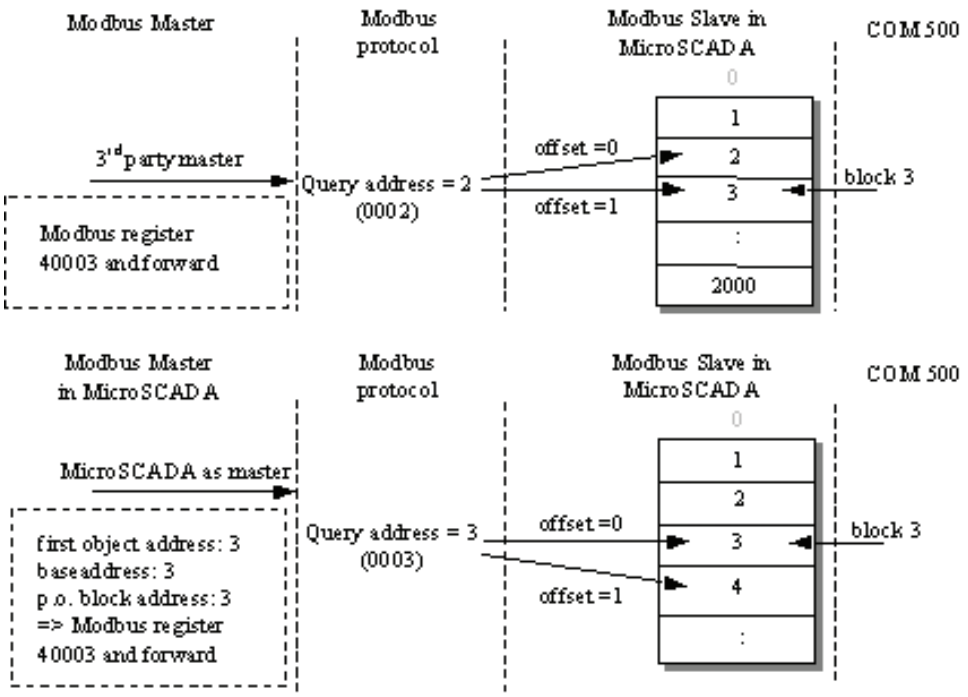

Figure 4: The addressing schema with analog values in the Modbus protocol

Offset parameter is also used with binary data. In SYS600 the discrete inputs and coils of the Modbus slave are mapped to RTU type blocks. Possible block address values are 1...4096 and bit values 0...15. The Modbus protocol does not have a block definition for binary data, it only uses data grouping of 8-bit bytes in query responses. The used memory area in protocol definition is 0xxxx. Coils and inputs are addressed starting from 1. However, in protocol queries the addressing begins from bit 0.

If SYS600 is used as a master, the bit 0 in query and master database configuration means the block 1, bit 0 address in COM500*i*. In the case of a 3rd party master, the bit address is 1 in the slave, if the offset parameter is used. This schema is used, if the master can define only binary addresses starting from 00001.

It must be remembered that the defined topic base address in the SYS600 master affects the used bit address in the process object. For example, if the used base address is 1 and bit 4 is wanted from the slave database, the BI process object's bit address is 4 (block 1). However, if the base address is 2 and the wanted input bit is 4, the used bit address must be 3. In this case block 1 begins from bit 2 instead of 1.

5.2.5 Device communication attributes

The following attributes are used to exchange data between SYS600 and the Modbus master. The attributes are similar to those of the RP 570 (SPI) stations with a few exceptions.

By default, the CPI application program does not respond, if some or all of the data requested block has an object status other than zero. This can be changed with the respond_also_if_invalid configuration, which is explained in Section 4.2.3. This applies to analog input, as well as to single and double indications, i.e. to function codes 1, 2, 3 and 4. If the station's In Use attribute is set to zero, all the statuses are 10. If the In Use attribute is set to 1, all the statuses are set to 2 to indicate suspicious values.

AV	Analog Value

Changes in analog measured values that are to be sent to the Modbus master are written to this attribute. A vector is assigned to the AV attribute consisting of a time stamp and analog value.

Data type:	Vector	
Value:	A vector of three elements: (TIME, VALUE, STATUS)	
	TIME	Time stamp for the process object whose value is sent. Time as RTU_ATIME format.
	VALUE	With configuration 'analog_format' value 5: Analog value (scaled to -32768…32767) With configuration 'analog_format' values 6 and 7: Analog value (scaled to -2147483648...2147483647)
	STATUS	Status code of the point. Value range: integer 0 … 3, valid = 0
Index range:	1…65535	
Access:	Write only	

Example:

```
;set AV block nr. 100 to 1234, status = OK (= 0 )
#SET STA99:SAV(100) = (RTU_ATIME(%RT,%RM),1234,0)
```

The time stamp information is ignored in Modbus.

