Using the Modbus Master Protocol Library (v1.2)

STEP 7–Micro/WIN Instruction Libraries makes communicating to Modbus slave devices easier by including pre-configured subroutines and interrupt routines that are specifically designed for Modbus communications. With the Modbus Master Protocol instructions, you can configure the S7-200 to act as a Modbus RTU master device and communicate to one or more Modbus slave devices.

The Modbus Master Protocol instructions can be installed into the Libraries folder of the STEP 7–Micro/WIN instruction tree. These new instructions allow you to make the S7-200 act as a Modbus master. When you select a Modbus Master instruction, one or more associated subroutines are automatically added to your project to support the Modbus Master Protocol.

There are two versions of the Modbus Master Protocol Library. One version utilizes port 0 of the CPU and the other utilizes port 1 of the CPU. This document describes both libraries. The port 1 library has an "_P1" appended to the POU names (i.e. MBUS_CTRL_P1) to denote that the POU utilizes port 1 on the CPU. The libraries are identical in all other respects.

Requirements for Using the Modbus Master Protocol

The Modbus Master Protocol instructions use the following resources from the S7-200:

- Initializing the Modbus Master Protocol dedicates the specific CPU port for Modbus Master Protocol communications. When the CPU port is being used for Modbus Master Protocol communications, it cannot be used for any other purpose, including communications with STEP 7-Micro/WIN. The MBUS_CTRL instruction controls assignment of Port 0 to Modbus Master Protocol or PPI. The MBUS_CTRL_P1 instruction (from the port 1 library) controls assignment of Port 1 to Modbus Master Protocol or PPI.

- The Modbus Master Protocol instructions affect all of the SM locations associated with Freeport communications on the affected CPU communication port.

- The Modbus Master Protocol instructions use 3 subroutines and 1 interrupt routine.

- The Modbus Master Protocol instructions require about 1620 bytes of program space for the two Modbus Master instructions and the support routines.

- The variables for the Modbus Master Protocol instructions require a 284 byte block of V memory. The starting address for this block is assigned by the user and is reserved for Modbus variables.

- The S7-200 CPU must be firmware revision 2.00 or greater to support the Modbus Master Protocol Library (CPU MLFB 21x-2xx23-0XB0).

- The Modbus master library utilizes the user interrupts for some functions. The user interrupts must not be disabled by the user program.

Note: **To change the operation of CPU communication port back to PPI so that you can communicate with STEP 7-Micro/WIN, set the Mode parameter of the MBUS_CTRL instruction to a zero (0).**

You can also set the mode switch on the S7-200 to the STOP mode position. Either of these methods will set the CPU communication port to communicate with STEP 7-Micro/WIN.

Execution Time for the Modbus Master Protocol

The Modbus Master Protocol requires a small amount of time every scan to execute the MBUS_CTRL instruction. The time will be about 1.11 milliseconds when the MBUS_CTRL is initializing the Modbus Master (first scan), and about 0.41 milliseconds on subsequent scans.

The scan time is extended when the MBUS_MSG subroutine executes a request. Most of the time is spent calculating the Modbus CRC for the request and the response. The CRC (Cyclic Redundancy Check) insures the integrity of the communications message. The scan time is extended by about 1.85 milliseconds for each word in the request and in the response. A maximum request/response (read or write of 120 words) extends the scan time by approximately 222 milliseconds. A read request extends the scan mainly when the response is received from the slave, and to a lesser extent when request is sent. A write request extends the scan mainly when the data sent to the slave, and to a lesser extent when the response is received.

Modbus Addressing

Modbus addresses are normally written as 5 character values containing the data type and the offset. The first character determines the data type, and the last four characters select the proper value within the data type. The Modbus Master instructions then map the addresses to the correct functions to send to the slave device. The following Modbus addresses are supported by the Modbus Master instructions:

- 00001 to 09999 are discrete outputs (coils)
- 10001 to 19999 are discrete inputs (contacts)
- 30001 to 39999 are input registers (generally analog inputs)
- 40001 to 49999 are holding registers

All Modbus addresses are one-based, meaning that the first data value starts at address one. The range of valid addresses will depend on the slave device. Different slave devices will support different data types and address ranges.

