Modbus RTU

PLC300

User's Manual

Modbus RTU User's Manual

Series: PLC300

Language: English

Document Number: 10002233450 / 00

Publication Date: 04/2013

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ABOUT THIS MANUAL

This manual supplies the necessary information for the operation of the PLC300 programable controller using the Modbus RTU protocol. This manual must be used together with the PLC300 user manual.

ABBREVIATIONS AND DEFINITIONS

ASCII	American Standard Code for Information Interchange
CRC	Cycling Redundancy Check
EIA	Electronic Industries Alliance
TIA	Telecommunications Industry Association
RTU	Remote Terminal Unit

NUMERICAL REPRESENTATION

Decimal numbers are represented by means of digits without suffix. Hexadecimal numbers are represented with the letter ‘h’ after the number. Binary numbers are represented with the letter ‘b’ after the number.

DOCUMENTS

The Modbus RTU protocol was developed based on the following specifications and documents:

Document	Version	Source
MODBUS Application Protocol Specification, December 28th 2006.	V1.1b	MODBUS.ORG
MODBUS Protocol Reference Guide, June 1996.	Rev. J	MODICON
MODBUS over Serial Line, December 20th 2006.	V1.02	MODBUS.ORG

In order to obtain this documentation, consult MODBUS.ORG, which is nowadays the organization that keeps, publishes and updates the information related to the Modbus protocol.

1 INTRODUCTION TO SERIAL COMMUNICATION

In a serial interface the data bits are sent sequentially through a communication channel or bus. Several technologies use the serial communication for data transfer, including the RS232 and RS485 interfaces.

The directions that specify the RS232 and RS485 standards, however, do neither specify the character format, nor its sequence for the data transmission and reception. Therefore, besides the interface, it is also necessary to identify the protocol used for the communication. Among the several existent protocols, one used a lot in the industry is the Modbus RTU protocol.

In the sequence the characteristics of the RS232 and RS485 serial interfaces available for the product will be presented, as well as the Modbus RTU protocol for the use of those interfaces.

2 NETWORK CONNECTIONS

The PLC300 programable controller has standard RS232 and RS485 interfaces. Information about the connection and installation of the equipment to the network is presented bellow.

2.1 RS232

2.1.1 RS232 Interface Characteristics

- The interface follows the EIA/TIA-232 standard.
- It operates only as a slave in the Modbus RTU network, configured for network address 1.
- It allows communication baud rates from 1200 up to 57600 Kbit/s.
- It allows the connection between the device and the network master (point-to-point).
- Maximum distance between devices: 10 meters.

2.1.2 Connector pinout

The RS232 interface is available at the XC3 connector with the following connections:

Table 2.1: *RS232 connector pinout*

Pin	Name	Function
9	TX	Data transmission (connected to the master RX)
10	RX	Data reception (connected to the master TX)
11	GND	Reference for RS232 circuit

2.1.3 Connection with the RS232 Network

- The slave RX and TX signals must be connected to the master TX and RX, besides the connection of the reference signal (GND).
- The RS232 interface is very susceptible to interferences. For this reason, the cable used for communication must be as short as possible – always shorter than 10 meters – and must be laid separately from the power cables that supply other devices.

2.2 RS485

2.2.1 RS485 Interface Characteristics

- The interface follows the EIA/TIA-485 standard.
- It operates as a slave or master in the Modbus RTU network.
- It allows communication baud rates from 1200 up to 57600 Kbit/s.
- The interface is electrically isolated and with differential signal, which grants more robustness against electromagnetic interference.
- It allows the connection of up to 32 devices to the same segment. More devices can be connected by using repeaters[1].
- A maximum bus length of 1000 meters.

2.2.2 Connector pinout

The RS485 interface is available at the XC3 connector with the following connections:

Table 2.2: *RS485 connector pinout*

Pin	Name	Function
12	A-Line (-)	RxD/TxD negative
13	B-Line (+)	RxD/TxD positive
14	GND	0V isolated from the RS485 circuit

[1] The limit number of devices that can be connected to the network depends also on the used protocol.

2.2.3 Indications

Besides the system markers, which provide different kinds of information about the RS485 interface, the PLC300 programable controller has as bicolor LED – green and red – in the front part of the product used for Serial Interface indication.

Figure 2.1: *Indication LED of the Serial interface*

During the initialization of the equipment, both LEDs are On for test for a period of approximately 500 ms alternately. After this period, for the RS485 interface, they will make the following indications.

- Green LED: turns on whenever a telegram is transmitted by the RS485 interface.
- Red LED: turns on whenever a byte is incorrectly received (parity or frame error) or CRC error is detected in the telegram received by the RS485 interface.

2.2.4 Switches to Enable to Terminating resistor

It is necessary to enable a terminating resistor at both ends of the main bus for each segment of the RS485 network. There are switches (S1) in the PLC300 programable controller that can be activated (by placing both switches to ON) to enable the terminating resistor.

2.2.5 Connection with the RS485 Network

The following points must be observed for the connection of the device using the RS485 interface:

- It is recommended the use of a shielded cable with a twisted pair of wires.
- It is also recommended that the cable has one more wire for the connection of the reference signal (GND). In case the cable does not have the additional wire, then the GND signal must be left disconnected.
- The cable must be laid separately (and far away if possible) from the power cables.
- All the network devices must be properly grounded, preferably at the same ground connection. The cable shield must also be grounded.
- Enable the termination resistors only at two points, at the extremes of the main bus, even if there are derivations from the bus.

3 INTERFACE CONFIGURATION

In order to configure the RS232 and RS485 interfaces, the following menus are provided by the Setup of the PLC300 programmable controller:

3.1 RS232 CONFIGURATION

BAUD RATE

Range:	0 = 1200 bit/s 1 = 2400 bit/s 2 = 4800 bit/s 3 = 9600 bit/s 4 = 19200 bit/s 5 = 38400 bit/s 6 = 57600 bit/s	**Default:** 4

Description:
It allows programming the baud rate for the serial communication interface, in bits per second. This baud rate must be the same for all the devices connected to the network.

PARITY

Range:	0 = no parity 1 = odd parity 2 = even parity	**Default:** 2

Description:
It allows programming the parity of the serial interface bytes. This configuration must be identical for all the devices connected to the network.

STOP BITS

Range:	0 = 1 stop bit 1 = 2 stop bits	**Default:** 0

Description:
It allows programming the stop bits of the serial interface bytes. This configuration must be identical for all the devices connected to the network.

NOTE!
The address of the Modbus RTU slave via RS232 interface is fixed in 1.

3.2 RS485 CONFIGURATION

BAUD RATE

Range:	0 = 1200 bit/s 1 = 2400 bit/s 2 = 4800 bit/s 3 = 9600 bit/s 4 = 19200 bit/s 5 = 38400 bit/s 6 = 57600 bit/s	**Default:** 4

Description:
It allows programming the baud rate for the serial communication interface, in bits per second. This baud rate must be the same for all the devices connected to the network.

PARITY

Range:	0 = no parity 1 = odd parity 2 = even parity	**Default:** 2

Description:
It allows programming the parity of the serial interface bytes. This configuration must be identical for all the devices connected to the network.

STOP BITS

Range:	0 = 1 stop bit 1 = 2 stop bits	**Default:** 0

Description:
It allows programming the stop bits of the serial interface bytes. This configuration must be identical for all the devices connected to the network.

OPERATION MODE

Range:	0 = slave 1 = master	**Default:** 1

Description:
Via RS485 interface, the PLC300 features two operating modes in the Modbus RTU network:

- *Slave:* as slave of the network, it provides functions for the reading and writing of the data and markers used in the configuration and programming in ladder of the product. For further information about this operating mode, refer to item 5.
- *Master:* as network master, the PLC300 provides blocks in ladder to send commands to the network slaves, according to the configuration in these blocks. In this mode, it will not be possible to access the data and configurations of the PLC300 via RS485 interface. Only one master can be configured to operate on the RS485 bus. For further information about this operating mode, refer to item 7 and the documentation of the WPS programming software.

SLAVE ADDRESS

Range: 1 to 247 **Default:** 1

Description:
It allows programming the slave address used for the PLC300 in the Modbus RTU network via RS485 interface. This address is only used if the interface is programmed in the slave mode; it has no function if the PLC300 is programmed as network master.

4 MODBUS RTU PROTOCOL

The Modbus RTU protocol was initially developed in 1979. Nowadays, it is a widely spread open protocol, used by several manufactures in many equipments.

4.1 TRANSMISSION MODES

Two transmission modes are defined in the protocol specification: ASCII and RTU. The modes define the way the message bytes are transmitted. It is not possible to use the two transmission modes in the same network.

The PLC300 programable controller uses only the RTU mode for the telegram transmission. The bytes are transmitted in hexadecimal format and its configuration depends on the programming done by means of setup menu.

4.2 MESSAGE STRUCTURE FOR RTU MODE

The Modbus RTU structure uses a master-slave system for message exchange. It allows up to 247 slaves, but only one master. Every communication begins with the master making a request to a slave, which answers to the master what has been asked. In both telegrams (request and answer), the used structure is the same: Address, Function Code, Data and CRC. Only the data field can have a variable size, depending on what is being requested.

Master (request telegram):

Address (1 byte)	Function (1 byte)	Request Data (n bytes)	CRC (2 bytes)

Slave (response telegram):

Address (1 byte)	Function (1 byte)	Response Data (n bytes)	CRC (2 bytes)

4.2.1 Address

The master initiates the communication sending a byte with the address of the slave to which the message is destined. When sending the answer, the slave also initiates the telegram with its own address. The master can also send a message to the address 0 (zero), which means that the message is destined to all the slaves in the network (broadcast). In that case, no slave will answer to the master.

