



O & M Manual



Model Q46 Modbus RTU Communications Manual

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Part 1 – Modbus RTU Description

1.1 Modbus Technical Overview

Modbus protocol is a messaging structure, widely used to establish master-slave communication between intelligent devices. A message sent from a master to a slave contains a one-byte slave address, a one-byte command, data bytes (depending on command), and a two byte CRC. The protocol is independent of the underlying physical layer and is traditionally implemented using RS232, RS422, or RS485 over a variety of media (e.g. fiber, radio, cellular, etc.).

The protocol comes in 2 flavors – ASCII and RTU. The formats of messages are identical in both forms, except that the ASCII form transmits each byte of the message as two ASCII hexadecimal characters. Therefore, ASCII messages are twice as long as RTU messages. The main advantage of the RTU mode is that it achieves higher throughput, while the ASCII mode allows time intervals of up to 1 second to occur between characters without causing an error. As stated earlier, the transmitter uses the RTU form and does not support the ASCII form.

The basic structure of an RTU frame is shown below:

[ADDRESS][FUNCTION][DATA][CRC]

The address field of a message frame contains an eight-bit slave device address in the range of 0 ... 247 decimal. The individual slave devices are assigned addresses in the range of 1 ... 247, and address 0 is reserved as a broadcast address. A master addresses a slave by placing the slave address in the address field of the message. When the slave sends its response message, it places its own address in this address field of the response to let the master know which slave is responding. All slaves accept broadcast messages (address 0) as though they were addressed specifically to them, but do not transmit a response message.

The function code field of a message frame contains an eight-bit code in the range of 1 ... 255 decimal. When a query message is sent from the master, the function code field tells the slave device what kind of action to perform. Examples include reading the contents of a group of registers, writing to a single register, writing to a group of registers, and reading the exception status.

When the slave device responds to the master, it uses the function code field to indicate either a normal (error-free) response or that some kind of error occurred (called an exception response). For a normal response, the slave simply echoes the original function code. For an exception response, the slave returns a code that is equivalent to the original function code with its most significant bit set to logic 1.

The data field is constructed of one or more bytes and contains additional information, which the slave must use to take the action defined by the function code. This can include items like discrete and register addresses, the quantity of items to be handled, and the count of actual data bytes in the field.

If no error occurs, the data field of a response from a slave to a master contains the data requested. If an error occurs, the field contains an exception code that the master application can use to determine the next action to be taken.

The data field can be nonexistent (of zero length) in certain kinds of messages. For example, in a request from a master device for a slave to respond with its communications event log (function code 0B hexadecimal), the slave does not require any additional information. The function code alone specifies the action.

Messages are terminated with a 16-bit CRC value that is computed from all of the bytes of the message. The two byte CRC is superior to just simple checksums because it can help reject more types of errors.