Installing the Modbus Master Protocol Library

Before you can use the Modbus Master Protocol Library, you must add the library to STEP 7-Micro/WIN.

1. Copy the Modbus Master Protocol Library (modbus master.mwl) to your computer. The library can be placed anywhere on the computer, but the default location for STEP 7-Micro/WIN libraries is the directory:

   C:\Program Files\SIEMENS\Step 7-MicroWin V4.0\Lib\

2. Select the **File > Add/Remove Libraries…** menu option. This will open the Add/Remove Libraries Dialog.

3. Click on the **Add** button and go to the directory where you placed the Modbus Master Protocol Library file (modbus master.mwl or modbus_master_port1.mwl).

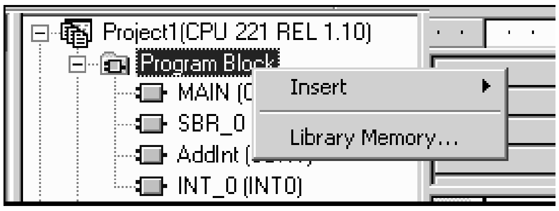
4. Click the **Save** button to install the library. There will now be a new folder under the Libraries entry in the Instruction Tree.

5. Open the Modbus Master (v1.x) folder and you will see the Modbus Master instructions included in the library.

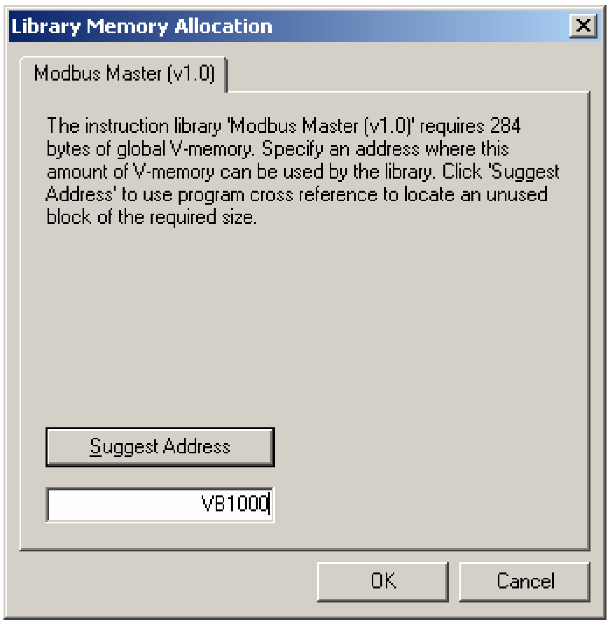
Assigning V Memory to the Modbus Master Library

The Modbus Master Protocol Library requires a block of V memory to operate the Modbus Master instructions. The user must specify the starting address for the block of memory needed by the Modbus Master Library.

Go to the Instruction Tree and right-click on the Program Block entry. You will see the following:



Select the **Library Memory…** option to display the following dialog:



The instruction library 'Modbus Master (v1.0)' requires 284 bytes of global V-memory. Specify an address where this amount of V-memory can be used by the library. Click 'Suggest Address' to use program cross reference to locate an unused block of the required size.

This dialog tells you how much memory is required for the included version of the Modbus Master Library. Click on the **Suggest Address** button to have STEP 7-Micro/WIN suggest an address for the block of V memory, or type in the V memory address where you want to locate the block. The address must be a VB address.

Using the Modbus Master Protocol Instructions

To use the Modbus Master Protocol instructions in your S7-200 program, follow these steps:

1. Install the Modbus Master Protocol Library. This was described in a prior section (Installing the Modbus Master Protocol Library).

2. Insert the MBUS_CTRL instruction in your program and execute the MBUS_CTRL on every scan. You can use the MBUS_CTRL instruction either to initiate or to change the Modbus communications parameters. When you insert the MBUS_CTRL instruction, several protected subroutines and interrupt routines are automatically added to your program.