4.2.2 Function Code

This field also contains a single byte, where the master specifies the kind of service or function requested to the slave (reading, writing, etc.). According to the protocol, each function is used to access a specific type of data.

For the available list of supported functions, refer to item 5.

4.2.3 Data Field

It is a variable size field. The format and contents of this field depend on the used function and the transmitted value. This field is described together with the function description (refer to item 5).

4.2.4 CRC

The last part of the telegram is the field for checking the transmission errors. The used method is the CRC-16 (Cycling Redundancy Check). This field is formed by two bytes; where first the least significant byte is transmitted (CRC-), and then the most significant (CRC+). The CRC calculation form is described in the protocol specification; however, information for its implementation is also supplied in the Appendix B.

4.2.5 Time Between Messages

In the RTU mode there is no specific character that indicates the beginning or the end of a telegram. The indication of when a new message begins or when it ends is done by the absence of data transmission in the network, for a minimum period of 3.5 times the transmission time of a data byte (11 bits). Thus, in case a

telegram has initiated after the elapsing of this minimum time, the network elements will assume that the first received character represents the beginning of a new telegram. And in the same manner, the network elements will assume that the telegram has reached its end when after receiving the telegram elements, this time has elapsed again.

If during the transmission of a telegram the time between the bytes is longer than this minimum time, the telegram will be considered invalid because the programable controller will discard the bytes already received and will mount a new telegram with the bytes that were being transmitted.

For communication rates higher than 19200 bits/s, the used times are the same as for that rate. The next table shows us the times for different communication transmission rates:

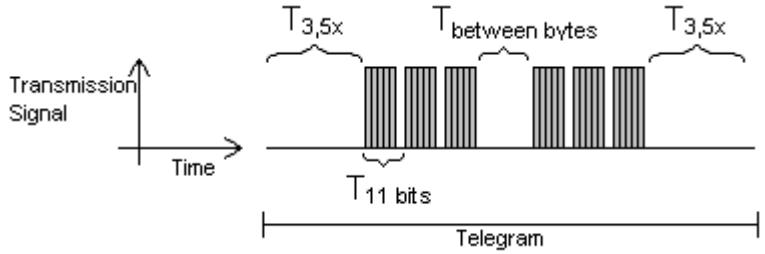


Table 4.1: *Communication rates and the time periods involved in the telegram transmission*

Baud rate	T11 bits	T3,5x
1200 bits/s	9.167 ms	32.083 ms
2400 bits/s	4.583 ms	16.042 ms
4800 bits/s	2.292 ms	8.021 ms
9600 bits/s	1.146 ms	4.010 ms
19200 bits/s	573 µs	2.005 ms
38400 bits/s	573 µs	2.005 ms
57600 bits/s	573 µs	2.005 ms

- $T_{11\ bits}$ = Time for transmitting one byte of the telegram.
- $T_{between\ bytes}$ = Time between bytes.
- $T_{3,5x}$ = Minimum interval to indicated beginning and end of a telegram (3.5 x T11bits).

5 OPERATION IN THE MODBUS RTU NETWORK – SLAVE MODE

The PLC300 programable controller has the following characteristics when operated as a slave in Modbus RTU network:

- Network connection via RS232 or RS485 serial interface.
- Address[2], communication rate and byte format defined by means of setup of the equipment.
- It allows accessing all the markers and data used in the ladder program of the PLC300.

NOTE!
The RS232, RS485, USB and Ethernet interfaces, for using the same functions to access the data and programming of the equipment, must not be used simultaneously to perform program download or on-line monitoring functions of the programmable controller PLC300, because conflicts may occur during the simultaneous access to the data.

5.1 AVAILABLE FUNCTIONS AND RESPONSE TIMES

In the Modbus specification are defined the functions used to access different types of data. In the PLC300, in order to access those data the following services (or functions) have been made available:

- Read Coils
  Description: reading of bit blocks of the coil type.
  Function code: 01.

- Read Discrete Inputs
  Description: reading of bit blocks of the discrete input type.
  Function code: 02.

- Read Holding Registers
  Description: reading of register blocks of the holding register type.
  Function code: 03.

- Read Input Registers
  Description: reading of register blocks of the input register type.
  Function code: 04.

- Write Single Coil
  Description: writing in a single bit of the coil type.
  Function code: 05.

- Write Single Register
  Description: writing in a single register of the holding type.
  Function code: 06.

- Write Multiple Coils
  Description: writing in bit blocks of the coil type.
  Function code: 15.

- Write Multiple Registers
  Description: writing in register blocks of the holding register type.
  Function code: 16.

- Read Device Identification
  Description: identification of the device model.
  Function code: 43.

The response time, from the end of transmission of the master until the response of the slave, varies from the minimum time between bytes in the Modbus RTU communication to the equipment scan cycle value.

[2] Programmable address only for the RS485 interface; for the RS232 interface, the address is fixed in 1.

5.2 MEMORY MAP

The PLC300 programable controller has different types of data accessible through the Modbus communication. These data are mapped at data addresses and access functions as described in the following items.

NOTE!
The WPS programming software has lists that allow the viewing of all types of markers available for the PLC300. In these lists, there is a field for indication of the address of the Modbus register to access the marker.

5.2.1 Reading System Marker – %SB / %SW / %SD

The reading system markers represent the data of the PLC300 used for indication of status and monitoring of the equipment functions.

- Access: read only.
- Data type: input register or input discrete.
- Modbus access functions: 02 and 04.
- Modbus address range for access via *input register*: 3000 ... 4999.
- Modbus address range for access via *input discrete*: 0 ... 15999.

The system markers related to the serial communication available for the PLC300 are described in item 8. For the description of other markers available and function of each marker, refer to the user's manual of the PLC300.

5.2.2 Command System Marker – %CB / %CW / %CD

The writing system markers represent the data of the PLC300 used to configure and control the equipment functions.

- Access: read/write.
- Data type: holding register or coil.
- Modbus access functions: 01, 03, 05, 06, 15 and 16.
- Modbus address range for access via holding register: 3000 ... 4999.
- Modbus address range for access via coil. 0 ... 15999.

The system markers related to the serial communication available for the PLC300 are described in item 8. For the description of other markers available and function of each marker, refer to the user's manual of the PLC300.

5.2.3 Inputs – %IB / %IW / %ID

Markers that represent the data related to the physical analog and digital inputs, available on the hardware of the PLC300.

- Access: read only.
- Data type: input register or input discrete.
- Modbus access functions: 02 and 04.
- Modbus address range for access via input register: 5000 ... 5999.
- Modbus address range for access via input discrete: 16000 ... 23999.

For the precise description of which markers are available and function of each marker, refer to the user's manual of the PLC300.

5.2.4 Outputs – %QB / %QW / %QD

Markers that represent the data related to the physical analog and digital outputs, available in hardware of the PLC300.

- Access: read/write.
- Data type: holding register or coil.

- Modbus access functions: 01, 03, 05, 06, 15 and 16.
- Modbus address range for access via holding register: 5000 ... 5999.
- Modbus address range for access via coil. 16000 ... 23999.

For the precise description of which markers are available and function of each marker, refer to the user's manual of the PLC300.

5.2.5 Network Inputs – %IB / %IW / %ID

Markers that represent data related to values received through the PLC300 network interfaces. They have the same terminology as the physical inputs, but their numbering begins from marker 2000 (example: %IB2000).

- Access: read only.
- Data type: input register or input discrete.
- Modbus access functions: 02 and 04.
- Modbus address range for access via input register: 6000 ... 7999.
- Modbus address range for access via input discrete: 24000 ... 39999.

5.2.6 Network Outputs – %QB / %QW / %QD

Markers that represent data related to values transmitted through the PLC300 network interfaces. They have the same nomenclature as the physical outputs, but their numbering begins from marker 2000 (example: %QB2000).

- Access: read/write.
- Data type: holding register or coil.
- Modbus access functions: 01, 03, 05, 06, 15 and 16.
- Modbus address range for access via holding register: 6000 ... 7999.
- Modbus address range for access via coil. 24000 ... 39999.

5.2.7 Internal Marker – %MB / %MW / %MD

General purposes markers for programming in ladder of the PLC300. They represent the global variables, dynamically created during the development of the program on the WPS software.

- Access: read/write.
- Data type: holding register or coil.
- Modbus access functions: 01, 03, 05, 06, 15 and 16.
- Volatile markers:
  - Modbus address range for access via holding register: 8000 ... 27999.
  - Modbus address range for access via coil. 40000 ... 49999.
- Retentive markers:
  - Modbus address range for access via holding register: 28000 ... 47999.
  - Modbus address range for access via coil. 50000 ... 59999.

The quantity of markers available in this area depends on the markers created on the PLC300 programming software. In order to be able to access the desired marker, first it is necessary to create this marker and download the user's program using the programming software.

NOTE!
The quantity of data accessible via coils and input discretes do not correspond to the entire memory area accessible via registers. For example, if it is created a quantity of markers on memory greater than the quantity accessible via coil (10000 bits = 1250 bytes), the additional markers can only be accessed via holding registers.

5.3 DATA ACCESS

Each of the memory regions described above is distributed in bytes. The Modbus protocol, though, allows the access to be performed only by bits of by registers of 16 bits. In order to access these memory regions, it is necessary to establish the relationship between the type and numbering of the data on the PLC300 with the

Modbus address type. The following tables show how the relationship between the numbering of the data on the PLC300 and the address of the Modbus registers that access these data is done.