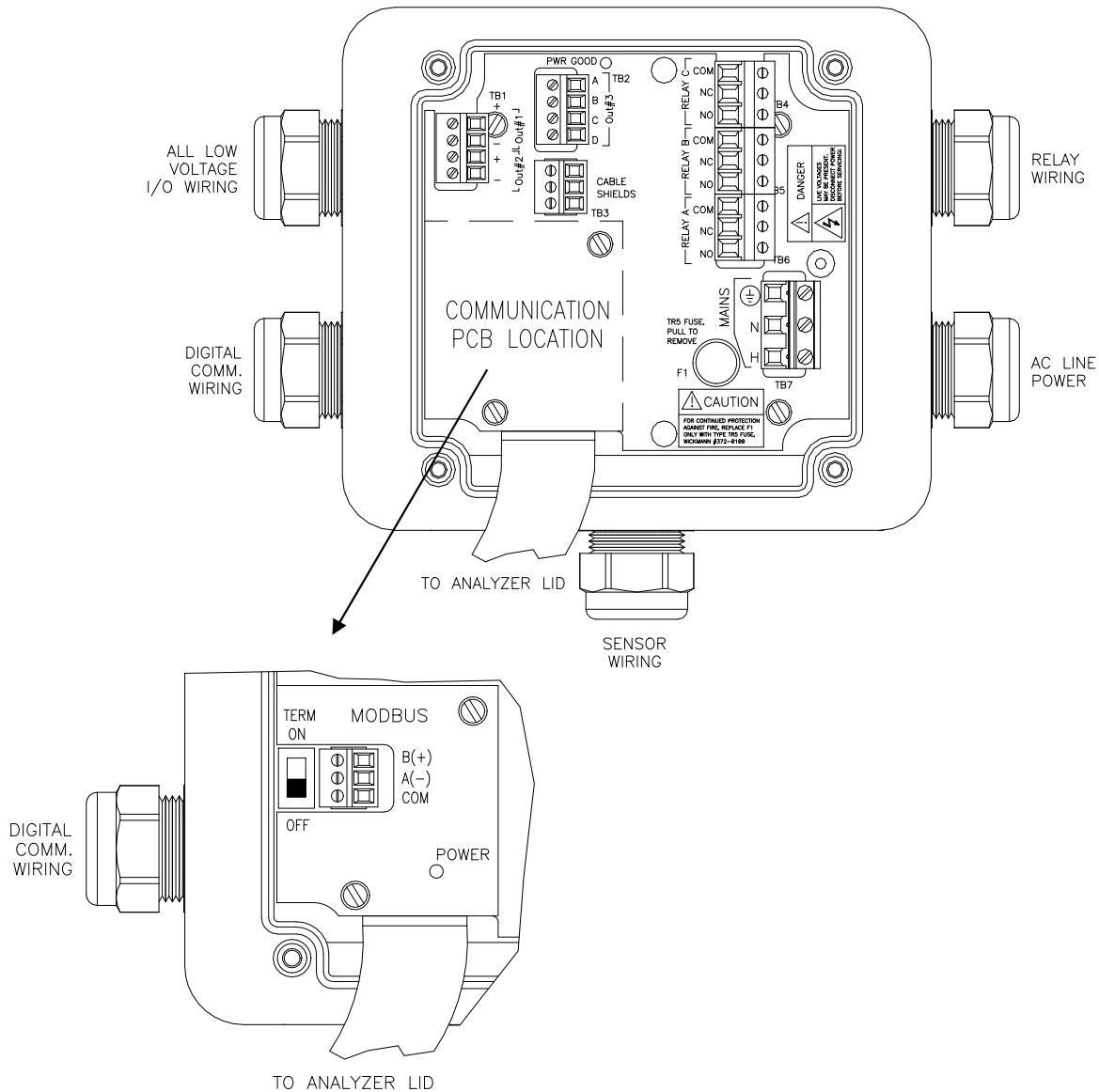


Figure 1 - Modbus Terminal Connections

1.2 Modbus Connection

Modbus wiring is done at a plug-in communication circuit board located in the outlined section of Figure 12 above. A call-out in that figure shows the location of RS-485 connections. The earth ground wire in the 485 cable should be terminated at “COM” on the Modbus card.

1.3 Registers and Coils

Modbus RTU protocol was originally designed to transfer data to and from PLCs (Programmable Logic Controllers), which organize data into groups of registers and coils. PLC registers containing i/o information are called input registers and are numbered 30001 to 39999, while registers containing data or the results of calculations are known as holding registers and are numbered from 40001 to 49999. The term coils, on the other hand, refers to discrete (0 or 1) inputs and outputs. Traditionally, these are inputs from such things as switch closures and outputs to the coils of relays, which are under the control of the PLC.

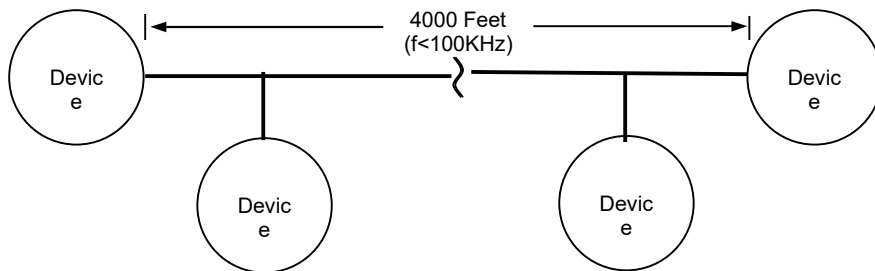
All registers are 16 bit values, which may be read or written to individually, or in blocks by using specific functions. Likewise for coils, which are one bit values. Since register functions transfer 16 bits and discrete (coil) functions transfer only one, it is usually more efficient to use register functions, which reduces the number of messages required to transfer data. For this reason, the Q46 Series transmitter organizes all of its data into input registers only, or more specifically, data is organized into the holding registers starting at 30001.

