

Application Note

MODBUS RTU Protocol, Addressing, Wiring & Programming

Introduction

This document describes programming MODBUS RTU with SoundWater flowmeters, as well as wiring RS485 half duplex (two wire) and full duplex (four wire) networks.

Background

MODBUS RTU

MODBUS[®] Protocol is a messaging structure, used to establish master-slave communication between electronic devices. A MODBUS message sent from a master to a slave call a "request" contains the address of the slave, command, command data, and a check sum. A MODBUS message sent from a slave to a master is called a "response". A slave may only respond to the master, i.e., it may not initiate a request to the master. Whether request or response, the message is a packet of data bytes called an Application Data Unit (ADU). The ADU is simply a packet of bytes containing the slave id, command, command data, and check sum.

The ADU fields all have byte size requirements (shown in figure 1). The Slave Id is one byte (0-FF), Function Code is one byte (0-FF), data may be N bytes, and the check sum must be two bytes (0 - FFFF). The entire ADU size must not exceed 256 bytes.

Since Modbus protocol is just a messaging structure, it is independent of the underlying physical layer. It is traditionally implemented using TCP/IP, RS232, RS422, or RS485. SoundWater flowmeters utilize an RS485 physical layer.

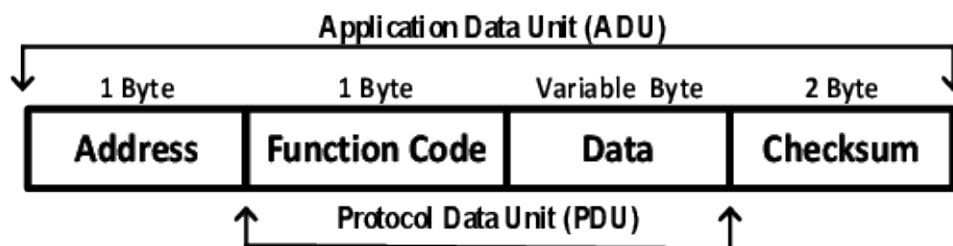


Figure 1 This figure displays all fields of an ADU packet.

Application Data Units (ADU)

The Master Request ADU

The request is an ADU transmitted by the master and received by the slave. It contains a byte called a function code which tells the addressed slave device what kind of action to perform. The bytes following the function code contain any additional information that the slave will need to perform the action. For example, function code 03 will request the slave to read holding registers and respond with their contents. The command's data field must then contain the information indicating to the slave which register to start at and how many registers to read. The error check field, or CRC, provides a method for the slave to validate the integrity of the message contents.

The Slave Response ADU

The response to a request is an ADU transmitted by the slave to the master. In a normal response, the function code in the response is an echo of the function code from the request. The response data bytes contain all data collected by the slave, such as register values or status. If an error occurs, the function code is modified to indicate that the response is an error response, and the data bytes contain a code that describes the error. The error check field allows the master to confirm that the ADU contents are valid.

ADU Framing

In RTU mode, ADU packets are framed by silent intervals - which can be specified by the user via the SoundWater flowmeter display and setup menus. The silent intervals parameter is known as a timeout. After a timeout, the first field transmitted in the ADU packet is the device address, followed by the function code, data, and checksum fields. Following the last transmitted character of the check sum field, another timeout (silent interval) marks the end of the message packet. A new message can then begin after this interval.

The entire message frame must be transmitted as a continuous stream. If a timeout occurs during the message transmission, then the final CRC field will not be valid for the message, and the slave will then respond with an error code.

Transmission Mode

Controllers can be setup to communicate on standard Modbus networks using either of two transmission modes: ASCII or RTU. SoundWater products all use RTU mode, so ASCII will not be covered herein.