Reading System Markers		
Marker Number PLC300		Register Address (input register) Modbus
%SB3001	%SB3000	3000
%SB3003	%SB3002	3001
⋮		⋮
%SB3101	%SB3100	3050
⋮		⋮

Command System Markers		
Marker Number PLC300		Register Address (holding register) Modbus
%CB3001	%CB3000	3000
%CB3003	%CB3002	3001
⋮		⋮
%CB3101	%CB3100	3050
⋮		⋮

Inputs		
Marker Number PLC300		Register Address (input register) Modbus
%IB1	%IB0	5000
%IB3	%IB2	5001
⋮		⋮
%IB2001	%IB2000	6000
⋮		⋮

Outputs		
Marker Number PLC300		Register Address (holding register) Modbus
%QB1	%QB0	5000
%QB3	%QB2	5001
⋮		⋮
%QB2001	%QB2000	6000
⋮		⋮

Internal markers (volatile and retentive)		
Marker Number PLC300		Register Address (holding register) Modbus
%MB1	%MB0	8000
%MB3	%MB2	8001
⋮		⋮
%MB40001	%MB40000	28000
⋮		⋮

The following table illustrates how the Modbus address is calculated with access via registers, for different types of data available for the PLC300:

Data	Description	Data type	Base address	Base address offset	Modbus address
%SW3002	Reading system marker which represents the scan cycle time.	Input Register	3000	2 bytes (1 word)	3001
%CW3030	Writing system marker to set the hour of the RTC.	Holding Register	3000	30 bytes (15 words)	3015
%IB0	Physical inputs, representing the digital inputs 1 to 8.	Input Register	5000	0 bytes (0 words)	5000 byte low
%MB11	Marker in volatile memory, representing a global variable created by the user with a size of one byte.	Holding Register	8000	11 bytes (5 words)	8005 byte high
%MD40004	Marker on retentive memory, representing a global variable created by the user with a size of four bytes.	Holding Register	28000	4 bytes (2 words)	28002 e 28003

Similarly, the access via binary data (coils or input discretes) also uses a base address plus the offset given by the number of the marker. However, since each byte has eight bits, for each byte from the base address, eight bits must be added to the address for access via binary data.

The data format and function in the memory area accessed, though, are not pre-defined, and depend on the programming done on the WPS software. For example, for the memory marker %M_0, it is possible to create the following variables on the WPS software:

- *%MB0:* byte marker, it takes only one memory byte, and it can represent an 8-bit integer with or without signal. In the access via registers, since the Modbus protocol allows the reading or writing access of at least 16 bits, whenever this marker is read or written, the bytes %MB0 and %MB1 are accessed.
- *%MW0:* word marker, it takes two memory bytes, and it can represent a 16-bit integer with or without signal. In this case, the bytes %MB0 and %MB1 are reserved for this marker.
- *%MD0:* double marker, it takes four memory bytes, and it can represent a 32-bit integer with or without signal. In this case, the bytes %MB0 and %MB3 are reserved for this marker. In the access by registers, it is necessary to read or write two registers in a row, with the least significant value in the first register, so that the four bytes will be accessed.

Table 5.1: *Example of data addressing for volatile markers on the PLC300*

Marker Type / Modbus addr. Register (bit)	Byte (%MB)	Word (%MW)	Double (%MD)
8000 (40000 ... 40015)	X	X	X
	X		
8001 (40016 ... 40031)	X	X	
	X		
8002 (40032 ... 40047)	X	X	X
	X		
8003 (40048 ... 40063)	X	X	
	X		

Similarly, it is possible to access the data using the bit access functions. In this case, a bit can be accessed individually, or in a group of bits that represents a marker. For example, if it is defined on the WPS software a word marker in address 8000 – %MW0 – it is possible to access this marker by using the functions of multiple coil reading or writing, using the bits 40000 to 40015.

At the memory addresses of the PLC300, variables with size above one byte are always stored with the least significant byte first. Thus, the available space on memory for Byte, Word or Double values follows the description of the following table.

Table 5.2: *Example of data addressing for volatiles markers on the PLC300*

Marker Type / Modbus addr. Register (bit)	Byte (%MB)		Word (%MW)		Double (%MD)	
8000 (40000 ... 40015)	%MB0	Unique value	%MW0	Value -signf. Value +signf.	%MD0	Value -signf. ... Value +signf.
	%MB1	Unique value				
8001 (40016 ... 40031)	%MB2	Unique value	%MW2	Value -signf. Value +signf.		
	%MB3	Unique value				
8002 (40032 ... 40047)	%MB4	Unique value	%MW4	Value -signf. Value +signf.	%MD4	Value -signf. ... Value +signf.
	%MB5	Unique value				
8003 (40048 ... 40063)	%MB6	Unique value	%MW6	Value -signf. Value +signf.		
	%MB7	Unique value				

Since the Modbus protocol defines that in order to transmit a 16-bit register, the most significant byte must be transmitted first, when accessing any register, the following memory address is transmitted first. Therefore, if four registers are read in a row, from the register 8000, the content of each register will be transmitted the following way:

1st Register – 8000		2nd Register – 8001		3rd Register – 8002		4th Register – 8003	
%MB1	%MB0	%MB3	%MB2	%MB5	%MB4	%MB7	%MB6

NOTE!
For the PLC300 programmable controller, the maximum size of each telegram, including address, function, data field and CRC, must not exceed 67 bytes.

6 DETAILED DESCRIPTION OF THE FUNCTIONS

A detailed description of the functions available in the PLC300 programable controller for the Modbus RTU is provided in this section. In order to elaborate the telegrams it is important to observe the following:

- The values are always transmitted in hexadecimal.
- The address of a datum, the number of data and the value of registers are always represented in 16 bits. Therefore, it is necessary to transmit those fields using two bytes – superior (high) and inferior (low).
- The telegrams for request, as well as for response, cannot exceed 64 bytes.

6.1 FUNCTION 01 – READ COILS

It reads the content of a group of bits (coils) that must be necessarily in a numerical sequence. This function has the following structure for the request and response telegrams (each field represents a byte):

Request (Master)	Response (Slave)
Slave Address	Slave Address
Function	Function
Address of the initial bit (high byte)	Byte count (number of data bytes)
Address of the initial bit (low byte)	Byte 1
Number of bits (high byte)	Byte 2
Number of bits (low byte)	Byte 3
CRC-	etc...
CRC+	CRC-
	CRC+

Each response bit is placed in a position of the data bytes sent by the slave. The first byte receives the eight first bits from the initial address indicated by the master. The other bytes keep the sequence if the number of reading bits is greater than eight. If the number of read bits is not a multiple of eight, the remaining bits of the last byte must be filled in with zero.

Example: reading of the eight bits of the output marker 2000, mapped as coil from address 24000, considering this marker with value 100 (64h).

- Address: 1 = 01h
- Number of the initial bit: 24000 = 5DC0h
- Number of read bits: 8 = 0008h

Request (Master)		Response (Slave)	
Field	*Value*	*Field*	*Value*
Slave Address	01h	Slave Address	01h
Function	01h	Function	01h
Initial bit (high)	5Dh	Byte count	01h
Initial bit (low)	C0h	Bit status 1 to 8	64h
Number of bits (high)	00h	CRC-	50h
Number of bits (low)	08h	CRC+	63h
CRC-	2Eh		
CRC+	5Ch		

6.2 FUNCTION 02 – READ INPUT DISCRETE

NOTE!
Function 02 – Read Input Discrete – has exactly the same structure as function 01. Only the function code and accessible data are different.

6.3 FUNCTION 03 – READ HOLDING REGISTER

It reads the content of a group of registers that must be necessarily in a numerical sequence. This function has the following structure for the request and response telegrams (each field represents a byte):

Request (Master)	Response (Slave)
Slave Address	Slave Address
Function	Function
Address of the initial register (high byte)	Byte count
Address of the initial register (low byte)	Datum 1 (high)
Number of registers (high byte)	Datum 1 (low)
Number of registers (low byte)	Datum 2 (high)
CRC-	Datum 2 (low)
CRC+	etc...
	CRC-
	CRC+

Example: reading of the memory marker %MD0, representing a float IEEE that takes four bytes of the memory. Considering the float value equal to 1.0 (3F800000h in representation of float IEEE).

- Address: 1 = 01h
- Initial register address: 8000 = 1F40h
- Number of read registers: 2 = 0002h

Request (Master)		Response (Slave)	
Field	*Value*	*Field*	*Value*
Slave Address	01h	Slave Address	01h
Function	03h	Function	03h
Initial register (high)	1Fh	Byte Count	04h
Initial register (low)	40h	Float value (low-high)	00h
Number of registers (high)	00h	Float value (low-low)	00h
Number of registers (low)	02h	Float value (high-high)	3Fh
CRC-	02h	Float value (high-low)	80h
CRC+	08h	CRC-	F7h
		CRC+	CFh

6.4 FUNCTION 04 – READ INPUT REGISTER

NOTE!
Function 04 – Read Input Register – has exactly the same structure as function 03. Only the function code and accessible data are different.