The protocol specifies which registers to access by the value of the function code embedded into the message. For example, to read one or more holding registers in a slave device, the master must use function 3 – “Read Holding Register”. Similarly, the master must use function 4 – “Read Input Register” to read one or more of the input registers. The Q46 only responds to request for reading input registers (Function 4).

For more information on the protocol, please refer to the “Modicon Modbus Protocol Reference Guide” at <http://www.modicon.com/techpubs/toc7.html> or, “Modbus Protocol Specification”, available for download at <http://www.modbus-ida.org/specs.php>. Deviations from this guide are noted in the appropriate section. More information regarding Modbus, in general, may be viewed at: <http://www.modbus-ida.org/>

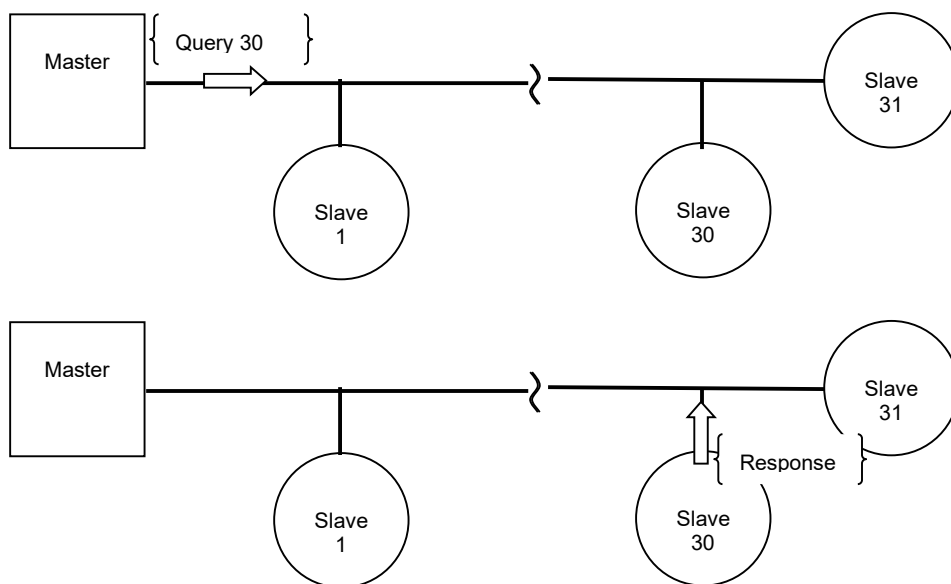
1.4 RS-485 Communication

Modbus data transmission is an RS-485 based communication protocol. The RS485 standard specifies a two-wire, half-duplex serial data bus for connecting up to 32 devices in parallel, at distances of up to 4000 feet at transmission rates at or below 100KHz. The RS485 standard allows the user to configure inexpensive local networks and multi-drop communications links using a twisted pair cable. A typical RS485 network can operate properly in the presence of reasonable ground differential voltages, withstand driver contentious situations, and provide reliable communications in electrically noisy environments with good common mode rejection.

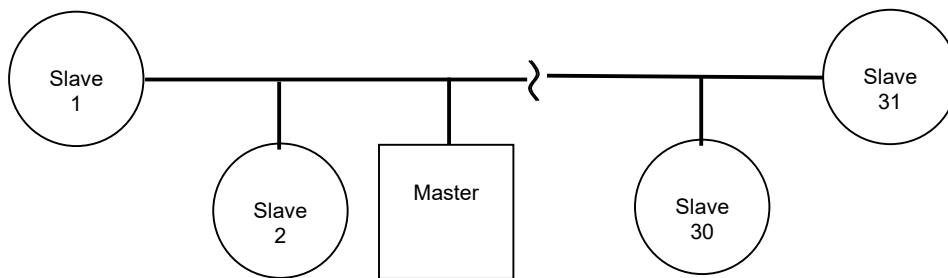


Half-duplex means outgoing messages share the same physical medium with incoming messages. Only one device may transmit at any given time. During any exchange of data communication, one device must act as master and one or more devices act as slaves. With no activity on the bus, the master device sends an addressed query to a slave and then gives up the bus. All slaves receive the message, but only the addressed slave responds.

Series Q46 Analyzer use a plug-in Modbus circuit board shown in Figure 6 on of this manual. Wiring connections for the communication bus are shown in that Figure.



The master node may be located anywhere on the network, not just at one end.