ID	InDications

Indication changes that are to be sent to the Modbus master are written to this attribute.

Data type:	Vector	
Value:	A vector with 4 … 6 elements as follows: (TIME, BIT_NR, BIT_VAL, STATUS [,ERMI_ENABLED[,TIME_QUALITY]])	
	TIME	Time stamp for the process object whose value is sent Time is given in RTU_ATIME format
	BIT_NR	BIT_NR The bit number for the changed bit (0...15)
	BIT_VAL	0...1
	STATUS	Status code of the point. Value range: integer 0 … 3, valid = 0
Index:	1...4096	
Access:	Write only	

The ERMI_ENABLED and TIME_QUALITY attributes are not used at the moment in the Modbus slave.

The Modbus protocol does not contain a field to indicate the validity of the data. As default, the Modbus slave does not respond to the requests initiated from Modbus master, if some or all of the data of the requested block has a STATUS other than zero. This applies to analog inputs and pulse counters as well as to single and double indications, i.e. to function codes 1, 2, 3 and 4. If the control flag 'respond_also_if_invalid' in the configuration file equals to 1, the rule above is ignored and the requests are responded to also when some of the data has an invalid STATUS.

IU **In Use**

The IU attribute indicates whether the station is in use or not. If the station has been taken out of use, no responses are sent to the serial line or to the TCP connections. Taking the station in use and out of use does not affect the validity of the data. Data updates using attributes ID, DD, AV and PC are accepted even if the station objects are out of use. If more than one STA object has been configured to the same modbus slave instance, it is recommended to have the same IU value for all of them.
When the IU is set to 0, and if the se_applevent_used configuration is 4 in the config.ini file, the station status code is set to 13489 "SPIP_STATION_STOPPED".

Data type:	Integer
Value:	0 = not in use 1 = in use
Default value:	1
Access:	No limitations

DI **Database Initialized**

The CPI application program sets DI to 0 at the start-up. When SYS600 has updated all the values in the CPI database, it sets this attribute to 1.The CPI application program does not process any requests from the Modbus master before DI equals 1. In case DTR bit controlling is enabled (see control flag 'dtr_control' in Section 4.2.3), the DTR signal of the serial port set to non-signaled state when DI = 1 and to signaled state when DI = 0. This signal can be wired to control the fallback switches if needed.

Data type:	Integer
Value:	0 or 1
Access:	No limitations

OS **Object Status**

The current status of the Modbus slave station. If the SE attribute is configured as 4, the stations statuses are also updated to the SSS process objects and have different status codes than when the SE is configured to value 1.

Data type:	Integer
Value:	
If SE is 1:	13484 = Not connected to the master / connection to master lost 13485 = Connected / Reconnected to master
If SE is 4:	0 = STATUS_OK 13484 = Not connected to the master / connection to master lost 13489 = Connection stopped (IU attribute is set to 0)
Access:	Read only

AI **Analog Initialization**

Writing to this attribute will initialize the analog and pulse counter values of the whole database. Writing to this attribute is allowed only when the attribute DI Database initialized is 0. When written successfully, the given VALUE and STATUS are applied to all AV and PC indices up to 65535 (Modbus addresses up to 65535).

Data type:	Vector	
Value:	A vector of three elements: (TIME, VALUE, STATUS)	
	TIME	Current time in RTU_ATIME format.
	VALUE	With configuration 'analog_format' value 5: Analog value (scaled to -32768…32767) With configuration 'analog_format' values 6 and 7: Analog value (scaled to -2147483648...2147483647)
	STATUS	Status code of the point. Value range: integer 0 … 3, valid = 0
Index range:	No index	
Access:	Write only (write allowed only when DI=0)	

II	Indication Initialization

Writing to this attribute initializes the single and double indication values of the whole database. Writing to this attribute is allowed only when the attribute DI Database initialized is 0. When written successfully, the given VALUE and STATUS are applied to all ID and DD indices up to 4096 (Modbus addresses up to 65535).

Data type:	Vector	
Value:	A vector of three elements: (TIME, VALUE, STATUS)	
	TIME	Current time in RTU_ATIME format.
	VALUE	0...1
	STATUS	Status code of the point. Value range: integer 0 … 3, valid = 0
Index range:	No index	
Access:	Write only (write allowed only when DI=0)	

PC	Pulse Counter

Pulse counter values that are to be sent to Modbus master are written to this attribute. The PC attribute is assigned a vector consisting of a time stamp, an end of period flag and a pulse counter value.
The pulse counter values are be stored as analog values in the CPI database. There should not be any address clash between the analog and pulse counter values.