6.5 FUNCTION 05 – WRITE SINGLE COIL

This function is used to write a value for a single bit (coil). The value for the bit is represented using two bytes, the value FF00h represents the bit in 1, and the value 0000h represents the bit in 0 (zero). It has the following structure (each field represents a byte):

Request (Master)	Response (Slave)
Slave Address	Slave Address
Function	Function
Bit address (byte high)	Bit address (high byte)
Bit address (byte low)	Bit address (low byte)
Value for the bit (byte high)	Value for the bit (high byte)
Value for the bit (byte low)	Value for the bit (low byte)
CRC-	CRC-
CRC+	CRC+

Example: writing of the first bit of the output marker %QB0, mapped as coil from address 16000.

- Address: 1 = 01h
- Bit number: 16000 = 3E80h
- Bit value: 1, so the value that must be written is FF00h

Request (Master)		Response (Slave)	
Field	*Value*	*Field*	*Value*
Slave Address	01h	Slave Address	01h
Function	05h	Function	05h
Bit number (high)	3Eh	Bit number (high)	1Fh
Bit number (low)	80h	Bit number (low)	40h
Value for the bit (high)	FFh	Value for the bit (high)	FFh
Value for the bit (low)	00h	Value for the bit (low)	00h
CRC-	80h	CRC-	8Ah
CRC+	3Ah	CRC+	3Ah

Note that for this function the slave response is an identical copy of the request made by the master.

6.6 FUNCTION 06 – WRITE SINGLE REGISTER

This function is used to write a value for a single register. It has the following structure (each field represents a byte):

Request (Master)	Response (Slave)
Slave Address	Slave Address
Function	Function
Register address (high byte)	Register address (high byte)
Register address (low byte)	Register address (low byte)
Value for the register (high byte)	Value for the register (high byte)
Value for the register (low byte)	Value for the register (low byte)
CRC-	CRC-
CRC+	CRC+

Example: writing of the writing system marker %CB3000. Since the writing is always done by sending a 16-bit register, the bytes mapped at addresses %CB3000 and %CB3001 will be written.

- Address: 1 = 01h
- Initial register address: 3000 = 0BB8h
- Marker value: 50 = 0032h

Request (Master)		Response (Slave)	
Field	*Value*	*Field*	*Value*
Slave Address	01h	Slave Address	01h
Function	06h	Function	06h
Register (high)	0Bh	Register (high)	0Bh
Register (low)	B8h	Register (low)	B8h
Value (high – %CB3001)	00h	Value (high – %CB3001)	00h
Value (low – %CB3000)	32h	Value (low – %CB3000)	32h
CRC-	8Ah	CRC-	8Ah
CRC+	1Eh	CRC+	1Eh

Note that for this function the slave response is an identical copy of the request made by the master.

6.7 FUNCTION 15 – WRITE MULTIPLE COILS

This function allows writing values for a group of bits (coils), which must be in a numerical sequence. It can also be used to write in a single bit (each field represents a byte):

Request (Master)	Response (Slave)
Slave Address	Slave Address
Function	Function
Initial bit address (high byte)	Initial bit address (high byte)
Initial bit address (low byte)	Initial bit address (low byte)
Number of bits (high byte)	Number of bits (high byte)
Number of bits (low byte)	Number of bits (low byte)
Byte count (number of data bytes)	CRC-
Byte 1	CRC+
Byte 2	
Byte 3	
etc...	
CRC-	
CRC+	

The value of each bit being written is placed in a position of the data bytes sent by the master. The first byte receives the first eight bits from the initial address indicated by the master. The other bytes (if the number of written bits is greater than eight) continue the sequence. If the number of written bits is not multiple of eight, the remaining bits of the last byte must be filled in with zero.

Example: writing of 16 bits from output marker %QW0, mapped as coil from address 16000.
- Address: 1 = 01h
- Number of the first bit: 16000 = 3E80h
- Quantity of bits: 16 = 0010h
- Value for the bits 0 to 7: 10 = 0Ah
- Value for bits 8 to 15: 20 = 14h

Request (Master)		**Response (Slave)**	
Field	*Value*	*Field*	*Value*
Slave Address	01h	Slave Address	01h
Function	0Fh	Function	0Fh
Initial bit (high)	3Eh	Initial bit (high)	1Fh
Initial bit (low)	80h	Initial bit (low)	40h
Number of bits (high)	00h	Number of bits (high)	00h
Number of bits (low)	10h	Number of bits (low)	10h
Byte count	02h	CRC-	52h
Value for bits 0 to 7	0Ah	CRC+	07h
Value for bits 8 to 15	14h		
CRC-	24h		
CRC+	8Ch		

FUNCTION 16 – WRITE MULTIPLE REGISTERS

This function allows writing values for a group of registers, which must be in a numerical sequence. It can also be used to write in a single register (each field represents a byte):

Request (Master)	**Response (Slave)**
Slave Address	Slave Address
Function	Function
Initial register address (high byte)	Initial register address (high byte)
Initial register address (low byte)	Initial register address (low byte)
Number of registers (high byte)	Number of registers (high byte)
Number of registers (low byte)	Number of registers (low byte)
Byte count (number of data bytes)	CRC-
Datum 1 (high)	CRC+
Datum 1 (low)	
Datum 2 (high)	
Datum 2 (low)	
etc...	
CRC-	
CRC+	

Example: writing of the writing memory marker %MD0, representing a 32-bit integer value – 4 bytes of the memory. Considering the value to be written equal to 16909060 decimal (01020304h).
- Address: 1 = 01h
- Initial register address: 8000 = 1F40h
- Number of registers: 2 = 0002h

Request (Master)		Response (Slave)	
Field	*Value*	*Field*	*Value*
Slave Address	01h	Slave Address	01h
Function	10h	Function	10h
Initial register (high)	1Fh	Initial register (high)	1Fh
Initial register (low)	40h	Initial register (low)	40h
Number of registers (high)	00h	Number of registers (high)	00h
Number of registers (low)	02h	Number of registers (low)	02h
Byte Count	04h	CRC-	47h
Value for the integer (low-high)	03h	CRC+	C8h
Value for the integer (low-low)	04h		
Value for the integer (high-high)	01h		
Value for the integer (high-low)	02h		
CRC-	BAh		
CRC+	7Bh		

6.8 FUNCTION 43 – READ DEVICE IDENTIFICATION

It is an auxiliary function that allows the reading of the product manufacturer, model and firmware version. It has the following structure:

Request (Master)	Response (Slave)
Slave Address	Slave Address
Function	Function
MEI Type	MEI Type
Reading code	Conformity Level
Object number	More Follows
CRC-	Next object
CRC+	Number of objects
	Code of the first object
	Size of the first object
	Value of the first object (n bytes)
	Code of the second object
	Size of the second object
	Value of the second object (n bytes)
	etc...
	CRC-
	CRC+

This function allows the reading of three information categories: Basic, Regular and Extended, and each category is formed by a group of objects. Each object is formed by a sequence of ASCII characters. For the PLC300 programable controller, only basic information formed by three objects is available:

- Objeto 00h – VendorName: represents the product manufacturer.
- Objeto 01h – ProductCode: formed by the product code (PLC300).
- Objeto 02h – MajorMinorRevision: it indicates the product firmware version, in the format 'VX.XX'.

The reading code indicates what information categories are read, and if the objects are accessed in sequence or individually. The PLC300 supports the codes 01 (basic information in sequence) and 04 (individual access to the objects). The other fields are specified by the protocol, and for the PLC300 they have fixed values.

Example: reading of basic information in sequence, starting from the object 02h, from a PLC300 at address 1:

Request (Master)		Response (Slave)	
Field	*Value*	*Field*	*Value*
Slave Address	01h	Slave Address	01h
Function	2Bh	Function	2Bh
MEI Type	0Eh	MEI Type	0Eh
Reading code	01h	Reading code	01h
Object number	02h	Conformity Level	81h
CRC-	70h	More Follows	00h
CRC+	77h	Next object	00h
		Number of objects	01h
		Object code	02h
		Object size	05h
		Object value	'V1.00'
		CRC-	3Ch
		CRC+	53h

In this example the value of the objects was not represented in hexadecimal, but using the corresponding ASCII characters instead. E.g.: for the object 02h, the value 'V1.00' was transmitted as being five ASCII characters, which in hexadecimal have the values 56h ('V'), 31h ('1'), 2Eh ('.'), 30h ('0') and 30h ('0').

6.9 COMMUNICATION ERRORS

Communication errors may occur in the transmission of telegrams, as well as in the contents of the transmitted telegrams. Depending on the type of error, the slave may or not send a response to the master.

When the master sends a message for an inverter configured in a specific network address, the product will not respond to the master if the following occurs:

- Parity bit error.
- CRC error.
- *Timeout* between the transmitted bytes (3.5 times the transmission time of a byte).

In those cases, the master must detect the occurrence of the error by means of the timeout while waiting for the slave response. In the event of a successful reception, during the treatment of the telegram, the slave may detect problems and send an error message, indicating the kind of problem found:

- Invalid function (Error code = 1): The requested function has not been implemented for the equipment.
- Invalid datum address (Error code = 2): the datum address does not exist.
- Invalid datum value (Error code = 3): It occurs in the following situations:
  - The value is out of the permitted range.
  - An attempt to write in a datum that cannot be changed (reading only register/bit).

NOTE!
It is important that it be possible to identify at the master what type of error occurred, in order to be able to diagnose problems during the communication.