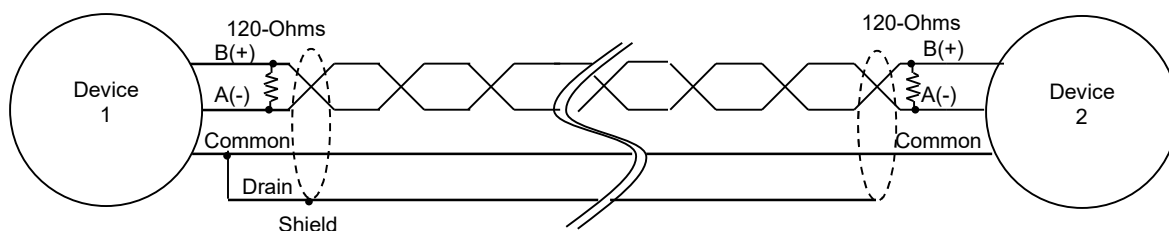


1.5 Cable Specification

The bus is a cable composed of a twisted pair of wires with a characteristic impedance of 120 ohms, and a 120-ohm termination resistor connecting the pair of wires at each end. Several manufacturers offer cables specifically designed for RS485, such as Belden's 3106A, which features one twisted pair, a separate signal common, a foil shield, and a drain wire in contact with the shield.

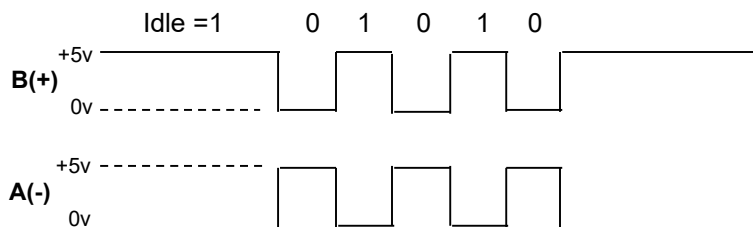


The twisted pair, labeled A and B (or – and +, respectively), form a differential transmission line capable of operating over a common mode voltage range from $-7v$ to $+12v$ ^(note 2). That is, the ground potential at each end of the network may differ by this amount. Connecting a signal common to each slave device will keep this potential to a minimum. The shield around the conductors provides protection from EMI (electromagnetic interference) and should be connected to common or ground at only one point to avoid circulating currents that might actually generate interference on the inner conductors. A schematic of the bus is shown below.



1.6 RS-485 Line Drivers/Receivers

The differential lines, A and B, may be operated at TTL levels of 0 and 5 volts. The RS485 line driver outputs the logic high state (marking, or idle state) by driving 5 volts on B, and 0 volts on A. Conversely, the driver outputs the logic low state (spacing) by driving 5 volts on A, and 0 volts on B.



Over a distance of 4000 feet, the 5 volts applied to either line may be dropped significantly. This usually doesn't present a problem since RS485 receivers are specified to operate with a differential voltage of only 0.200 volts. In practice, however, the differential voltage should remain above 1.5v.

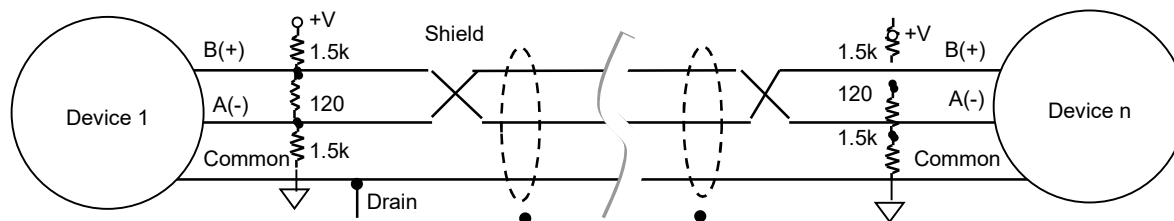
Logic State High (Idle or Marking State): $(B - A) \geq 200\text{mV}$
 Logic State Low (Spacing State): $(A - B) \geq 200\text{mV}$

1.7 120 Ohm Termination

The two devices at the furthest end of the bus require termination resistors to cancel reflections. Intermediate devices do not. The Q46 has a selectable termination resistor on the Modbus card just behind the terminal strip. **ONLY** set to "ON" position if the Q46 is an End-of-Bus unit.