Data type:	Vector
Value:	Vector (TIME, VALUE, STATUS) Parameters are as in the AV attribute.
Index	range: 1...65535
Access:	Write only

DD	Double Indication

Double indications are sent to the CPI database using this attribute.

Data type:	Vector
Value:	(TIME, BIT_NR, BIT_VAL, STATUS [,ERMI_ENABLED[,TIME_QUALITY]]) BIT_NR is 0, 2, 4, 6, 8, 10, 12 or 14 BIT_VAL is 0,1,2 or 3 Other parameters as in the ID attribute
Index:	1…4096
Access:	Write only

The ERMI_ENABLED and TIME_QUALITY attributes are not used at the moment in the Modbus slave.

5.2.6 Node attributes

EX	Exit

The Modbus slave instance exits itself when value 1 is written to this attribute. This may be needed when the main application goes to COLD state or there are some other reasons to stop the instance.

Data type:	Integer
Value:	1 = Exit
Access:	Write only

5.3 Command procedures

5.3.1 Command procedures in COM500*i*

Signals are sent from the process units to the Modbus master and commands are sent from the Modbus master to the process units. COM500*i* reroutes the signals using command procedures and cross-references (see Figure 5).

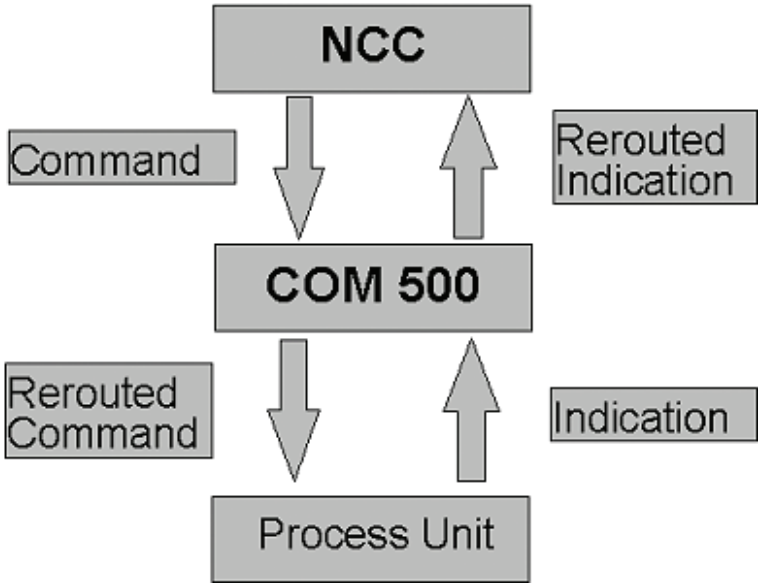

Figure 5: COM500i reroutes the signals

If Modbus slave protocol is used with COM500*i*, the command procedures available for COM500*i* are used. The cross-reference information is entered in the Signal Cross-Reference Tool. For more information, see SYS600 COM500*i* User's Guide. Table 1 shows the COM500*i* command procedures and event channels used.

Table 1: Used event channels and command procedures

Process Object Type	Event Channel	Command Procedure
Analog Input	COM_USAI	COM_USAI
Single Indication	COM_USDI	COM_USDI
Double Indication	COM_USDB	COM_USDB
Pulse Counter	COM_USPC	COM_USPC
Digital Commands	COM_DSBO	COM_DSBO
Analog Commands	COM_DSAO	COM_DSAO

5.3.2 Command procedures in SYS600

5.3.2.1 Command procedures for process data

If COM500*i* is not used, all read command procedures and event channels must be done by the user. The following chapter describes examples of command procedures.

The attribute interface of the Modbus slave CPI application program is similar to that of the RP 570 slave (SPI) station type in SYS600. Details of the device communication attributes used by the Modbus slave can be found in chapter Section 5.2.5

The connection between the SYS600 process objects and messages to and from the Modbus master is made by using cross-reference data. Cross-reference data can be written to the FX (Free teXt) and FI (Free Integer) attributes of the process objects by using the Process Object Definition Tool.

If COM500*i* is used, the upstream cross-references for indications are stored in Free-type process objects.

Cross-references for data transfer from SYS600 to the Modbus master are written in the FX attribute, which is a string of max 30 characters. The general syntax for a Modbus cross-reference is (an example of a syntax):

<STA_NUMBER.><BLOCK_NUMBER.>[<BIT_NUMBER.>]

STA_NUMBER:	Logical STA number (range 1...255). The value is stored as 3 ASCII digits with leading spaces added if necessary. FX string positions 1...3 are used for this value.
BLOCK_NUMBER:	The block number of the Modbus master (range 1...125). Stored as 3 ASCII digits with leading spaces added if necessary. FX string positions 4...6 are used for this value.
BIT_NUMBER:	Bit number (range 0…15) is the bit position in the indication data word. It is stored as ASCII digits with a leading space added if necessary. FX string positions 7...8 are used for this value. The bit number is defined only if the data point is to be sent to the Modbus master as an indication. If it is sent as an analog value, it is undefined (but reserved).