3. Assign a starting address for the 284 bytes of consecutive V memory required for Modbus Master Protocol instructions as described in the previous section (Assigning V Memory to the Modbus Library).

4. Place one or more MBUS_MSG instructions in your program. You can add as many MBUS_MSG instructions to your program as you require, but only one of these instructions can be active at a time.

5. Connect a communications cable between Port 0 on the S7-200 CPU (or Port 1 for the Port 1 library) and the Modbus slave devices.

Caution: Interconnecting equipment with different reference potentials can cause unwanted currents to flow through the interconnecting cable. These unwanted currents can cause communications errors or damage equipment.

Ensure that all equipment that is connected with a communications cable either shares a common circuit reference or is isolated to prevent unwanted current flows.

The Modbus Master protocol instructions utilize the Modbus functions shown in the table below to read or write a specific Modbus address. The Modbus slave device must support the Modbus function(s) required to read or write a particular Modbus address.

Table 1 – Required Slave Function Support

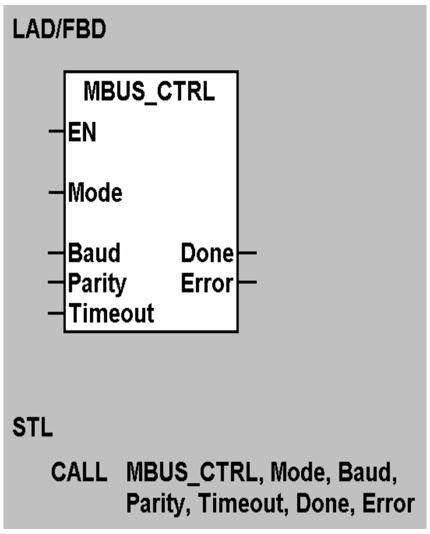
Modbus Address	**Read or Write**	**Modbus Slave Function Required**
00001 – 09999 discrete outputs	Read	Function 1
	Write	Function 5 for a single output point Function 15 for multiple output points
10001 – 19999 discrete inputs	Read	Function 2
	Write	not possible
30001 – 39999 input registers	Read	Function 4
	Write	not possible
40001 – 49999 holding registers	Read	Function 3
	Write	Function 6 for a single register Function 16 for multiple registers

Instructions for the Modbus Master Protocol

MBUS_CTRL Instruction

The MBUS_CTRL instruction (or MBUS_CTRL_P1 for port 1) is used to initialize, monitor or to disable Modbus communications. Before the MBUS_MSG instruction can be used, the MBUS_CTRL instruction must be executed without errors. The instruction completes and the Done bit is set immediately before continuing to the next instruction. This instruction is executed on each scan when the **EN** input is on.

The MBUS_CTRL instruction must be called every scan (including the first scan) to allow it to monitor the progress of any outstanding messages initiated with the MBUS_MSG instruction. The Modbus Master Protocol will not operate correctly unless MBUS_CTRL is called every scan.



The value for the **Mode** input selects the communications protocol. An input value of 1 assigns the CPU port to Modbus protocol and enables the protocol. An input value of 0 assigns the CPU port to PPI system protocol and disables Modbus protocol.

The parameter **Baud** sets the baud rate to 1200, 2400, 4800, 9600, 19200, 38400, 57600, or 115200 baud.

The parameter **Parity** is set to match the parity of the Modbus slave device. All settings use one start bit and one stop bit. The allowed values are:

- 0 - no parity
- 1 - odd parity
- 2 - even parity

The parameter **Timeout** is set to the number of milliseconds to wait for the response from the slave. The Timeout value can be set anywhere in the range of 1 millisecond through 32767 milliseconds. A typical value would be 1000 milliseconds (1 second). The Timeout parameter should be set to a value large enough so that the slave device has time to respond at the selected baud rate.

The Timeout parameter is used to determine if the Modbus slave device is responding to a request. The Timeout value determines how long the Modbus Master will wait for the first character of the response after the last character of the request has been sent. The Modbus Master will receive the entire response from the Modbus slave device if at least one character of the response is received within the Timeout time.