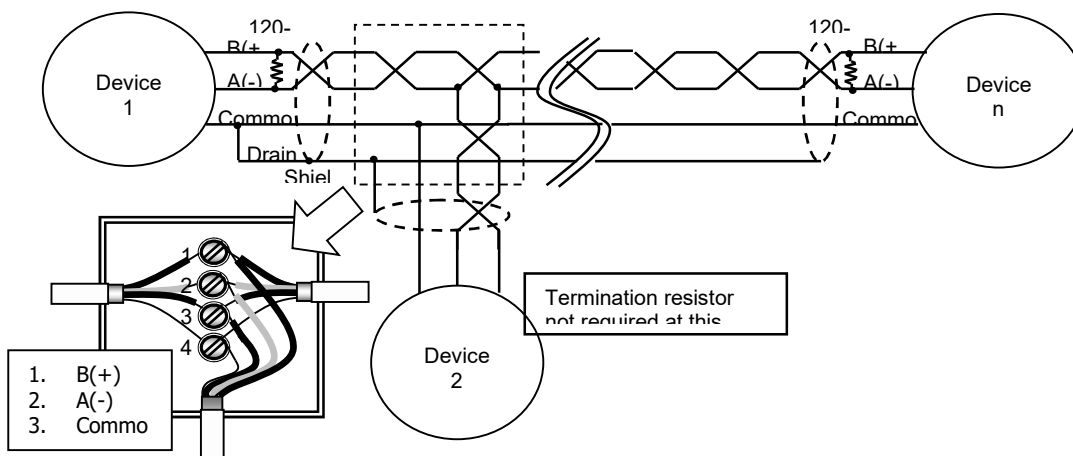
1.8 Bias

When there is no communication on the network, the A and B lines are floating. A small amount of noise could appear as the start of a message, which might interfere with the framing of valid messages. Biasing the transmission line keeps it in the idle state while it is not driven. The bias resistors maintain a differential of 200mV between the A and B lines. Note that bias resistors are not required for Q46 Series transmitters, as the Modbus driver includes a "Failsafe" built-in Bias Design.



1.9 Drops

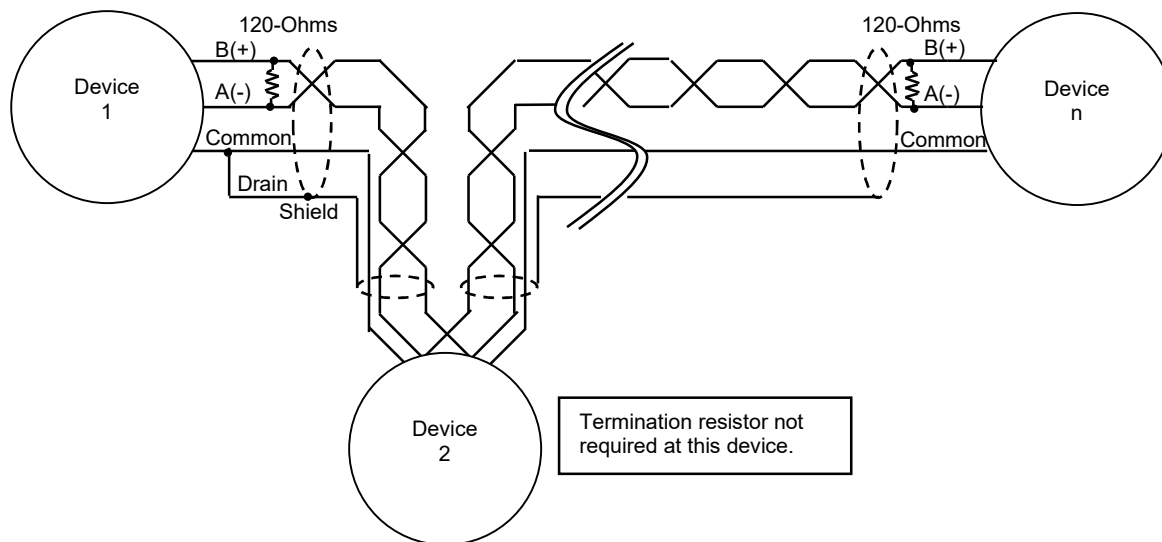
Often, a short length of cable is used at a junction box to form a branch, or “drop”, from the bus to the device. These cables must very short as compared to the main trunk length of the bus so as to avoid signal reflections and require termination that would load the bus excessively. A rule of thumb is to not allow any single branch length to exceed 3% of the total trunk length. Again, only the devices at each end of bus require termination resistors, intermediate connections along the bus do not (bias resistors not shown for clarity).