The FI attribute is used for storing the object index. Modbus commands activate digital and analog process input objects in SYS600. The "real" output process object has the same logical name as this input (i.e. it belongs to the same group), but a different index. This index is kept in the FI attribute of the input object.

Analog inputs
Analog values are sent to the Modbus master as integers in the range -32768… 32767. All analog signals must be scaled to this range (or part of it).

Analog values are sent to the Modbus master by using the AV attribute. The value set to the AV attribute is:

(TIME, VALUE, STATUS)

The block number of the analog input is set to the index of the AV attribute.

Time and status information is not supported in the Modbus protocol and therefore it is not sent to the master. Status information is stored in the CPI application program and the analog value is sent to the master, only if the status is OK.

All the analog values are connected to the same event channel/command procedure combination. The command procedure is activated each time the process object is updated. It reads the updated value, scales it and sends it to the CPI application program. An example of the command procedure is listed below:

```
;read cross-reference data
@STA_NR = DEC_SCAN(SUBSTR('LN':PFX('IX'),1,3))
@BLK_NR = DEC_SCAN(SUBSTR('LN':PFX('IX'),4,3))

@VAL = 'LN':POV('IX')
@T = RTU_ATIME(%RT,%RM)

;send value to CPI application
#SET STA'STA_NR':SAV(%BLK_NR) = (%T,ROUND(%VAL),0)
```

Single indications

All the binary inputs are connected to an event channel/command procedure combination. The command procedure is activated each time the process object is updated. It reads the updated value and sends it to the CPI application program.

Single indications are sent to the Modbus master by using the ID attribute. The value set to the ID attribute is:

(TIME, BIT_NUMBER, BIT_VALUE, STATUS)

The block number of the single indication is set to the index of the ID attribute.

An example of a command procedure handling single indications is listed below. Note that zero status is assumed.

```
;read cross-reference data
@STA_NR = DEC_SCAN(SUBSTR('LN':PFX('IX'),1,3))
@BLK_NR = DEC_SCAN(SUBSTR('LN':PFX('IX'),4,3))
@BIT_NR = DEC_SCAN(SUBSTR('LN':PFX('IX'),7,2))
@T = RTU_ATIME(%RT,%RM)

;send value to CPI application, assume ok status
#SET STA'STA_NR':SID(%BLK_NR)=(%T,%BIT_NR,%BI,0)
```

It is not possible to send time stamp and status information in Modbus messages. See attribute description for more information.

Double indications

Double indications are not supported directly in the Modbus protocol. Double indications are converted into two single indication messages by the CPI application program.

Double indications are sent to the Modbus master by using the DD attribute. The value set to the DD attribute is:

(TIME, BIT_NUMBER, BIT_VALUE, STATUS)

The block number of a single indication is set to the index of the DD attribute.

```
;read cross-reference data
@STA_NR = DEC_SCAN(SUBSTR('LN':PFX('IX'),1,3))
@BLK_NR = DEC_SCAN(SUBSTR('LN':PFX('IX'),4,3))
@BIT_NR = DEC_SCAN(SUBSTR('LN':PFX('IX'),7,2))

;send value to CPI application
@T = RTU_ATIME(%RT,%RM)
#SET STA'STA_NR':SDD(%BLK_NR) = (%T,%BIT_NR,%DB,0)
```

It is not possible to send time stamp and status information in Modbus messages. See attribute description for more information.

Pulse counters

The pulse counter values are treated as analog values by the Modbus slave. The pulse counter values are sent to the Modbus master using the PC attribute. The value set to the PC attribute is:

(TIME, VALUE, STATUS)

The block numbers of analog and pulse counter objects should be different since they are both treated as analog values.

```
;read cross-reference data
@STA_NR = DEC_SCAN(SUBSTR('LN':PFX('IX'),1,3))
@BLK_NR = DEC_SCAN(SUBSTR('LN':PFX('IX'),4,3))

;send value to CPI application
@T = RTU_ATIME(%RT,%RM)
#SET STA'STA_NR':SPC(%BLK_NR) = (%T,%PC,0)
```

5.3.2.2 Command procedures for commands

No configuration actions described in this chapter are needed if COM500*i* is used.

Since the SYS600 application sees the CPI program as an RTU type station, data that is transferred from the master to the slave must be handled as input data. When this kind of input is updated, the value is read by a command procedure and, if necessary, converted before it is written to the actual output object. The command procedure is activated through an event channel bound to the input object.