In the event of any of those errors, the slave must send a message to the master indicating the type of error that occurred. The error messages sent by the slave have the following structure:

Request (Master)	Response (Slave)
Slave Address	Slave Address
Function	Function (with the most significant bit in 1)
Data	Error code
CRC-	CRC-
CRC+	CRC+

Example: the master requests to the slave at the address 1 the writing in the register 2900 (nonexistent register):

Request (Master)		**Response (Slave)**	
Field	*Value*	*Field*	*Value*
Slave Address	01h	Slave Address	01h
Function	06h	Function	86h
Register (high)	0Bh	Error code	02h
Register (low)	54h	CRC-	C3h
Value (high)	00h	CRC+	A1h
Value (low)	00h		
CRC-	CAh		
CRC+	3Eh		

7 OPERATION IN THE MODBUS RTU NETWORK – MASTER MODE

Besides the operation as a slave, the PLC300 programmable controller also allows operation as a master for the Modbus RTU network. For this operation, it is necessary to observe the following points:

- Only interface RS485 allows operation as a network master.
- It is necessary to program, in product configurations, the operation mode as "Master", besides the communication rate, parity, and stop bits, which must be the same for the whole equipment in the network.
- The Modbus RTU network master does not have an address, so the address configured in the PLC300 is not used.
- Sending and receiving telegrams via RS485 interface using the Modbus RTU protocol is programmed by using blocks in ladder programming language. It is necessary to know the available blocks and the ladder programming software in order to be able to program the network master.
- The following functions are available for the sending of requisitions by the Modbus master:
  Function 01: Read Coils
  Function 02: Read Discrete Inputs
  Function 03: Read Holding Registers
  Function 04: Read Input Registers
  Function 05: Write Single Coil
  Function 06: Write Single Register
  Function 15: Write Multiple Coils
  Function 16: Write Multiple Registers

7.1 BLOCKS TO PROGRAM THE MASTER

In order to control and monitor the Modbus RTU communication using the PLC300 programmable controller, the following blocks were developed, and they must be used when programming in ladder.

7.1.1 MB Read Binary – Reading of Bits

Block for the reading of bits. It allows the reading of up to 128 sequential bits of the destination slave, using functions 1 (Read Coils) and 2 (Read Discrete Inputs) in the Modbus.

It has an "Execute" block enabling input, and a "Done" output which is activated after the end of the function's successful performance. After the positive transition of "Execute", a new telegram is sent by the Modbus RTU master when the RS485 serial interface is free. At the operation successful end – response received from the slave – the "Done" output is activated, remaining active while the input is active, and the received data is copied to "Value". In case of error in the requisition performance, the "Error" output is enabled, and the error code is put to "ErrorID".

Input:

<arg0>: “SlaveAddress” – VAR_IN: insert a variable (tag).
Types of data: BYTE
Description: Address of destination slave – 1 to 247.

<arg1>: "Function#" – VAR_IN: insert a constant.
Types of data: BYTE
Description: Reading function code: 1= "Read Coils"; 2= "Read Discrete Inputs".

<arg2>: "InitialDataAddress" – VAR_IN: insert a variable (tag).
Types of data: WORD
Description: Address of initial bit – 0 to 65535.

<arg3>: "NumberOfData" – VAR_IN: insert a variable (tag).
Types of data: BYTE
Description: Number of bits read in sequence starting with the initial address – 1 to 128.

<arg4>: "Timeout#" – VAR_IN: insert a constant.
Types of data: WORD
Description: Waiting time for the arrival of the response by the slave, starting with the sending by the master – 20 to 5000 ms.

<arg5>: "Offset#" – VAR_IN: insert a constant.
Types of data: BOOL
Description: It indicates if the address of the data programmed in "InitialDataAddress#" has offset, i.e. if the address of the data programmed in the block must be subtracted from 1 in order to send through the Modbus network. FALSE= "Without Offset"; TRUE= "With Offset of 1".

Output:

<arg6>: "Active" – VAR_OUT: insert a variable (tag).
Types of data: BOOL
Description: Active block, requisition for reading sent to the slave and awaiting response.
Note: The variable must have writing permission.

<arg7>: "Busy" – VAR_OUT: insert a variable (tag).
Types of data: BOOL
Description: Block enabled, though resource is not available (RS485 interface busy with another requisition), waiting for release so that the request is sent by the block. If the enabling input is removed while the block makes that indication, the requisition is rejected.
Note: The variable must have writing permission.

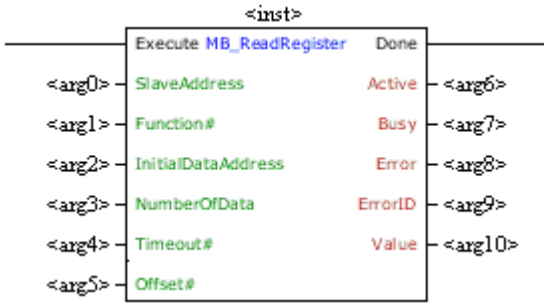
<arg8>: "Error" – VAR_OUT: insert a variable (tag).
Types of data: BOOL
Description: error during requisition performance.
Note: The variable must have writing permission.

<arg9>: "ErrorID" – VAR_OUT: insert a variable (tag).
Types of data: BYTE or USINT
Description: In case of requisition error, the type of error occurred will be indicated. Possible results: 0= "Successfully performed"; 1= "Some input data invalid" (example: Master disabled); 4= "Timeout in the response by the slave"; 5= "Slave returned error".
Note: The variable must have writing permission.

<arg10>: "Value" – VAR_OUT: insert a variable (tag).
Types of data: BOOL[1 ... 128]
Description: Variable or array where the slave's read data will be stored.
Note: The variable must have writing permission.

7.1.2 MB Read Register – Reading of Registers

Block for the reading of 16 bit registers. It allows the reading of up to 16 sequential registers of the destination slave, using functions 3 (Read Holding Registers) and 4 (Read Input Registers) in the Modbus.



It has an "Execute" block enabling input, and a "Done" output which is activated after the end of the function's successful performance. After the positive transition of "Execute", a new telegram is sent by the Modbus RTU master when the RS485 serial interface is free. At the operation successful end – response received from the slave – the "Done" output is activated, remaining active while the input is active, and the received data is copied to "Value". In case of error in the requisition performance, the "Error" output is enabled, and the error code is put to "ErrorID".

Input:

<arg0>: "SlaveAddress" – VAR_IN: insert a variable (tag).
Types of data: BYTE
Description: Address of destination slave – 1 to 247.

<arg1>: "Function#" – VAR_IN: insert a constant.
Types of data: BYTE
Description: Reading function code: 3= "Read Holding Registers"; 4= "Read Input Registers".

<arg2>: "InitialDataAddress" – VAR_IN: insert a variable (tag).
Types of data: WORD
Description: Address of initial register – 0 to 65535.

<arg3>: "NumberOfData" – VAR_IN: insert a variable (tag).
Types of data: BYTE
Description: Number of registers read starting with the initial address – 1 to 16.

<arg4>: "Timeout#" – VAR_IN: insert a constant.
Types of data: WORD
Description: Waiting time for the arrival of the response by the slave, starting with the sending by the master – 20 to 5000 ms.

<arg5>: "Offset#" – VAR_IN: insert a constant.
Types of data: BOOL
Description: It indicates if the address of the data programmed in "InitialDataAddress#" has offset, i.e. if the address of the data programmed in the block must be subtracted from 1 in order to send through the Modbus network. FALSE= "Without Offset"; TRUE= "With Offset of 1".

Output:

<arg6>: "Active" – VAR_OUT: insert a variable (tag).
Types of data: BOOL
Description: Active block, requisition for reading sent to the slave and awaiting response.
Note: The variable must have writing permission.

<arg7>: "Busy" – VAR_OUT: insert a variable (tag).
Types of data: BOOL
Description: Block enabled, though resource is not available (RS485 interface busy with another requisition), waiting for release so that the request is sent by the block. If the enabling input is removed while the block makes that indication, the requisition is rejected.
Note: The variable must have writing permission.

<arg8>: "Error" – VAR_OUT: insert a variable (tag).
Types of data: BOOL
Description: error during requisition performance.
Note: The variable must have writing permission.

<arg9>: "ErrorID" – VAR_OUT: insert a variable (tag).
Types of data: BYTE or USINT
Description: In case of requisition error, the type of error occurred will be indicated. Possible results: 0= "Successfully performed"; 1= "Some input data invalid" (example: Master disabled); 4= "Timeout in the response by the slave"; 5= "Slave returned error".
Note: The variable must have writing permission.

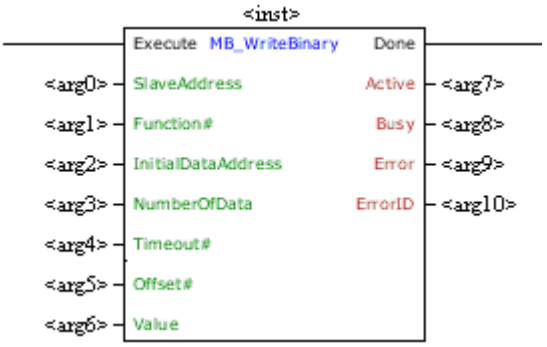
<arg10>: "Value" – VAR_OUT: insert a variable (tag).
Types of data: BYTE[1 ... 32], SINT[1 ... 32], USINT[1 ... 32], WORD[1 ... 16], UINT[1 ... 16], INT[1 ... 16], DWORD[1 ... 8], UDINT[1 ... 8], DINT[1 ... 8] or REAL[1 ... 8]
Description: Variable or array where the slave's read data will be stored.
Note: The variable must have writing permission.

NOTE!

- The Modbus RTU protocol, using functions 3 and 4, allows the reading of 16 bit registers only; for the reading of data with more than 16 bits (a REAL, for instance), it is possible to perform the reading of multiple registers and store the value in a variable which size is bigger than 16 bits.
- It is important that the quantity of read registers is compatible with the size of the variable or the array where the data will be stored.