Long branches requiring termination may be connected, however, a repeater must be used at a short distance from the connection. Star topologies should be avoided, since terminating each spoke will load the network excessively and reliable communications cannot be guaranteed.

1.10 Daisy Chaining

For devices not located at the ends of the bus, it may be possible to run the cable in and out of the device, a practice referred to as “daisy-chaining”. Although this method eliminates the need for a separate drop wire, it will require more connections inside the transmitter housing and therefore consume more space.



1.11 Shielding

While it goes against conventional wisdom and can cause a problem with circulating currents, grounding a shielded cable at both ends can be very effective at keeping induced electrical noise away from the communications lines. In the alternative, ground one end of the shield and connect the other end to ground through a bi-directional transient protector (from a few volts to a few hundred volts depending on the situation).

Note that Q46 Series transmitters are galvanically isolated from the RS-485 (Modbus) port. And utilize extensive spike/surge protection from lightening and other electrical sources.

1.12 Slave Connection Detail

The Modbus RTU connection settings will appear in the CONFIG listing of the Q46 software once the menu item “**^Com Mode**” has been set to “**3-Modb.**” Once set, Modbus menu items for slave, baud, etc. will appear in CONFIG listed menus. Note that those follow-up menus only appear if 3-Modb is selected.

Once set to Modb...

- 1- Press UP arrow. Now you will see the menu “**^Com Address**” come up next. Default Address is 101. Range of entry is 1-247.
- 2- Press UP arrow. Next you will see the menu “**^Com Baud**” come up. Default is 9.6kHz. Range of entry is 200 Hz, 600 Hz, 1200 Hz, 2400 Hz, 4800 Hz, 9600 Hz, 14.4 kHz, 19.2 kHz, 28.8 kHz, 38.4 kHz, 57.6 kHz, 115.2 kHz.
- 3- Press UP arrow. Next you will see the menu “**^Com Parity**” come up. Default is 1-none. Range of entry is 1-none, 2-odd, 3-even. Stop bits are adjusted automatically to 1 or 2.

We recommend a simple master Modbus RTU test program, by the name of SimplyModbus, for any pre-testing of Modbus slaves. This particular program is very easy to use, and provides many same-page fields to enter all required communication parameters on one screen. In addition, this test program allows the user the flexibility to set different data types by combining various numbers of 16-bit registers into any desired field length.

<http://www.simplymodbus.ca/RTUmaster.htm>

NOTE - On the Q46 power supply, the green **POWER** light on the Modbus RTU interface board in the lower left corner should be flashing to indicate it is powered and operating. In addition, the green **PWR GOOD** light at the top of the actual Q46 power supply board should be quickly triple flashing to indicate that the power supply has initialized the Modbus RTU interface board.

Here is a screenshot the Simply Modbus PC tool, and an FTDI USB/RS485 interface cable used to make the physical connection. This particular test is running at all the default settings of slave address 101, 9.6 kHz baud, 8 data bits, no parity. The Q46 only responds to “input” register requests (30000 block,) so only function code 4 is accepted. 10 total registers contain measurement data. Endian arrangement is set in the high byte/low byte, high/word low word check box.

Simply Modbus Master 7.1.2

mode: RTU, COM port: 3, baud: 9600, data bits: 8, stop bits: 2, parity: none

Slave ID: 101, First Register: 0, No. of Regs: 10

function code: 4, minus offset: 0, 16 bit registers

Request: 65 04 00 00 00 0A 78 29

Response: 65 04 14 00 00 02 FD 00 00 0B 5C 00 00 03 E5 00 00 00 00 00 00 00 00 31 64 58

copy down	register #	bytes	results	notes	clear notes
32bit INT	0	0000 02FD	765	D.O. (0.00 ppm)	
32bit INT	2	0000 0B5C	2908	temperature (0.00C)	
32bit INT	4	0000 03E5	997	saturation (0.0%)	
32bit INT	6	0000 0000	0	PID (OFF)	
8 boolean	8	00	0000 0000	status bits 1	
8 boolean	8	00	0000 0000	status bits 2	
8 boolean	9	00	0000 0000	Alarms (relays)	
8 boolean	9	31	0011 0001	ID (Q46D=49)	

Request: 65 04 00 00 00 0A 78 29

Response: 65 04 14 00 00 02 FD 00 00 0B 5C 00 00 03 E5 00 00 00 00 00 00 00 00 31 64 58