It is also possible to utilize input data to perform arbitrary internal operations in the application program.

The procedures that are presented below cover the basic cases, when SINCDAC commands and setpoints are mapped directly to the corresponding output objects. If a more complex relationship between the input and output objects is needed, application specific command procedures need to be built.

Process commands
Process commands from the Modbus master are handled as digital inputs with object addresses (OA attribute) in the range 0…2000 (object commands). When the CPI application program receives a process command message, it reads the object number (register address) from the message. It also activates a SYS600 process object with the corresponding object address and sets its value according to the command (1 = ON, 0 = OFF).

The command is transferred to a binary output process object with a command procedure. The cross-reference between the input and output objects is accomplished by using the same logical name, but different indexes for the input and output objects. Input objects hold the index of the corresponding output object in their FI attribute. This makes it possible to use a common command procedure for most process commands. Only the commands that require validity checking or other special processing need individual SCIL procedures.

Below is a command procedure that is used when no special processing is needed.

```
;read cross-reference data
@OBJ_IX = 'LN':PFI(%IX)

;set value to output object
#SET 'LN':PBO(%OBJ_IX) = %DI
```

Analog setpoints
Analog commands from the Modbus master can be received by analog input process objects. The object address range starts from 3000 (decimal). The block number (register address) is added to get the address that is used for a particular setpoint.

Analog setpoints are received as integers in the range -32768… 32767 and may have to be scaled.

An example of a command procedure for handling analog setpoints:

```
;read cross-reference data
@OBJ_IX = 'LN':PFI(%IX)
```

```
;scale value
@VAL = %AI-'SC':XSC(1)
@VAL = %VAL / ('SC':XSC(2)-'SC':XSC(1))
@VAL = %VAL * ('SC':XSC(4)-'SC':XSC(3))
@VAL = %VAL + 'SC':XSC(3)

;set value to output object
 #SET 'LN':PAO(%OBJ_IX) = %VAL
```

5.4 Function codes

The used CPI application program is for Modbus slave protocol in SYS600. The Modicon Modbus protocol has many function codes. There are different types of Modicon controllers available which supports different types of functions. There are 24 functions supported in Modbus protocol. All the controllers do not necessarily support all the functions. The Modbus function codes implemented in the Modbus CPI application program are 1, 2, 3, 4, 5, 6, 8, 11, 15 and 16. These function codes can access the CPI database, which reflects the data in the SYS600 process database. An exception response is sent to all other Modbus function codes. For details of exception responses, see Modbus Modicon Protocol Reference Guide.

Function code 8 is only accessible from serial line connection. If a master connected with TCP/IP sends a request using function code 8, an exception response is sent back.

According to the Modbus protocol, all the data is stored in registers or coils. Each register consists of 2 bytes and each coil consists of one ON/OFF bit.

In the Modbus slave CPI application with serial line communication, every message from master to slave or vice versa, has CRC (Cyclic Redundancy Check) error check bytes in the end of the message. In the Modbus TCP communication, no CRC bytes are added to the responses or to the requests. Sending a message without CRC with serial line communication causes an exception.

There are four different addressable memory areas in the Modbus protocol as shown in Table 2.

Table 2: Modbus memory areas

Address	Description
00001...09999	Discrete Outputs
10001...19999	Discrete Inputs
30001...39999	Input Registers
40001...49999	Holding Registers

These memory areas can be accessed by using different function codes as shown in Table 3.

Table 3: Function codes and the corresponding memory areas

Function Code	Description	Memory area
01	Read coil status	00001...09999
02	Read input status	10001...19999
03	Read holding register	40001...49999
04	Read input registers	30001...39999
05	Force single coil	00001...09999
Table continues on next page		

Function Code	Description	Memory area
06	Write single register	40001...49999
15	Force multiple coils	00001...09999
16	Write multiple registers	40001...49999

In the Modbus CPI application program there is no difference in the handling of function codes 1 and 2, as well as function codes 3 and 4. Function codes 1 and 2 access the same data. This is also the case with function codes 3 and 4.

Table 4 lists the Modbus function codes and the used process object types.

Table 4: Function codes and the corresponding process object types

Function Code	Description	Process Object Type
01	Read coil status	Indication (single & double)
02	Read input status	Indication (single & double)
03	Read holding register	Analog Input
04	Read input registers	Analog Input
05	Force single coil	Digital input
06	Write single register	Analog Input
15	Force multiple coils	Digital Input
16	Write multiple registers	Analog Input

Table 5 shows the subfunction codes of function code 8. This function does not affect the CPI database, which also means that the process database is not affected. Some subfunction codes update the diagnostic counters in the CPI database. Requests to the function code 8 can only be done from serial line connection.