Table 3 – Parameters for the MBUS_CTRL instruction

Inputs/Outputs	**Data Type**	**Operands**
Mode	BOOL	I, Q,M, S, SM, T, C, V, L
Baud	DWORD	VD, ID, QD, MD, SD, SMD, LD, AC, Constant, *VD, *AC, *LD
Parity	BYTE	VB, IB, QB, MB, SB, SMB, LB, AC, Constant, *VD, *AC, *LD
Baud	DWORD	VD, ID, QD, MD, SD, SMD, LD, AC, Constant, *VD, *AC, *LD
Timeout	INT	VW, IW, QW, MW, SW, SMW, LW, AC, Constant, *VD, *AC, *LD
Done	BOOL	I, Q,M, S, SM, T, C, V, L
Error	BYTE	VB, IB, QB, MB, SB, SMB, LB, AC, *VD, *AC,*LD

When the MBUS_CTRL instruction completes, the **Done** output is turned on.

The **Error** output contains the result of executing the instruction. The following table defines the error conditions that could result from executing the MBUS_CTRL instruction.

Table 2 – MBUS_CTRL Error Codes

Error Code	Description
0	No error
1	Parity selection is not valid
2	Baud rate selection is not valid
3	Timeout selection is not valid
4	Mode selection is not valid

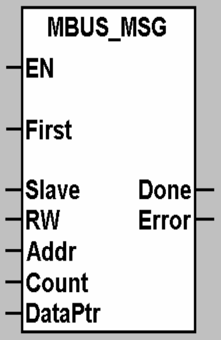
MBUS_MSG Instruction

The MBUS_MSG instruction (or MBUS_MSG_P1 for port 1)is used to initiate a request to a Modbus slave and process the response.

The MBUS_MSG instruction initiates a request to a Modbus slave when the both the EN input and the First inputs are on. Sending the request, waiting for the response and processing the response usually requires several scans. The EN input must be on to enable the sending of the request, and should remain on until the Done bit is set.

Note: **Only one MBUS_MSG instruction can be active at a time. If there is more than one MBUS_MSG instruction enabled, the first MBUS_MSG instruction executed will be processed and all subsequent MBUS_MSG instructions will abort with an error code 6.**

LAD/FBD



STL

CALL MBUS_MSG, First, Slave RW, Addr, Count, DataPtr, Done, Error

The parameter **First** should be on for only one scan when there is a new request to send. The First input should be pulsed on through an edge detection element (i.e. Positive Edge) which will cause the request to be transmitted one time. See the example program below.

The parameter **Slave** is the address of the Modbus slave device. The allowed range is 0 through 247. Address 0 is the broadcast address and can only be used for write requests. There is no response to a broadcast request to address 0. Not all slave devices will support the broadcast address. The S7-200 Modbus Slave Library does not support the broadcast address.

The parameter **RW** specifies if this message is to be a read or a write. The following two values are allowed for RW.

- 0 – Read
- 1 – Write

Discrete outputs (coils) and holding registers support both read and write requests. Discrete inputs (contacts) and input registers only support read requests.

Table 4 – Parameters for the MBUS_MSG instruction

Inputs/Outputs	**Data Type**	**Operands**
First	BOOL	I, Q,M, S, SM, T, C, V, L (Power flow conditioned by a positive edge detection element)
Slave	BYTE	VB, IB, QB, MB, SB, SMB, LB, AC, Constant, *VD, *AC, *LD
RW	BYTE	VB, IB, QB, MB, SB, SMB, LB, AC, Constant, *VD, *AC, *LD
Addr	DWORD	VD, ID, QD, MD, SD, SMD, LD, AC, Constant, *VD, *AC, *LD
Count	INT	VW, IW, QW, MW, SW, SMW, LW, AC, Constant, *VD, *AC, *LD
DataPtr	DWORD	&VB
Done	BOOL	I, Q,M, S, SM, T, C, V, L
Error	BYTE	VB, IB, QB, MB, SB, SMB, LB, AC, *VD, *AC, *LD

The parameter **Addr** is the starting Modbus address.   The following ranges of values are allowed:

- 00001 to 09999 for discrete outputs (coils)
- 10001 to 19999 for discrete inputs (contacts)
- 30001 to 39999 for input registers
- 40001 to 49999 for holding registers

The specific range of values for Addr are based on the addresses that the Modbus slave device supports.