High byte/Low byte, High word/Low word, expected response bytes: 6458, 25

send continuously, response time: 0.2, max: 0.2, avg: 0.135, min: 0.1

time between sends: 0.0, responses failed: 0

RTS delay: ON 0, OFF 0

LOG DATA, SAVE LOG, clear log

2015/12/15 11:35:59 < 65 04 14 00 00 02 FD 00 00 0B 5C 00 00 03 E5 00 00 00 00 00 00 00 00 31 64 58

2015/12/15 11:35:59 >>> 65 04 00 00 00 0A 78 29

2015/12/15 11:36:00 < 65 04 14 00 00 02 FD 00 00 0B 5C 00 00 03 E5 00 00 00 00 00 00 00 00 31 64 58

C:\Program Files (x86)\Simply Modbus 0 1 187425 0 0 0

433A 5C50 726F 6772 616D 2046 696C 6573 5C43 6F6D 6D6F 6E20 4669 6C65 735C 736D 622E 6461 7434 3530 3643 3041 38

Figure 2 - Modbus RTU Set-up Screen

1.13 Q46 Modbus RTU Register Assignment

The following tables summarize the registers used for the Modbus data in all Q46 communication boards. Specific parameter values for all variations are listed in table 5. As mentioned previously, the Q46 only supports the “04 – Read Input Register” function.

Register	Byte	Data Type	Sensor	Description	Data Format
30001 (HI) 30002 (LO)	1 to 4	long(32)	Main	Measured Main	See Figure 5
30003 (HI) 30004 (LO)	5 to 8	long(32)	Main	Measured Temperature	25.00° C = 2500
30005 (HI) 30006 (LO)	9 to 12	long(32)	Aux1	Measured Aux1	See Figure 5
30007 (HI) 30008 (LO)	13 to 16	long(32)	Aux2	Measured Aux2	See Figure 5
30009	17	Char(8)	NA	System Status 1	(binary) 00000000
	18	Char(8)	NA	System Status 2	(binary) 00000000
30010	19	Char(8)	NA	Alarm Status	(binary) 00000000
	20	Char(8)	NA	Instrument ID	See Figure 5

Figure 3 - Q46 Modbus Input Base Register Data

Register	Bitfield	Description
30009	0 (lsb)	Raw Hi ¹
	1	Raw Lo ¹
	2	Main Hi
	3	Main Lo
	4	Temp Hi
	5	Temp Lo
	6	Aux1 Hi ²
	7	Aux1 Lo
	0	NU
	1	NU
	2	LCD Controller Fail
	3	Cal Main Fail
	4	PID Controller Fail
	5	Cal TC Fail
	6	TC Error
7	Acknowledge Fail (global)	
30010	0	Alarm 1, Relay A
	1	Alarm 2, Relay B
	2	Alarm 3, Relay C
	3	Alarm 4, Relay D (optional)
	4	Alarm 5, Relay E (optional)
	5	Alarm 6, Relay F (optional)
	6	NU
	7	NU

Figure 4 – Base Status Register Bitfield Flags

Instrument	Main	Aux1	Aux2	Main Data Format	Aux1 Data Format	Aux2 Data Format
Q46H/62/63 /79PR ID=41	Chlorine	pH	PID	14920= 1.4920 ppm	700= 7.00pH	475= 47.5%
Q46S/66 ID=81	Sulfite	None	PID	14920= 1.4920 ppm	None	475= 47.5%
Q46S/81 ID=81	Sulfide	None	PID	14920= 1.4920 ppm	None	475= 47.5%
Q46H/64 ID=41	Ozone	pH	PID	14920= 1.4920 ppm	700= 7.00pH	475= 47.5%
Q46H/65 ID=41	Chlor Diox	pH	PID	14920= 1.4920 ppm	700= 7.00pH	475= 47.5%
Q46D ID=49	D.O.	Sat	PID	840= 8.40 ppm	980= 98.0% sat	475= 47.5%
Q46P ID=53	pH	None	PID	700= 7.00 pH	None	475= 47.5%
Q46R ID=57	ORP	None	PID	-137= -137 mV	None	475= 47.5%
Q46N ID=45	Total Amm	Mono Chloramine	Free Amm	100= 1.00 ppm	51= 0.51 ppm	321= 3.21 ppm
Q46C2 ID=69	Conductivity	³ Concentration	³ TDS	100123= 100.123 uS	13= 1.3%	2235= 223.5 mg/L
Q46C4 ID=65	Conductivity	³ Concentration	³ TDS	2238= 2.238 mS	13= 1.3%	2235= 223.5 mg/L
Q46CT ID=61	Conductivity	³ Concentration	³ TDS	2238= 2.238 mS	13= 1.3%	2235= 223.5 mg/L
Q46F ID=73	Fluoride	None	PID	1000= 1.000 ppm	None	475= 47.5%
Q46T ID=85	Turbidity	None	PID	16= 0.16 NTU	None	475= 47.5%