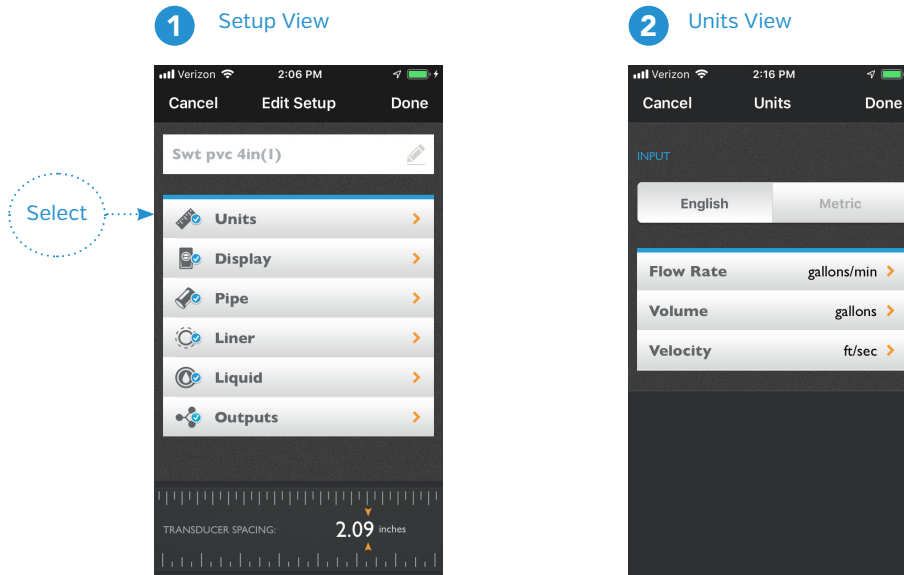
When controllers are setup to communicate on a Modbus network using RTU (Remote Terminal Unit) mode, each byte in a message contains two hexadecimal characters. The main advantage of this mode is that its greater character density allows better data throughput than ASCII for the same baud rate. Each message must be transmitted in a continuous stream.

The allowable characters transmitted for all fields are hexadecimal 0 ... 9, A ... F. Networked devices monitor the network bus continuously, including during the silent intervals. When the first field (the address field) is received, each device decodes it to find out if it is the addressed device.

Programming Setup

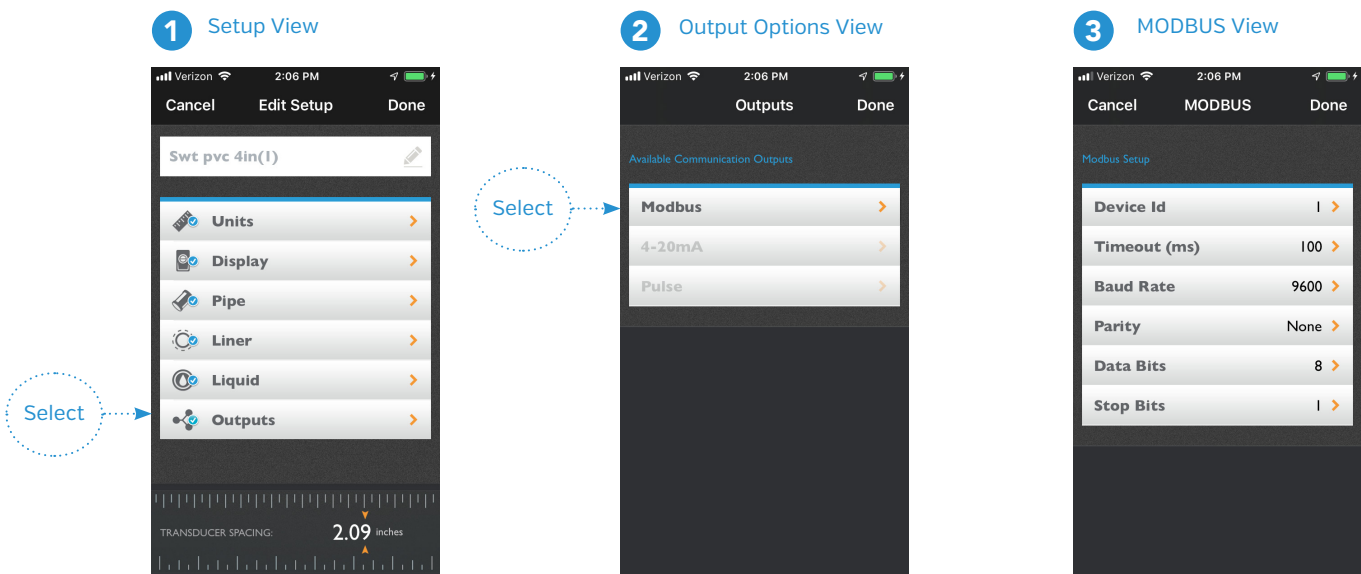
Units Selection

Any numerical flow value returned by *Orcas SP*, or *Camano* flowmeters is associated with a unit., e.g., gallons/minute [flow rate], or Acre-Feet [volume]. Units for flow rate, volume [total], or velocity may be selected from the flowmeter's display (user interface) and "Setup" view. Image one below, displays the *Orcas SP* "Setup" view. From Setup view, simply select the first menu option "Units" to navigate to the "Units" view (image two) where units may be selected for each type of measurement.



