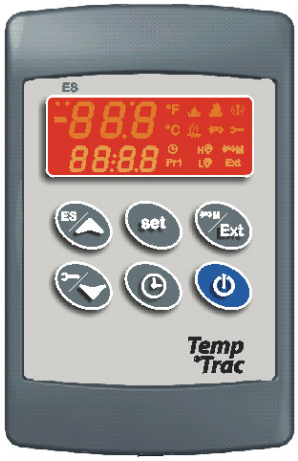
MODBUS-RTU applied to TempTrac® and XR10CX Operating Controls

TempTrac®



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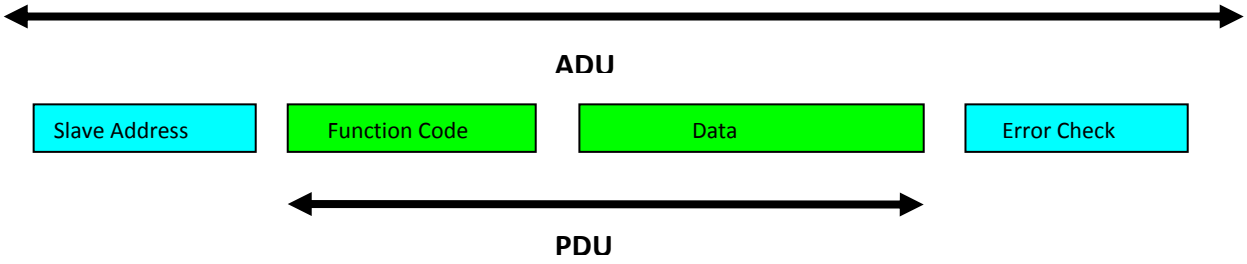
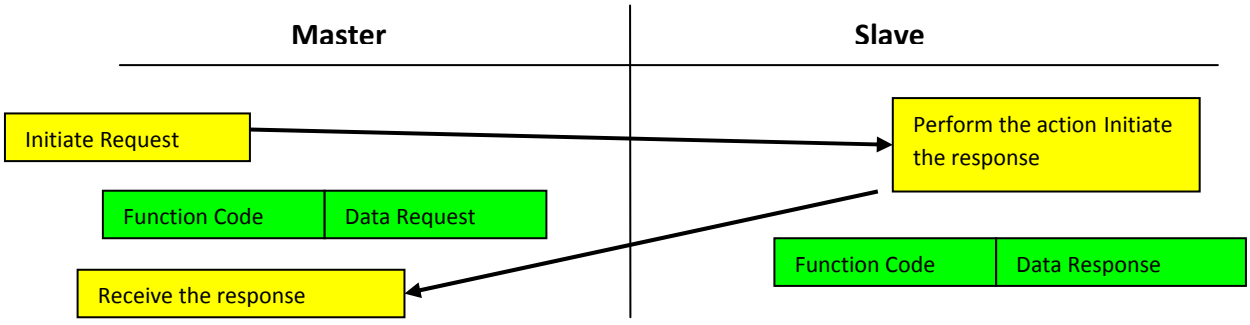
MODBUS-RTU PROTOCOL DISCRIPTION

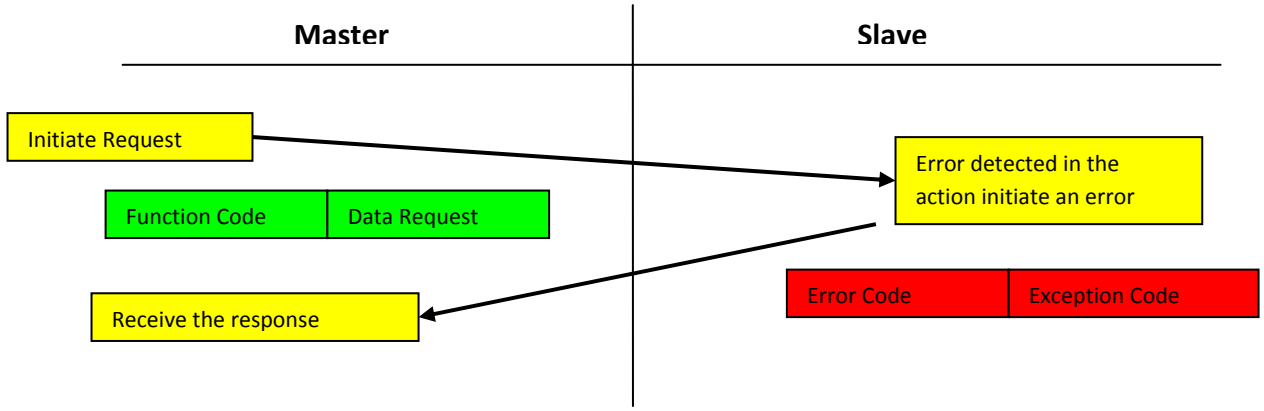
The MODBUS protocol defines a simple protocol data unit **(PDU)** independent of the underlying communication layers. The mapping of MODBUS protocol on specific buses or networks can introduce some additional fields on the application data unit **(ADU)**.