Figure 5 – Parameter Specific Data Formats

¹ Raw Hi/Lo is an internal sensor flag signal that indicates the raw signal is measuring too high or low, and can indicate sensor service is required or it may simply mean the sensor is presently out of the process liquid. This signal does not apply to the Q46T/C2/C4/CT.

² This bit flag is the glass break diagnostic for pH.

³ For Conductivity units, concentration data shows for concentration instruments, and TDS shows for standard conductivity units (not both.)

PRODUCT WARRANTY

Analytical Technology, Inc. (Manufacturer) warrants to the Customer that if any part(s) of the Manufacturer's equipment proves to be defective in materials or workmanship within the earlier of 18 months of the date of shipment or 12 months of the date of start-up, such defective parts will be repaired or replaced free of charge. Inspection and repairs to products thought to be defective within the warranty period will be completed at the Manufacturer's facilities in Collegeville, PA. Products on which warranty repairs are required shall be shipped freight prepaid to the Manufacturer. The product(s) will be returned freight prepaid and allowed if it is determined by the manufacturer that the part(s) failed due to defective materials or workmanship.

This warranty does not cover consumable items, batteries, or wear items subject to periodic replacement including lamps and fuses.

Gas sensors carry a 12 months from date of shipment warranty and are subject to inspection for evidence of misuse, abuse, alteration, improper storage, or extended exposure to excessive gas concentrations. Should inspection indicate that sensors have failed due to any of the above, the warranty shall not apply.

The Manufacturer assumes no liability for consequential damages of any kind, and the buyer by acceptance of this equipment will assume all liability for the consequences of its use or misuse by the Customer, his employees, or others. A defect within the meaning of this warranty is any part of any piece of a Manufacturer's product which shall, when such part is capable of being renewed, repaired, or replaced, operate to condemn such piece of equipment.

This warranty is in lieu of all other warranties (including without limiting the generality of the foregoing warranties of merchantability and fitness for a particular purpose), guarantees, obligations or liabilities expressed or implied by the Manufacturer or its representatives and by statute or rule of law.

This warranty is void if the Manufacturer's product(s) has been subject to misuse or abuse, or has not been operated or stored in accordance with instructions, or if the serial number has been removed.

Analytical Technology, Inc. makes no other warranty expressed or implied except as stated above.

WATER QUALITY MONITORS

Dissolved Oxygen
Free Chlorine
Combined Chlorine
Total Chlorine
Residual Chlorine Dioxide
Potassium Permanganate
Dissolved Ozone
pH/ORP
Conductivity
Hydrogen Peroxide
Peracetic Acid
Dissolved Sulfide
Residual Sulfite
Fluoride
Dissolved Ammonia
Turbidity
Suspended Solids
Sludge Blanket Level
MetriNet Distribution Monitor

GAS DETECTION PRODUCTS

NH ₃	Ammonia
CO	Carbon Monoxide
H ₂	Hydrogen
NO	Nitric Oxide
O ₂	Oxygen
CO	Cl ₂ Phosgene
Br ₂	Bromine
Cl ₂	Chlorine
ClO ₂	Chlorine Dioxide
F ₂	Fluorine
I ₂	Iodine
H _x	Acid Gases
C ₂ H ₄ O	Ethylene Oxide
C ₂ H ₆ O	Alcohol
O ₃	Ozone
CH ₄	Methane (Combustible Gas)
H ₂ O ₂	Hydrogen Peroxide
HCl	Hydrogen Chloride
HCN	Hydrogen Cyanide
HF	Hydrogen Fluoride
H ₂ S	Hydrogen Sulfide
NO ₂	Nitrogen Dioxide
NO _x	Oxides of Nitrogen
SO ₂	Sulfur Dioxide
H ₂ Se	Hydrogen Selenide
B ₂ H ₆	Diborane
GeH ₄	Germane
AsH ₃	Arsine
PH ₃	Phosphine
SiH ₄	Silane
HCHO	Formaldehyde
C ₂ H ₄ O ₃	Peracetic Acid
DMA	Dimethylamine