Table 5: Subfunction codes of function code 8

Subfunction Code	Description
00	Return query data
01	Restart communications option
04	Force listen only mode
10	Clear counters and diagnostic register
11	Return bus message count
12	Return bus communication error count
13	Return bus exception count
15	Return slave no response count

The broadcast mode is not supported by any of the function codes.

5.4.1 Function codes for process data

5.4.1.1 Function code 01 - Read coil status

This function reads the value (ON/OFF) of coils from the specified address. The function can access single and double indication process objects via the CPI database. Modbus protocol does not allow direct transmission of a double indication. A double indication is transmitted

as two single indications to the Modbus master. This has to be taken care of at the master's side. The least significant bit of a double indication is transmitted first and the most significant bit last.

The query message contains the following information:

- Slave address
- Function code
- Start coil address high
- Start coil address low
- Number of coils high
- Number of coils low
- CRC - error check (Serial port communication only)

Slave address is the logical station address from which the data is requested. The coil address depends on the process object address.

The coil address for a process object is calculated in the following way:

Coil address = 16 * (block number-1) + bit no + 1

The block number for a coil address is calculated in the following way:

Block number = (Coil address - 1 - bit no) / 16 + 1

Examples:

Coil address for a process object with block number 2 and bit number 0:

Coil address = 16 * (block 2 number -1) + bit no 0 + 1 = 17

For a double indication with block number 3 and bit number 2:

Coil address1 = 16 * (3-1) + 2 +1 = 35

Coil address2 = 16 * (3-1) + (2 +1) + 1 = 36

The address range is 1…65535. If some or all of the requested data is outside this address range, an exception response is sent indicating an illegal address value.

The response message contains the following information:

- Slave address
- Function code
- Number of bytes
- Data high
- Data low
- CRC - error check (Serial port communication only)

The number of coil values that can be read at a time depends on the master. The slave has no limitations in this regard.

5.4.1.2 Function code 02 - Read input status

This function is equivalent to function 01 described above.

5.4.1.3 Function code 03 - Read holding registers

This function reads analog values from the holding registers. The function can access analog input process objects from the process database. Different types of formats are available for reading the data as shown in Table 6

Table 6: Formats of analog data

Format Type	Code	Description
WORD	5	Integer value, two bytes long (unsigned for the SYS600 Modbus master and signed for any other Modbus master).
WORD	6	Signed 32 bit value, four bytes long in msb-lsb order*
MSB_LONG	7	Signed 32 bit value, four bytes long in lsb-msb order*

* The most significant byte - the least significant byte order (and vice versa).

The format of analog data is defined in Modbus slave with the format_analog parameter in the config.ini. This parameter affects all analog values.

The format configured in the configuration is used. If format 5 is used, each piece of data is two bytes long. The format has to be chosen based on the master. All the above formats are implemented in the SYS600 master.

If format 6 or 7 is used, it must be remembered that a single value takes two blocks from the address base.

The query message contains the following information:

- Slave address
- Function code
- Start register address high
- Start register address low
- Number of registers high
- Number of registers low
- CRC - error check (Serial port communication only)

Slave address is the logical station address from which the data is requested. The start register address is the same as the block number of the first process object. For example, if the block number of a process object is 10, the register address is also 10.

The address range is 1…65535. Any request for data outside this range results in an exception response.

The number of registers that can be requested in one message is limited to 125. If more than 125 registers are requested, an exception response is returned.

5.4.1.4 Function code 04 - Read input registers

This function code is equivalent to function code 03 described above.

5.4.2 Function codes for commands

5.4.2.1 Function code 05 - Forcing a coil

This function forces the value of a coil to be either 0 or 1. This function sends an object command in case SYS600 is the Modbus master. When this message is received from the master, the slave treats it as a digital value and forces this process object to 1 or 0. The

command procedure in the SYS600 Modbus slave forwards these commands to the process side. For more information about this subject, see the Process commands in Section 5.3.2.2.

The query message contains the following information:

- Slave address
- Function code
- Coil address high
- Coil address low
- Forcing value high (00 or FF hexadecimal)
- Forcing Value low (00 hexadecimal)
- CRC - error check (Serial port communication only)

The slave address is the logical address of the station to which the command is sent. The coil address is the object number of the process object. For example, if the block number of an object command is 100, the coil address is also 100. The normal response message to this query is an echo of the query itself.

5.4.2.2 Function code 06 - Modify register content

This function code sets a single register to a particular value specified in the query message. In the case of the SYS600 Modbus master, this is an analog set point. The command procedures forward these commands to the process side. For more information about this subject, see Analog setpoints in Section 5.2.4.