7.1.3 MB Write Binary – Writing of Bits

Block for the writing of bits. It allows the writing of up to 128 bits using functions 5 (Write Single Coil), and 15 (Write Multiple Coils) in the Modbus.



It has an "Execute" block enabling input, and a "Done" output which is activated after the end of the function's successful performance. After the positive transition of "Execute", a new telegram is sent by the Modbus RTU master when the RS485 serial interface is free. At the operation successful end – response received from the slave – the "Done" output is activated, remaining active while the input is active. In case of error in the requisition performance, the "Error" output is enabled, and the error code is put to "ErrorID".

Input:

<arg0>: "SlaveAddress" – VAR_IN: insert a variable (tag).
Types of data: BYTE
Description: Address of destination slave – 1 to 247.

<arg1>: "Function#" – VAR_IN: insert a constant.
Types of data: BYTE
Description: Writing function code: 5= "Write Single Coil"; 15= "Write Multiple Coils".

<arg2>: "InitialDataAddress" – VAR_IN: insert a variable (tag).
Types of data: WORD
Description: Address of initial bit – 0 to 65535.

<arg3>: "NumberOfData" – VAR_IN: insert a variable (tag).
Types of data: BYTE
Description: Number of bits written in sequence starting with the initial address – 1 to 128.

<arg4>: "Timeout#" – VAR_IN: insert a constant.
Types of data: WORD
Description: Waiting time for the arrival of the response by the slave, starting with the sending by the master – 20 to 5000 ms.

<arg5>: "Offset#" – VAR_IN: insert a constant.
Types of data: BOOL
Description: It indicates if the address of the data programmed in "InitialDataAddress#" has offset, i.e. if the address of the data programmed in the block must be subtracted from 1 in order to send through the Modbus network. FALSE= "Without Offset"; TRUE= "With Offset of 1".

<arg6>: "Value" – VAR_IN: insert a variable (tag).
Types of data: BOOL[1 ... 128]
Description: Variable or array with the data to be written in the slave.

Output:

<arg7>: "Active" – VAR_OUT: insert a variable (tag).
Types of data: BOOL
Description: Active block, requisition for reading sent to the slave and awaiting response.
Note: The variable must have writing permission.

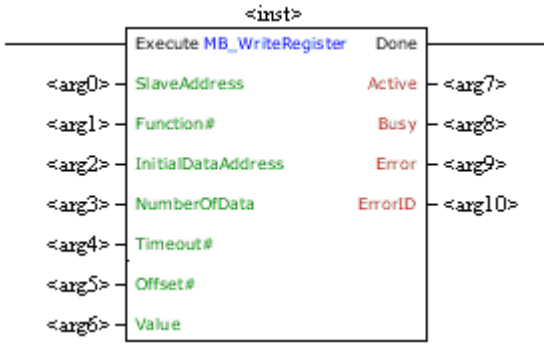
<arg8>: "Busy" – VAR_OUT: insert a variable (tag).
Types of data: BOOL
Description: Block enabled, though resource is not available (RS485 interface busy with another requisition), waiting for release so that the request is sent by the block. If the enabling input is removed while the block makes that indication, the requisition is rejected.
Note: The variable must have writing permission.

<arg9>: "Error" – VAR_OUT: insert a variable (tag).
Types of data: BOOL
Description: error during requisition performance.
Note: The variable must have writing permission.

<arg10>: "ErrorID" – VAR_OUT: insert a variable (tag).
Types of data: BYTE or USINT
Description: In case of requisition error, the type of error occurred will be indicated. Possible results: 0= "Successfully performed"; 1= "Some input data invalid" (example: Master disabled); 4= "Timeout in the response by the slave"; 5= "Slave returned error".
Note: The variable must have writing permission.

7.1.4 MB Write Register – Writing of Registers

Block for the writing of registers. It allows the writing of up to 16 sequential registers using function 6 (Write Holding Register), or 16 (Write Multiple Registers) in the Modbus.



It has an "Execute" block enabling input, and a "Done" output which is activated after the end of the function's successful performance. After the positive transition of "Execute", a new telegram is sent by the Modbus RTU master when the RS485 serial interface is free. At the operation successful end – response received from the slave – the "Done" output is activated, remaining active while the input is active. In case of error in the requisition performance, the "Error" output is enabled, and the error code is put to "ErrorID".

Input:

<arg0>: "SlaveAddress" – VAR_IN: insert a variable (tag).
Types of data: BYTE
Description: Address of destination slave – 1 to 247.

<arg1>: "Function#" – VAR_IN: insert a constant.
Types of data: BYTE
Description: Writing function code: 6= "Write Single Register"; 16= "Write Multiple Registers".

<arg2>: "InitialDataAddress" – VAR_IN: insert a variable (tag).
Types of data: WORD
Description: Address of initial register – 0 to 65535.

<arg3>: "NumberOfData" – VAR_IN: insert a variable (tag).
Types of data: BYTE
Description: Number of registers written starting with the initial address – 1 to 16.

<arg4>: "Timeout#" – VAR_IN: insert a constant.
Types of data: WORD
Description: Waiting time for the arrival of the response by the slave, starting with the sending by the master – 20 to 5000 ms.

<arg5>: "Offset#" – VAR_IN: insert a constant.
Types of data: BOOL
Description: It indicates if the address of the data programmed in "InitialDataAddress#" has offset, i.e. if the address of the data programmed in the block must be subtracted from 1 in order to send through the Modbus network. FALSE= "Without Offset"; TRUE= "With Offset of 1".

<arg6>: "Value" – VAR_IN: insert a variable (tag).
Types of data: BYTE[1 ... 32], USINT[1 ... 32], SINT[1 … 32], WORD[1 … 16], UINT[1 … 16], INT[1 … 16], DWORD[1 … 8], UDINT[1 … 8], DINT[1 … 8] or REAL[1 … 8]
Description: Variable or array with the data to be written in the slave.

Output:

<arg7>: "Active" – VAR_OUT: insert a variable (tag).
Types of data: BOOL
Description: Active block, requisition for reading sent to the slave and awaiting response.
Note: The variable must have writing permission.

<arg8>: "Busy" – VAR_OUT: insert a variable (tag).
Types of data: BOOL
Description: Block enabled, though resource is not available (RS485 interface busy with another requisition), waiting for release so that the request is sent by the block. If the enabling input is removed while the block makes that indication, the requisition is rejected.
Note: The variable must have writing permission.

<arg9>: "Error" – VAR_OUT: insert a variable (tag).
Types of data: BOOL
Description: error during requisition performance.
Note: The variable must have writing permission.

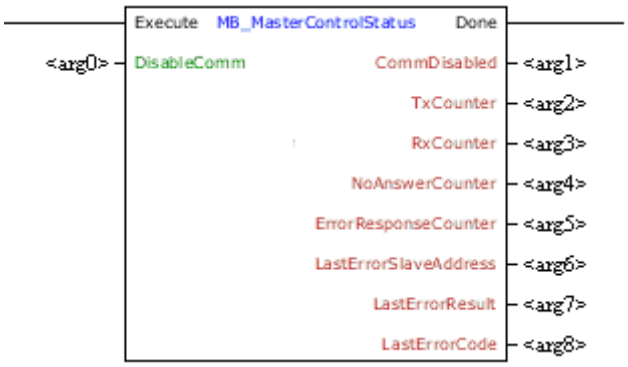
<arg10>: "ErrorID" – VAR_OUT: insert a variable (tag).
Types of data: BYTE or USINT
Description: In case of requisition error, the type of error occurred will be indicated. Possible results: 0= "Successfully performed"; 1= "Some input data invalid" (example: Master disabled); 4= "Timeout in the response by the slave"; 5= "Slave returned error".
Note: The variable must have writing permission.

NOTE!

- The Modbus RTU protocol, using function 16, allows the writing of 16 bit registers only. For the writing of data with more than 16 bits (one REAL, for instance), it is possible to perform the writing of multiple registers, and use a variable which size is bigger than 16 bits as data source.
- It is important that the quantity of written registers is compatible with the size of the variable or the array where the data will be used.

7.1.5 MB Master Control/Status – Control and Status of Modbus RTU Master

Block to control and monitor the master in the Modbus RTU network. Whenever a Modbus RTU network is assembled with the PLC300 as the network master, it is recommended to use this block in order to obtain information on the communication state.



It has an "Execute" block enabling input, and a "Done" output which is activated after the end of the function's successful performance. While the "Execute" enabling input is active, the input data is used and the output data is updated. In case the input is zeroed, the input values are disregarded and the output arguments are zeroed. Output "Done" reflects the value of the input.

Input:

<arg0>: "DisableComm" – VAR_IN: insert a constant or a variable (tag).
Types of data: BOOL
Description: It allows to disable the Modbus master. When disabling the master, the Modbus RTU master's status counters and markers are also zeroed: 0= "Master in performance"; 1= "Disables master".

Output:

<arg1>: "CommDisabled" – VAR_OUT: insert a variable (tag).
Types of data: BOOL
Description: It indicates if the master is disabled or not. It may occur by user request, or, in case the interface is programmed to operate as the network slave: 0= "Master Enabled"; 1= "Master disabled".
Note: The variable must have writing permission.

<arg2>: "TxCounter" – VAR_OUT: insert a variable (tag).
Types of data: WORD or UINT
Description: Counter of requests sent by the network master to the slaves. It is zeroed whenever the equipment is disconnected or the master is disabled – 0 to 65535.
Note: The variable must have writing permission.