The parameter **Count** specifies then number of data elements to read or write in this request.   The Count will be the number of bits for the bit data types, and the number of words for the word data types.

- Address 0xxxx – Count is the number of bits to read or write
- Address 1xxxx – Count is the number of bits to read
- Address 3xxxx – Count is the number of input register words to read
- Address 4xxxx – Count is the number of holding register words to read or write

The MBUS_MSG instruction will read or write a maximum of 120 words or 1920 bits (240 bytes of data). The actual limit on the value of Count will depend upon the limits in the Modbus slave device.

The parameter **DataPtr** is an indirect address pointer which points to the V memory in the S7-200 CPU for the data associated with the read or write request.   For a read request, DataPtr should point to the first CPU memory location used to store the data read from the Modbus slave. For a write request, DataPtr should point to the first CPU memory location of the data to be sent to the Modbus slave.

The DataPtr value is passed into MBUS_MSG as an indirect address pointer. For example, if the data to be written to a Modbus slave devices starts at address VW200 in the S7-200 CPU, the value for the DataPtr would be &VB200 (address of VB200). Pointers must always be a type VB even if they point to word data.

Holding registers (address 4xxxx) and input registers (address 3xxxx) are word values (2 bytes or 16 bits). S7-200 CPU words are formatted the same as Modbus registers. The lower numbered V-memory address is the most significant byte of the register. The higher numbered V-memory address is the least significant byte of the register. Figure 1 below shows how the S7-200 byte and word addressing corresponds to the Modbus register format.

Figure 1 – S7-200 CPU Memory and Holding Registers (data in hexadecimal)

S7-200 CPU Memory with Byte Addressing

VB200	12
VB201	34
VB202	56
VB203	78
VB204	9A
VB205	BC

S7-200 CPU Memory with Word Addressing

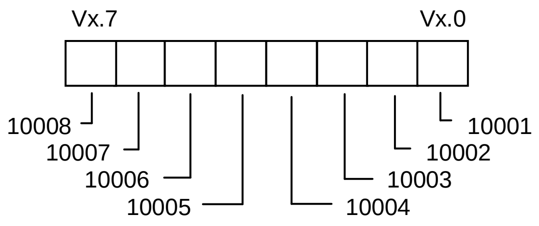
VW200	12 34
VW202	56 78
VW204	9A BC

Modbus Holding Registers

40001	12 34
40002	56 78
40003	9A BC

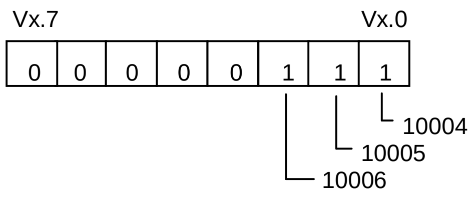
The bit data (addresses 0xxxx and 1xxxx) areas are read and written as packed bytes, that is, 8 bits are packed into each byte of data. The least significant bit of the first data byte is the addressed bit number (the parameter Addr). If only a single bit is written then the bit must be in the least significant bit of the byte pointed to by DataPtr.

Figure 2 – Format for Packed Bytes (Discrete input addresses shown)



For bit data addresses that do not start on even byte boundaries, the bit corresponding to the starting address must be must be in the least significant bit of the byte. See Figure 3 for an example of the packed byte format for 3 bits starting at Modbus address 10004.

Figure 3 – Format for Packed Bytes (Discrete input starting at address 10004)



When writing to the discrete output data type (coils), the user is responsible for placing the bits in the correct bit positions within the packed byte before the data is passed to the MBUS_MSG instruction via DataPtr.

The **Done** output is off while a request is being sent and the response is being received. The Done output is on when the response is complete or when the MBUS_MSG instruction was aborted because of an error.

The **Error** output is valid only when the Done output is on. Table 5 on the next page is a list of error codes returned by the MBUS_MSG instruction.