On the slave's side this command modifies the corresponding analog input process object with the object address 3000 analog offset + register address.

The query message contains the following information:

- Slave address
- Function code
- Register address high
- Register address low
- Data high
- Data low
- CRC - error check (Serial port communication only)

The slave address is the logical address of a station to which this command is sent. The register address is same as the object address of the process object. For example, if the object number is 200, the register address is also 200. The valid address range is 1…1095. Any register address outside this range results in exception response.

Only two-byte signed integer values can be sent to the slave. If floating point values are sent, the decimal portion is truncated.

5.4.2.3 Function code 08 - Diagnostics (Serial line only)

This function serves to check the communication between the slave and the master. The following sections describe the subfunction codes of the function code 8.

Subfunction code 00 - Return query data
The data passed in the query data field is to be returned in the response. This is just for checking the line between the slave and the master.

Both the query and response messages contain the following information:

- Slave address
- Function code
- Subfunction code high
- Subfunction code low
- Data field high
- Data field low
- CRC - error check

Subfunction code 01 - Restart communication option
This function sets the Listen Only Mode off and restarts the communication by closing the specific TCP connection which received this command. If a serial port connection receives this command, the connection is not closed. If the slave is in the Listen Only Mode, no response is sent to the master but the slave is forced out of the Listen Only Mode. If the Listen Only Mode is not used, a normal response is sent. The query structure is the same as above.

This message sent to any of the slaves in SYS600 forces all the stations connected to it out of the Listen Only Mode. However, restart is considered as a connection specific message.

Subfunction code 04 - Force Listen Only Mode
Forces the slave into the Listen Only mMode. In the Listen Only Mode, the slave receives messages normally, but none of the messages are handled, except for the function code 8 subfunction code 1 message, which turns the Listen Only Mode off. The Listen Only Mode is used for monitoring communication.

No response is sent to this message.

Subfunction code 10 - Clear counters and diagnostic register
The diagnostic register is not relevant to SYS600. This function clears all the counters. Counters are also cleared on power up. There is only one set of diagnostic counters for the SYS600 Modbus slave. There are no separate counters for individual stations connected to SYS600. This applies wherever counters are mentioned. The query and response are the same as above.

Subfunction code 11 - Return bus message count
The response data field contains the quantity of messages that the slave has detected on the communication system since power up as follows:

- Slave address
- Function code
- Subfunction code high
- Subfunction code low
- Data field high
- Data field low
- CRC - error check

Subfunction code 12 - Return bus communication error count
The response data field returns the number of CRC errors encountered by the slave since its last restart or power up.

The query and return messages contain the following information:

- Slave number
- Function code
- Subfunction code high
- Subfunction code low
- Data field high
- Data field low
- CRC - error check

Subfunction code 13 - Return bus communication error count
The response data field returns the quantity of Modbus exception responses. The query and return fields are the same as in code 12.

Subfunction code 14 - Return slave message count
The response data field returns the quantity of messages addressed to the slave which the slave has processed since start-up. The query and response fields are the same as in code 12.

Subfunction code 15 - Return slave no response count
The response data field returns the quantity of messages addressed to the slave to which no response has been returned. The query and response fields are the same as in code 12.

For subfunction codes 03, 16, 17, 18, 19 and 20 the data fields of the request are returned in the response, because these function codes are either hardware dependent or not relevant.

The subfunction code 21 is not supported.

5.4.2.4 Function code 11 - Fetch communication event counter

This function code returns a status word and an event count (2 bytes each). The event count is incremented for each successful message completion. This counter is not incremented for exception responses or fetch event counter commands. The events counter can be reset with function code 8.

The status word is FFFF (hexadecimal), if the slave is busy. Otherwise the status word is zero.

The query message contains the following information:

- Slave address
- Function code
- CRC-error check (Serial port communication only)

The response message contains the following information:

- Slave address
- Function code
- Status high
- Status low
- Event count high
- Event count low
- CRC - error check (Serial port communication only)

There is no individual counter for each station connected to SYS600, but there is only one common event counter for all the stations.

5.4.2.5 Function code 15 - Force multiple coils

This function code sets a number of commands in one Modbus message. The slave treats these commands as digital inputs and also stores them as such. This function code is equivalent to function code 5 described earlier.

The maximum number of commands that can be sent in one message is limited to 38. If the master tries to send more than 38 commands in one message, an exception response with an error code is sent to the master. The valid address range is 1…2048. Any value outside this range results in an exception response.

5.4.2.6 Function code 16 - Modify multiple registers

This function code is equivalent to function code 6 with only one difference: it handles multiple commands. On the slave's side, the commands are treated as analog input values with an object number 3000 + register address.