Ports Settings & Slave Identification

Port Settings for the MODBUS physical layer (RS 485) may be configured from the flowmeter's display (user interface) by navigating to the MODBUS setup menu. Configuration options include slave ID, timeout, baud rate, parity, stop bits, and data bits. Image one below, displays the *Orcas SP* "Setup" view. From Setup view, simply select the item labeled "Outputs" to navigate to the "Outputs" view (image two). Next, select the item labeled "MODBUS" to navigate to the "MODBUS" view (image three) where the MODBUS physical layer may be configured. Simply select any MODBUS menu item and select the desired configuration from a list of options.



Addressing

Register Address Table

Table 1 lists all readable registers for SoundWater flowmeters. Any address may be read by issuing an ADU with function code 0x03. Each register is associated with a two byte address. The Response ADU contains a data field with a four byte floating point number. Each register is a two byte data value. To read a complete data value from a flowmeter, the number registers read must be two, which would return the complete four byte floating point number [See the Examples section below].

Register Address	Number of Registers	Data Byte Size	Description
0x0001	2	4	Flow rate in user defined units
0x0003	2	4	Flow velocity in user defined units
0x0005	2	4	Flow volume in user defined units
0x0007	2	4	Measured liquid sound speed in user defined units
0x0009	2	4	Ultrasound signal quality as percentage (0% worst, 100% best)

Coil Address Table

Table 2 lists all writable coils for SoundWater flowmeters. Any coil may be set/cleared by issuing an ADU with function code 0x05. Each coil register is associated with a two byte address. The Request ADU must contain a two byte value of 0xFF00 or 0x0000 to set the coil ON or OFF respectively [See the Examples section below].

Register Address	Description
0x0001	Reset flow volume

Error Code Table

Table 3 lists errors codes. These codes are returned in the response ADU error code field when an error occurs.

Error Code	Description
0x01	Invalid function code.
0x02	Invalid register address.
0x03	Invalid data value.
0x04	Slave device error. An internal error occurred.

Examples

Reading Registers

This first example below displays the request and response ADU's for reading flow rate from a flowmeter. In this case the slave ID of the flowmeter was programmed as 0x01. The flow rate returned has a value of 122.8 when converted to a floating point number. Note that units may be setup from the flowmeter display and setup menus [See the User Instruction Manual for either *Orcas SP* or *Camano* for more detail regarding menu navigation and setup].

	Slave ID	Function Code	Start Address (flow rate)	Num Registers	Check Sum (CRC)
Master Request ADU:	[0x01]	[0x03]	[0x00][0x01]	[0x00][0x02]	[0x95][0xCB]
	Slave ID	Function Code	Num Data Bytes	Data Bytes	Check Sum (CRC)
Slave Response ADU:	[0x01]	[0x03]	[0x04]	[0x42][0xF5][0xA4][0x23]	[0xC5][0x60]

Writing Coils

The next example below displays the request and response ADU's for resetting a flowmeter's totalized flow volume.

	Slave ID	Function Code	Coil Address	Coil Data	Check Sum (CRC)
Master Request ADU:	[0x01]	[0x05]	[0x00][0x01]	[0xFF][0x00]	[0xDD][0xFA]
	Slave ID	Function Code	Coil Address	Coil Data	Check Sum (CRC)
Slave Response ADU:	[0x01]	[0x05]	[0x00][0x01]	[0xFF][0x00]	[0xDD][0xFA]

Error Handling

This last example below shows the request and response ADU when an error occurs. In this particular example the request ADU contains a command to reset the flowmeter totalized volume. However, the request ADU's function code is invalid (i.e., it is not a function code that is listed in Table 1). The slave responds by echoing the function code, and also places an error code in the data field. To signify an error response ADU, the highest bit in the function code is set.

	Slave ID	Function Code	Coil Address	Coil Data	Check Sum (CRC)
Master Request ADU:	[0x01]	[0x0F]	[0x00][0x0F]	[0xFF][0x00]	[0xBC][0x39]
	Slave ID	Function Code	Error Code	Check Sum (CRC)	
Slave Response ADU:	[0x01]	[0x85]	[0x02]	[0xF4][0xC3]	

Note that the high bit in the response function code is set to signify an error. Also, note the error code 0x02 is an "invalid register address" as shown in Table 3 "Error Code Table."

Hardware Wiring

SoundWater Flowmeters may be wired to RS485 MODBUS RTU networks. However, specific wiring depends upon the flowmeter model. *Orcas SP* may ONLY be wired as two wire [half duplex], while *Camano* may be wired as either two wire [half duplex] or four wire [full duplex]. Wiring diagrams for half duplex (two wire), full duplex (four wire), and full duplex converted to half duplex (four wire converted to two wire) are shown below.