<arg3>: "RxCounter" – VAR_OUT: insert a variable (tag).
Types of data: WORD or UINT
Description: Counter of telegrams received by the network master. It is zeroed whenever the equipment is disconnected or the master is disabled – 0 to 65535.
Note: The variable must have writing permission.

<arg4>: "NoAnswerCounter" – VAR_OUT: insert a variable (tag).
Types of data: WORD or UINT
Description: Counter of requests by the master that were not responded by the slaves. It is zeroed whenever the equipment is disconnected or the master is disabled – 0 to 65535.
Note: The variable must have writing permission.

<arg5>: "ErrorResponseCounter" – VAR_OUT: insert a variable (tag).
Types of data: WORD or UINT
Description: Counter of requests by the master that the slaves responded with some error response. The error code may be obtained in the marker that indicates the code of the last detected error. It is zeroed whenever the equipment is disconnected or the master is disabled – 0 to 65535.
Note: The variable must have writing permission.

<arg6>: "LastErrorSlaveAddress" – VAR_OUT: insert a variable (tag).
Types of data: BYTE or USINT
Description: It indicates the address of the slave in which the last communication error was detected. It is zeroed whenever the equipment is disconnected or the master is disabled – 0 to 247.
Note: The variable must have writing permission.

<arg7>: "LastErrorResult" – VAR_OUT: insert a variable (tag).
Types of data: BYTE or USINT
Description: It indicates the operation result – timeout or error response, conforming to the block's ERROR ID – for the slave in which the last communication error was detected. It is zeroed whenever the equipment is disconnected or the master is disabled: 0= "Without detected error"; 4= "Timeout in the response by the slave"; 5= "Slave returned error".
Note: The variable must have writing permission.

<arg8>: "LastErrorCode" – VAR_OUT: insert a variable (tag).
Types of data: BYTE or USINT
Description: It indicates the error code, in case the master receives an error response from some slave. It is zeroed whenever the equipment is disconnected or the master is disabled – 0 to 255.
Note: The variable must have writing permission.

NOTE!
The data accessed through the use of this block is also available through reading and writing system markers, as described in item 8.

7.1.6 MB Slave Status – Modbus RTU Network Slave Status

Block to monitor the slaves in the Modbus RTU network. It must be used in case it is desired to identify problems in the communication between the master and some slave in the Modbus RTU network.

It has an "Execute" block enabling input, and a "Done" output which is activated after the end of the function's successful performance. While the "Execute" enabling input is active, the input data is used and the output data is updated at every performance of the block. Output "Done" reflects the value of the input.

Input:

<arg0>: "ErrorsToSetOffline#" – VAR_IN: insert a constant.
Types of data: BYTE
Description: It allows programming, for this block, the quantity of communication errors which the master must identify until the communication with a network slave is considered offline. The following is considered communication error: every request (reading or writing) a master sent to a slave and did not receive a response, the received response had CRC error.

<arg1>: "AddressSlave1#" – VAR_IN: insert a constant.
<arg2>: "AddressSlave2#" – VAR_IN: insert a constant.
<arg3>: "AddressSlave2#" – VAR_IN: insert a constant.
<arg4>: "AddressSlave2#" – VAR_IN: insert a constant.
Types of data: BYTE
Description: It allows programming the address of up to 4 slaves which quantity of communication errors will be monitored in order to make known if they are online or offline. In case the quantity of sequential communication errors detected in the reading and writing blocks via Modbus reaches the value programmed in "ErrorsToSetOffline", the respective output is activated. In case it is desired to monitor a smaller number of slaves, any of the inputs may be set in zero: 0= "Ignores input"; 1 to 247.

Output:

<arg5>: "GeneralOffline#" – VAR_OUT: insert a variable (tag).
Types of data: BOOL
Description: If any of the outputs of the indicated slaves is activated, this output will also be activated. It works as an OR logic between the 4 outputs of slave indication – 0 to 65535.
Note: The variable must have writing permission.

<arg6>: "Slave1Offline#" – VAR_OUT: insert a variable (tag).
<arg7>: "Slave2Offline#" – VAR_OUT: insert a variable (tag).
<arg8>: "Slave3Offline#" – VAR_OUT: insert a variable (tag).
<arg9>: "Slave4Offline#" – VAR_OUT: insert a variable (tag).
Types of data: BOOL
Description: Output activated in case the quantity of sequential communication errors for the slaves indicated in the respective inputs reaches the value programmed in "ErrorsToSetOffline".
Note: The variable must have writing permission.

8 SYSTEM MARKERS FOR RS232 AND RS485

For RS232 and RS485 serial interfaces, the following reading system markers (%S) and writing system markers (%C) were provided for control and monitoring:

8.1 READING SYSTEM MARKERS

Modbus Master Status (RS485): reading marker set that indicates the Modbus master status, besides information for network diagnosis.	
Marker	Description
%SB3100	Status of the Modbus master: 0 = Normal operation. 1 = Mater disabled.
%SB3101	Reserved.
%SW3102	Counter of requests made by the master. Counter incremented every time a new telegram is sent by the Modbus RTU network master. It is reset whenever it reaches the maximum limit.
%SW3104	Counter of successfully received responses. Counter incremented every time the master receives a successful response from a network slave. It is reset whenever it reaches the maximum limit.
%SW3106	Counter of requests without response – timeout. Counter incremented every time a timeout occurs for a request made by the Modbus RTU network master to a slave. It is reset whenever it reaches the maximum limit or the interface is disabled.
%SW3108	Counter of responses received with error. Counter incremented whenever the slave returns an error response to a request made by the Modbus RTU master. It is reset whenever it reaches the maximum limit or the interface is disabled. Whenever this error is detected, the data for the slave address, error type and error code will be saved on the markers %SB3110 to %SB3112.
%SB3110	Last error occurred: slave address.
%SB3111	Last error occurred: error type. 0 = No error. 4 = Timeout at the response. 5 = Slave returned error response. It is reset whenever the interface is disabled.
%SB3112	Last error occurred: code of the received error, if the type is error response. It is reset whenever the interface is disabled.
%SB3113	Reserved.

Status of the Modbus slave (RS485): set of reading markers that indicate the quantity of telegrams sent and received by the Modbus RTU slave.	
Marker	Description
%SW3120	Number of received telegrams. Specific for the slave mode.
%SW3122	Number of transmitted telegrams Specific for the slave mode.

8.2 WRITING SYSTEM MARKERS

Configuration of the RS232 Interface: set of writing markers to program the configurations of the RS232 interface. They are also accessible through the Setup menu.	
Marker	Description
%CB3060	Reserved.
%CB3061	Reserved.
%CB3062	Byte format: 0 = no parity, 1 stop bit 1 = odd parity, 1 stop bit 2 = even parity, 1 stop bit 3 = reserved 4 = no parity, 2 stop bits 5 = odd parity, 2 stop bits 6 = even parity, 2 stop bits
%CB3063	Baud rate for RS232: 0 = 1200 bit/s 1 = 2400 bit/s 2 = 4800 bit/s 3 = 9600 bit/s 4 = 19200 bit/s 5 = 38400 bit/s 6 = 57600 bit/s

Configuration of the RS485 Interface: set of writing markers to program the configurations of the RS485 interface. They are also accessible through the Setup menu.	
Marker	Description
%CB3068	Serial address (slave modo) 1 ... 247.
%CB3069	Operation mode: 0 = Modbus RTU slave. 1 = Modbus RTU master.
%CB3070	Byte format: 0 = no parity, 1 stop bit 1 = odd parity, 1 stop bit 2 = even parity, 1 stop bit 3 = reserved 4 = no parity, 2 stop bits 5 = odd parity, 2 stop bits 6 = even parity, 2 stop bits
%CB3071	Baud rate for RS485: 0 = 1200 bit/s 1 = 2400 bit/s 2 = 4800 bit/s 3 = 9600 bit/s 4 = 19200 bit/s 5 = 38400 bit/s 6 = 57600 bit/s

Control of the Modbus Master (RS485): set of writing markers for control of the Modbus master.	
Marker	Description
%CW3100	Control of the Modbus master: 0 = Normal operation. 1 = Disable interface.