The low numbered error codes (1 through 8) are errors that are detected by the MBUS_MSG instruction. These error codes generally indicate a problem with the input parameters of the MBUS_MSG instruction, or a problem receiving the response from the slave. Parity and CRC errors indicate that there was a response but that the data was not received correctly. This is usually caused by an electrical problem such as a bad connection or electrical noise.

The high numbered error codes (starting with 101) are errors that are returned by the Modbus slave device. These errors indicate that the slave does not support the requested function or that the requested address (either data type or range of addresses) is not supported by the Modbus slave device.

Table 5 – MBUS_MSG Error Codes

Error Code	Description
0	No error
1	Parity error in response. This is only possible if even or odd parity is used. The transmission was disturbed and possibly incorrect data was received. This error is usually caused by an electrical problem such as incorrect wiring or electrical noise affecting the communication.
2	Not used
3	Receive timeout. There was no response from the slave within the Timeout time. Some possible causes are: bad electrical connection to the slave device, master and slave are set to different baud rates and/or parity settings, incorrect slave address.
4	Error in request parameter. One or more of the input parameters (Slave, RW, Addr, or Count) is set to an illegal value. Check the documentation for allowed values for the input parameters.
5	Modbus master not enabled. Call MBUS_CTRL on every scan prior to calling MBUS_MSG.
6	Modbus is busy with another request. Only one MBUS_MSG instruction can be active at a time.
7	Error in response. The response received does not correspond to the request. This indicates some problem in the slave device or that the wrong slave device answered the request.
8	CRC error in response. The transmission was disturbed and possibly incorrect data was received. This error is usually caused by an electrical problem such as incorrect wiring or electrical noise affecting the communication.
101	Slave does not support the requested function. See Table 1 for the required slave function support needed for the requested address.
102	Slave does not support the data address. The requested address range of Addr plus Count is outside the allowed address range of the slave.
103	Slave does not support the data type. The Addr type is not supported by the slave device.
104	Slave device failure.
105	Slave accepted the message but the response is delayed. This is an error for MBUS_MSG and the user program should resend the request at a later time.
106	Slave is busy and rejected the message. You can try the same request again to get a response.
107	Slave rejected the message for an unknown reason.
108	Slave memory parity error. There is an error in the slave device.

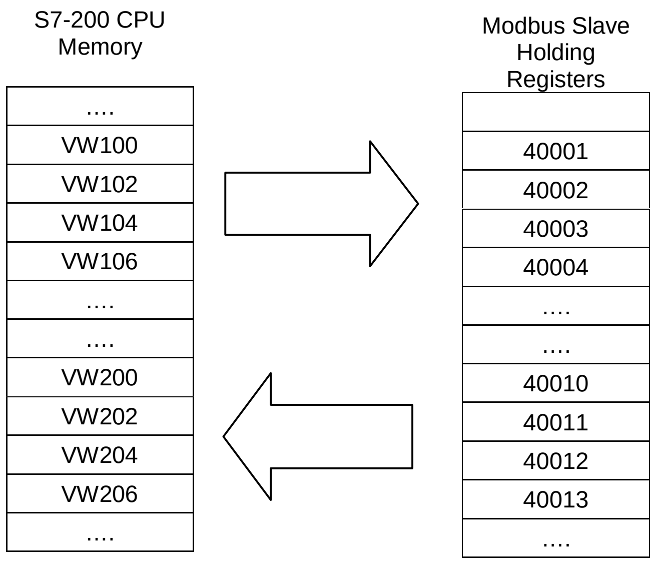
Example Program

This example program shows how to use the Modbus Master instructions to write and then read 4 holding registers to and from a Modbus slave each time input I0.0 is turned on.