The maximum number of commands that can be sent in one message is 28. If more than 28 commands are sent in one message, an exception response is sent to the master. The valid address range is 1…1095. Any value outside this range results in an exception response.

5.5 Status codes

The following status codes are defined:

- 13450 SPIC_INVALID_INDEX_RANGE
  The error reply status to an invalid index value.
- 13451 SPIC_UNKNOWN_SPI_ATTRIBUTE_VALUE
  The error reply status to an invalid attribute value.
- 13455 SPIC_UNKNOWN_SPI_ATTRIBUTE
  The error reply status to an unknown attribute.
- 13459 SPIC_FCOM_COLDSTART_RECEIVED
  The status reply when the restart communication request is received. The request is function code 8 and sub-function code 1, as defined in the Modbus protocol specification.
- 13469 SPIC_ARGUMENT_EXPECTED
  The error reply status to too few arguments in an attribute command.
- 13470 SPIC_TOO_MANY_ARGUMENTS
  The error reply status to too many arguments in an attribute command.
- 13484 SPIP_COMMUNICATION_WITH_CS_LOST
  The status reply when communication to every Modbus master has been lost. Also at restart this status reply implements that a master connection is not yet received.
- 13485 SPIP_COMMUNICATION_WITH_CS_ESTABLISHED
  The status reply when a connection to a Modbus master has been made.
- 13499 SPIP_INITIATE_DATABASE_REINITIALIZATION
  The status reply when TCP/IP connection to the SYS600 base system has been reconnected after it was lost.
- 14016 NETW_UNKNOWN_DESTINATION_DEVICE
  The status reply when MicroSCADA is trying to access an unknown device.

When used with COM500*i*, only the following error codes are available:

- 13459 SPIC_FCOM_COLDSTART_RECEIVED
  The status reply when the restart communication request is received. The request is function code 8 and sub-function code 1, as defined in the Modbus protocol specification.
- 13484 SPIP_COMMUNICATION_WITH_CS_LOST
  The status reply when communication to every Modbus master has been lost. Also at restart this status reply implements that no master connection is yet received.
- 13485 SPIP_COMMUNICATION_WITH_CS_ESTABLISHED
  This is the status reply when the station is running and a connection to a Modbus master has been made.
- 13499 SPIP_INITIATE_DATABASE_REINITIALIZATION
  The status reply when TCP/IP connection to the SYS600 base system has been reconnected after it was lost.

When se_applevent_used config.ini configuration is set to 4, the following status codes are also used:

- 0 STATION_OK
  The status reply when the station is running and connected to the master.
- 13489 SPIP_STATION_STOPPED

The status reply when the station set to the Not In Use state.

5.6 Interoperability list

Functions and parameters:

☒ **Supported** by SYS600 Modbus Slave

☐ **Not supported** by SYS600 Modbus Slave

5.6.1 Network Configurations

- ☒ Point-to-point
- ☒ Multipoint star
- ☒ Multiple point-to-point

5.6.2 Physical Layer

Electrical Interface

- ☒ RS-232
- ☒ RS-485
- ☒ Ethernet

5.6.3 Link Layer

Protocol Mode

- ☐ ASCII
- ☒ RTU

Message Length

255 Maximum length L (number of characters)

5.6.4 Transmission Speed (only serial)

- ☒ 300 bit/s
- ☒ 600 bit/s
- ☒ 1200 bit/s
- ☒ 2400 bit/s
- ☒ 4800 bit/s
- ☒ 9600 bit/s
- ☒ 19200 bit/s
- ☒ 38400 bit/s
- ☒ 57600 bit/s

5.6.5 Transmission Settings (only serial)

Parity Check

- [x] No parity check
- [x] Even parity check
- [x] Odd parity check
- [x] Mark parity check
- [x] Space parity check

Stop Bits

- [x] 1 stop bit
- [x] 1,5 stop bits
- [x] 2 stop bits

5.6.6 Application Layer

Function Codes

- [x] <1> Read Coil Status
- [x] <2> Read Input Status
- [x] <3> Read Holding Register
- [x] <4> Read Input Registers
- [x] <5> Force Single Coil
- [x] <6> Write Single Register
- [ ] <7> Read Exception Status
- [x] <8> Diagnostics (Serial line only)
- [x] <11> Get Communication Event Counter
- [ ] <12> Get Communication Event Log
- [x] <15> Force Multiple Coils
- [x] <16> Write Multiple Registers
- [ ] <17> Report Slave ID
- [ ] <20> Read File Record
- [ ] <21> Write File Record
- [ ] <22> Mask Write Register
- [ ] <23> Read/Write Multiple Registers
- [ ] <24> Read FIFO Queue

Index

R

S

T

V

W

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