I. APPENDICES

APPENDIX A. ASCII TABLE

Table I.1: ASCII Characters

Dec	Hex	Chr		Dec	Hex	Chr	Dec	Hex	Chr	Dec	Hex	Chr
0	00	NUL	(Null char.)	32	20	Sp	64	40	@	96	60	`
1	01	SOH	(Start of Header)	33	21	!	65	41	A	97	61	a
2	02	STX	(Start of Text)	34	22	"	66	42	B	98	62	b
3	03	ETX	(End of Text)	35	23	#	67	43	C	99	63	c
4	04	EOT	(End of Transmission)	36	24	$	68	44	D	100	64	d
5	05	ENQ	(Enquiry)	37	25	%	69	45	E	101	65	e
6	06	ACK	(Acknowledgment)	38	26	&	70	46	F	102	66	f
7	07	BEL	(Bell)	39	27	'	71	47	G	103	67	g
8	08	BS	(Backspace)	40	28	(	72	48	H	104	68	h
9	09	HT	(Horizontal Tab)	41	29	)	73	49	I	105	69	i
10	0A	LF	(Line Feed)	42	2A	*	74	4A	J	106	6A	j
11	0B	VT	(Vertical Tab)	43	2B	+	75	4B	K	107	6B	k
12	0C	FF	(Form Feed)	44	2C	,	76	4C	L	108	6C	l
13	0D	CR	(Carriage Return)	45	2D	-	77	4D	M	109	6D	m
14	0E	SO	(Shift Out)	46	2E	.	78	4E	N	110	6E	n
15	0F	SI	(Shift In)	47	2F	/	79	4F	O	111	6F	o
16	10	DLE	(Data Link Escape)	48	30	0	80	50	P	112	70	p
17	11	DC1	(Device Control 1)	49	31	1	81	51	Q	113	71	q
18	12	DC2	(Device Control 2)	50	32	2	82	52	R	114	72	r
19	13	DC3	(Device Control 3)	51	33	3	83	53	S	115	73	s
20	14	DC4	(Device Control 4)	52	34	4	84	54	T	116	74	t
21	15	NAK	(Negative Acknowledgement)	53	35	5	85	55	U	117	75	u
22	16	SYN	(Synchronous Idle)	54	36	6	86	56	V	118	76	v
23	17	ETB	(End of Trans. Block)	55	37	7	87	57	W	119	77	w
24	18	CAN	(Cancel)	56	38	8	88	58	X	120	78	x
25	19	EM	(End of Medium)	57	39	9	89	59	Y	121	79	y
26	1A	SUB	(Substitute)	58	3A	:	90	5A	Z	122	7A	z
27	1B	ESC	(Escape)	59	3B	;	91	5B	[	123	7B	{
28	1C	FS	(File Separator)	60	3C	<	92	5C	\	124	7C	|
29	1D	GS	(Group Separator)	61	3D	=	93	5D	]	125	7D	}
30	1E	RS	(Record Separator)	62	3E	>	94	5E	^	126	7E	~
31	1F	US	(Unit Separator)	63	3F	?	95	5F	_	127	7F	DEL

APPENDIX B. CRC CALCULATION USING TABLES

Next, a function using programming language "C" is presented, which implements the CRC calculation for the Modbus RTU protocol. The calculation uses two tables to supply pre-calculated values of the necessary displacement for the calculation.

```
/* Table of CRC values for high–order byte */
static unsigned char auchCRCHi[] = {
0x00, 0xC1, 0x81, 0x40, 0x01, 0xC0, 0x80, 0x41, 0x01, 0xC0, 0x80, 0x41, 0x00, 0xC1, 0x81, 0x40,
0x01, 0xC0, 0x80, 0x41, 0x00, 0xC1, 0x81, 0x40, 0x00, 0xC1, 0x81, 0x40, 0x01, 0xC0, 0x80, 0x41,
0x01, 0xC0, 0x80, 0x41, 0x00, 0xC1, 0x81, 0x40, 0x00, 0xC1, 0x81, 0x40, 0x01, 0xC0, 0x80, 0x41,
0x00, 0xC1, 0x81, 0x40, 0x01, 0xC0, 0x80, 0x41, 0x01, 0xC0, 0x80, 0x41, 0x00, 0xC1, 0x81, 0x40,
0x01, 0xC0, 0x80, 0x41, 0x00, 0xC1, 0x81, 0x40, 0x00, 0xC1, 0x81, 0x40, 0x01, 0xC0, 0x80, 0x41,
0x00, 0xC1, 0x81, 0x40, 0x01, 0xC0, 0x80, 0x41, 0x01, 0xC0, 0x80, 0x41, 0x00, 0xC1, 0x81, 0x40,
0x00, 0xC1, 0x81, 0x40, 0x01, 0xC0, 0x80, 0x41, 0x01, 0xC0, 0x80, 0x41, 0x00, 0xC1, 0x81, 0x40,
0x01, 0xC0, 0x80, 0x41, 0x00, 0xC1, 0x81, 0x40, 0x00, 0xC1, 0x81, 0x40, 0x01, 0xC0, 0x80, 0x41,
0x01, 0xC0, 0x80, 0x41, 0x00, 0xC1, 0x81, 0x40, 0x00, 0xC1, 0x81, 0x40, 0x01, 0xC0, 0x80, 0x41,
0x00, 0xC1, 0x81, 0x40, 0x01, 0xC0, 0x80, 0x41, 0x01, 0xC0, 0x80, 0x41, 0x00, 0xC1, 0x81, 0x40,
0x00, 0xC1, 0x81, 0x40, 0x01, 0xC0, 0x80, 0x41, 0x01, 0xC0, 0x80, 0x41, 0x00, 0xC1, 0x81, 0x40,
0x01, 0xC0, 0x80, 0x41, 0x00, 0xC1, 0x81, 0x40, 0x00, 0xC1, 0x81, 0x40, 0x01, 0xC0, 0x80, 0x41,
0x01, 0xC0, 0x80, 0x41, 0x00, 0xC1, 0x81, 0x40, 0x00, 0xC1, 0x81, 0x40, 0x01, 0xC0, 0x80, 0x41,
0x00, 0xC1, 0x81, 0x40, 0x01, 0xC0, 0x80, 0x41, 0x01, 0xC0, 0x80, 0x41, 0x00, 0xC1, 0x81, 0x40 };


/* Table of CRC values for low–order byte */
static char auchCRCLo[] = {
0x00, 0xC0, 0xC1, 0x01, 0xC3, 0x03, 0x02, 0xC2, 0xC6, 0x06, 0x07, 0xC7, 0x05, 0xC5, 0xC4, 0x04,
0xCC, 0x0C, 0x0D, 0xCD, 0x0F, 0xCF, 0xCE, 0x0E, 0x0A, 0xCA, 0xCB, 0x0B, 0xC9, 0x09, 0x08, 0xC8,
0xD8, 0x18, 0x19, 0xD9, 0x1B, 0xDB, 0xDA, 0x1A, 0x1E, 0xDE, 0xDF, 0x1F, 0xDD, 0x1D, 0x1C, 0xDC,
0x14, 0xD4, 0xD5, 0x15, 0xD7, 0x17, 0x16, 0xD6, 0xD2, 0x12, 0x13, 0xD3, 0x11, 0xD1, 0xD0, 0x10,
0xF0, 0x30, 0x31, 0xF1, 0x33, 0xF3, 0xF2, 0x32, 0x36, 0xF6, 0xF7, 0x37, 0xF5, 0x35, 0x34, 0xF4,
0x3C, 0xFC, 0xFD, 0x3D, 0xFF, 0x3F, 0x3E, 0xFE, 0xFA, 0x3A, 0x3B, 0xFB, 0x39, 0xF9, 0xF8, 0x38,
0x28, 0xE8, 0xE9, 0x29, 0xEB, 0x2B, 0x2A, 0xEA, 0xEE, 0x2E, 0x2F, 0xEF, 0x2D, 0xED, 0xEC, 0x2C,
0xE4, 0x24, 0x25, 0xE5, 0x27, 0xE7, 0xE6, 0x26, 0x22, 0xE2, 0xE3, 0x23, 0xE1, 0x21, 0x20, 0xE0,
0xA0, 0x60, 0x61, 0xA1, 0x63, 0xA3, 0xA2, 0x62, 0x66, 0xA6, 0xA7, 0x67, 0xA5, 0x65, 0x64, 0xA4,
0x6C, 0xAC, 0xAD, 0x6D, 0xAF, 0x6F, 0x6E, 0xAE, 0xAA, 0x6A, 0x6B, 0xAB, 0x69, 0xA9, 0xA8, 0x68,
0x78, 0xB8, 0xB9, 0x79, 0xBB, 0x7B, 0x7A, 0xBA, 0xBE, 0x7E, 0x7F, 0xBF, 0x7D, 0xBD, 0xBC, 0x7C,
0xB4, 0x74, 0x75, 0xB5, 0x77, 0xB7, 0xB6, 0x76, 0x72, 0xB2, 0xB3, 0x73, 0xB1, 0x71, 0x70, 0xB0,
0x50, 0x90, 0x91, 0x51, 0x93, 0x53, 0x52, 0x92, 0x96, 0x56, 0x57, 0x97, 0x55, 0x95, 0x94, 0x54,
0x9C, 0x5C, 0x5D, 0x9D, 0x5F, 0x9F, 0x9E, 0x5E, 0x5A, 0x9A, 0x9B, 0x5B, 0x99, 0x59, 0x58, 0x98,
0x88, 0x48, 0x49, 0x89, 0x4B, 0x8B, 0x8A, 0x4A, 0x4E, 0x8E, 0x8F, 0x4F, 0x8D, 0x4D, 0x4C, 0x8C,
0x44, 0x84, 0x85, 0x45, 0x87, 0x47, 0x46, 0x86, 0x82, 0x42, 0x43, 0x83, 0x41, 0x81, 0x80, 0x40 };


/* The function returns the CRC as a unsigned short type */
unsigned short CRC16(puchMsg, usDataLen)
unsigned char *puchMsg;                 /* message to calculate CRC upon    */
unsigned short usDataLen;               /* quantity of bytes in message     */
{
    unsigned char uchCRCHi = 0xFF;      /* high byte of CRC initialized     */
    unsigned char uchCRCLo = 0xFF;      /* low byte of CRC initialized      */
    unsigned uIndex;                    /* will index into CRC lookup table */
    while (usDataLen--)                 /* pass through message buffer      */
    {
        uIndex = uchCRCLo ^ *puchMsgg++; /* calculate the CRC               */
        uchCRCLo = uchCRCHi ^ auchCRCHi[uIndex};
        uchCRCHi = auchCRCLo[uIndex];
    }

    return (uchCRCHi << 8 | uchCRCLo);
}
```

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