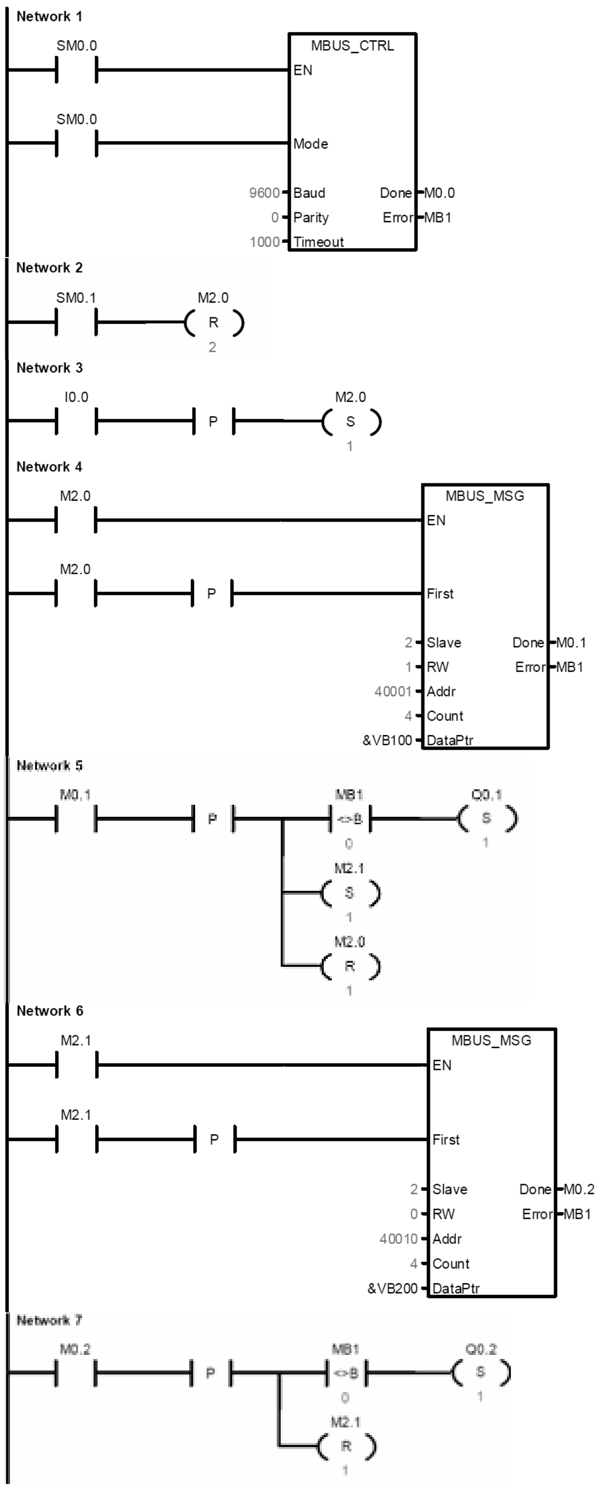
The S7-200 CPU will write 4 words starting at VW100 to the Modbus stave. The data will be written to 4 holding registers in the slave starting at address 40001.

The S7-200 CPU will then read 4 holding registers from the Modbus stave. The data will come from holding registers 40010 – 40013 and be placed into the V-memory of the S7-200 CPU starting at VW200.

Figure 4 – Example Program Data Transfers



The program will turn on outputs Q0.1 and Q0.2 if there is an error returned from the MBUS_MSG instructions.



Initialize and monitor the Modbus Master by calling MBUS_CTRL on every scan.

The Modbus Master is set for 9600 baud and no parity. The slave is allowed 1000 milliseconds (1 second) to respond.

On the first scan reset the enable flags (M2.0 and M2.1) used for the two MBUS_MSG instructions.

When I0.0 changes from OFF to ON, set the enable flag for the first MBUS_MSG instruction (M2.0).

Call the MBUS_MSG instruction when the first enable flag (M2.0) is ON. The First parameter must be set for only the first scan that the instruction is enabled.

This instruction writes (RW = 1) 4 holding registers to slave 2. The write data is taken from VB100–VB107 (4 words) in the CPU and written to address 40001 – 40004 in the Modbus slave.

When the first MBUS_MSG instruction is complete (Done goes from 0 to 1), clear the enable for the first MBUS_MSG and set the enable for the second MBUS_MSG instruction.