Two Wire Networks (Half Duplex)

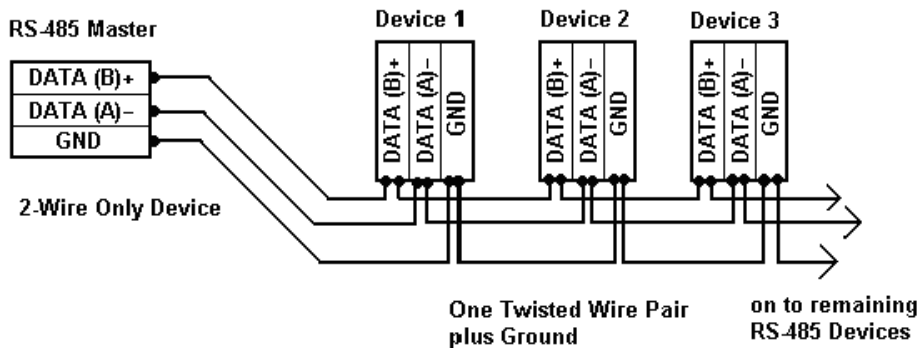
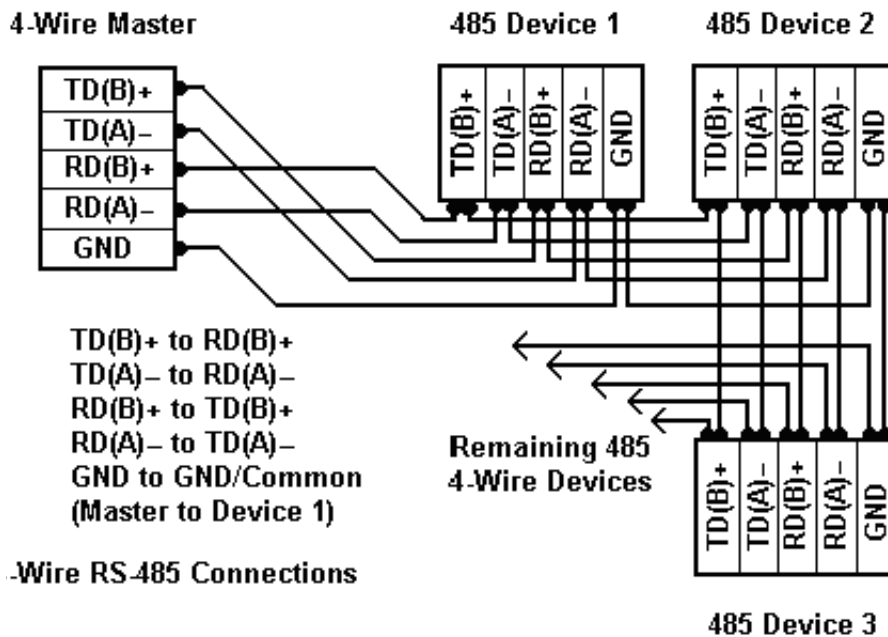


Fig. 1
2-Wire RS-485 Connections

Four Wire Networks (Full Duplex)



4-Wire RS-485 Connections

Hardware Wiring Clontinued...

Two Wire Converted Networks (Full to Half Duplex)

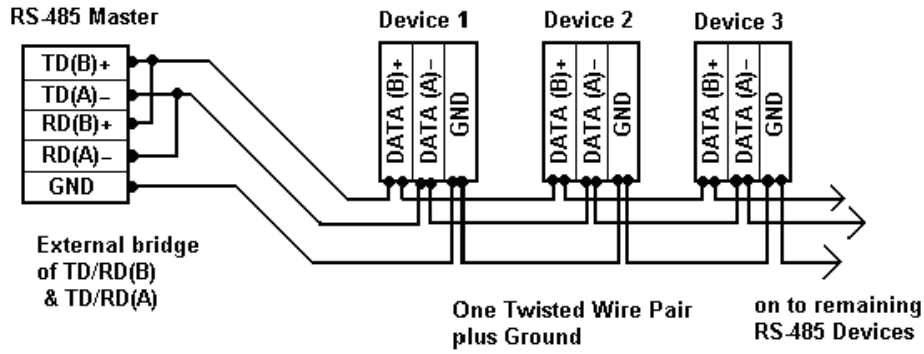


Fig. 3
2-Wire RS-485 Connections