If Error (MB1) is not zero then set Q0.1 to show the error.

Call the second MBUS_MSG instruction when the second enable flag (M2.1) is ON. The First parameter must be set for only the first scan that the instruction is enabled.

This instruction reads (RW = 0) 4 holding registers from slave 2. The data is read from address 40010 – 40013 in the Modbus slave and copied to VB200 – VB207 (4 words) in the CPU.

When the second MBUS_MSG instruction is complete (Done goes from 0 to 1), clear the enable for the second MBUS_MSG instruction.

If Error (MB1) is not zero then set Q0.2 to show the error.

Advanced Information

This section contains information for advanced uses of the Modbus Master Protocol Library. Most users of the Modbus Master Protocol Library should not need this information and should not modify the default operation of the Modbus Master Protocol Library.

Retries

The Modbus Master instructions will automatically resend the request to the slave device if one of the following errors is detected:

- There is no response within the response timeout time (parameter Timeout on the MBUS_CTRL) instruction (Error code 3).
- The time between characters of the response exceeded the allow value (Error code 3).
- There is a parity error in the response from the slave (Error code 1).
- There is a CRC error in the response from the slave (Error code 8).
- The returned function did not match the request (Error code 7).

The Modbus Master will resend the request two additional times before setting the Done and Error output parameters.

The number of retries can be changed by finding the symbol *mModbusRetries* in the Modbus Master symbol table and changing this value after MBUS_CTRL has been executed. The *mModbusRetries* value is a BYTE with a range of 0 to 255 retries.

Intercharacter Timeout

The Modbus Master will abort a response from a slave device if the time between characters in the response exceeds a specified time limit. The default time is set to 100 milliseconds which should allow the Modbus Master Protocol to work with most slave devices over wire or telephone modems. If this error is detected, the MBUS CTRL Error parameter will be set to error code 3.

There may be cases where a longer time between characters is required, either because of the transmission medium (i.e. telephone modem) or because the slave device itself requires more time. This timeout can be lengthened by finding the symbol *mModbusCharTimeout* in the Modbus Master symbol table and changing this value after MBUS_CTRL has been executed. The *mModbusCharTimeout* value is an INT with a range of 1 to 30000 milliseconds.

Single vs. Multiple Bit/Word Write Functions

Some Modbus slave devices do not support the Modbus functions to write a single discrete output bit (Modbus function 5) or to write a single holding register (Modbus function 6). These devices only support the multiple bit write (Modbus function 15) or multiple register write (Modbus function 16) instead. The MBUS_MSG instruction will return an error code 101 if the slave device does not support the single bit/word Modbus functions.

The Modbus Master Protocol allows you to force the MBUS_MSG instruction to use the multiple bit/word Modbus functions instead of the single bit/word Modbus functions. You can force the multiple bit/word instructions by finding the symbol *mModbusForceMulti* in the Modbus Master symbol table and changing this value after MBUS_CTRL has been executed. The *mModbusForceMulti* value is an BOOL value and should be set to a ‘1’ to force the use of the multiple bit/word functions when a single bit/register is written.

Accumulator Usage

The accumulators (AC0, AC1, AC2, AC3) are utilized by the Modbus Master instructions and appear in the Cross Reference listing. The values in the accumulators are saved and restored by the Modbus Master instructions. All user data in the accumulators is preserved while executing the Modbus Master instructions.

Holding Registers Addresses Greater Than 9999

Modbus holding addresses are generally within the range of 40001 through 49999. This range is adequate for most applications but there are some Modbus slave devices with data mapped into holding registers with addresses greater than 9999. These devices do not fit the normal Modbus addressing scheme.

The Modbus Master instructions support addressing holding registers greater than 9999 via an alternate addressing method. The MBUS_MSG instruction allows an additional range for the parameter **Addr** to support an extended range of holding register addresses.

- 400001 to 465536 for holding registers

For example: to access holding register 16768, the **Addr** parameter of MBUS_MSG should be set to 416768.

The extended addressing allows access to the full range of 65536 possible addresses supported by the Modbus protocol. This extended addressing is only supported for holding registers.