The MODBUS application data unit is built by the Master that initiates a MODBUS transaction. The function indicates to the slave what kind of action to perform. The MODBUS application protocol establishes the format of a request initiated by a Master. The function code field of a MODBUS data unit is coded in one byte. Valid codes are in the range of 1 to 255 decimal. The Temptrac however will only utilize three function codes which will be described later in this document. When a message is sent from a Master to a Slave device the function code field tells the Slave what kind of action to perform. The data field of messages sent from a Master to a Slave devise contains additional information that the Slave uses to take the action defined by the function code. This can include items such as register addresses, the quantity of items to be handled, and the count of actual data bytes in the field. If no error occurs related to the MODBUS function requested in a properly received MODBUS ADU the data field of a response from a Slave to a Master contains the data requested. If an error related to the MODBUS function requested occurs, the field contains an exception code that the Slave application can use to determine the next action to be taken. For example a Master can read the ON/OFF states of the relay outputs or digital inputs or it can read/write the data contents of a group of registers. When the Slave 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.



MODBUS Transaction (Error Free)



MODBUS Transaction (Exception Code)

CRC CHECKING

MODBUS-RTU includes an error-checking field that is based on a Cyclical Redundancy Checking (CRC) method performed on the message contents. The CRC field checks the contents of the entire message. The CRC field contains a 16-bit value implemented as two 8-bit bytes. The CRC field is appended to the message as the last field in the message. When this is done, the low-order byte of the field is appended first, followed by the high-order byte. The CRC high-order byte is the last byte to be sent in the message. The CRC value is calculated by the sending devise, which appends the CRC to the message. The receiving device recalculated a CRC during receipt of the message, and compares the calculated value to the actual value it received in the CRC field. If the two values are not equal, an error results.

For the purpose of application the details of this method are not necessarily required. Most Energy Management software packages will automatically perform this function as a normal part of the protocol.

COMMAND DISCRIPTIONS

The TempTrac Boiler and Water Heater control requires only one command or function code to read and write to all control registers. The Temptrac and XR10CX will allow communication with no more than 5 registers per transaction. The following are illustrations or the required format of the three commands.

READ or Write HOLDING REGISTER (0x04):

Slave Address	Function Code	Register Address	Register Address	Number of Registers	Number of Registers	CRC (LSByte)	CRC (MSByte)

Slave Address: Defines the device address that receives the communication data.

Function Code: Code of the desired function = 0X04

Register Address: The address of the first register to be read.

Number of Registers: Defines the number of Elements (Registers) that the device has to return (3 = 3 Registers). No more than 5 Elements allowed.

CRC: Defines the CRC calculated for the frame data received and has to be used to verify the integrity of data received.

The answer message has the following format:

Slave Address	Function Code	Number of Bytes	Byte Data 1		Byte Data n	CRC (LSByte)	CRC (MSByte)

Number of Bytes: Defines the number of bytes followed minus the CRC.

Byte Data: Byte data buffer.

SERIAL CONFIGURATION

Physical Layer: RS485
Baud Rate: 9600bps
Data Length: 8 bit
Parity: None
Stop Bit: 1
Start/Stop: Silent interval of 3 characters
Min Time Between Retry: 500 msec

Slave Address:
This field range is 1-247. Address 0 is used for the broadcast address. In this case the slave will execute the command (only Write Holding Register command) but does not return a response.

Register Address:
The LByte of the address will code up to 255. In some software systems it may be necessary to convert the address to binary and then enter the MByte and LByte separately.

Exception Code:
Temptrac and XR10CX will answer with an exception code when it is not able to execute the last command received. The exception configuration is:

1. **Not implemented function (0X01).** In this case a function is requested that the device is not able to support (any function other than 0X04).
2. **Not implemented area (0X02).** In this case a resource which is requested is absent from the devise.
3. **Area index not valid (0X03).** In this case the value of the selected resource is out of range. Example: more than 5 Elements are requested.
4. **Read Write error (0X04).** The devise did not succeed in reading or writing the requested operation.
5. **Busy state for slave active (0X06).** The devise cannot execute the requested operation because it is busy with another analogue operation. The request has to be repeated another time.

The exception answer has the following format:

Slave Address	Error Code or HEX 80+ Function Code	Exception Code	Error Check

MODBUS SYSTEMS OVER A SERIAL LINE

A new MODBUS system over serial line should implement an electrical interface in accordance with EIA/TIA-485 (also known as RS485 standard). This standard allows point to point and multipoint systems, in a “two-wire configuration”. In addition, some devices may implement a “Four-Wire” RS485-Interface. This document will discuss the “Two-Wire” only.

A devise may also implement an RS-232-Interface when a converter is used.

On standard MODBUS systems, all the devices are connected (in parallel) on a trunk cable constituted by 3 conductors. Two of those conductors (the “Two-Wire” configuration) form a balanced twisted pair, on which bi-directional data is transmitted, typically at a baud rate of 9600 bits per second.

The end to end length of the trunk cable must be limited. The maximum length for a “Two Wire configuration” at 9600bps and AWG26 or larger wire is 1000m. Category 5 cables may operate RS485-MODBUS, to a maximum length of 600m.
The recommended color code is as follows:

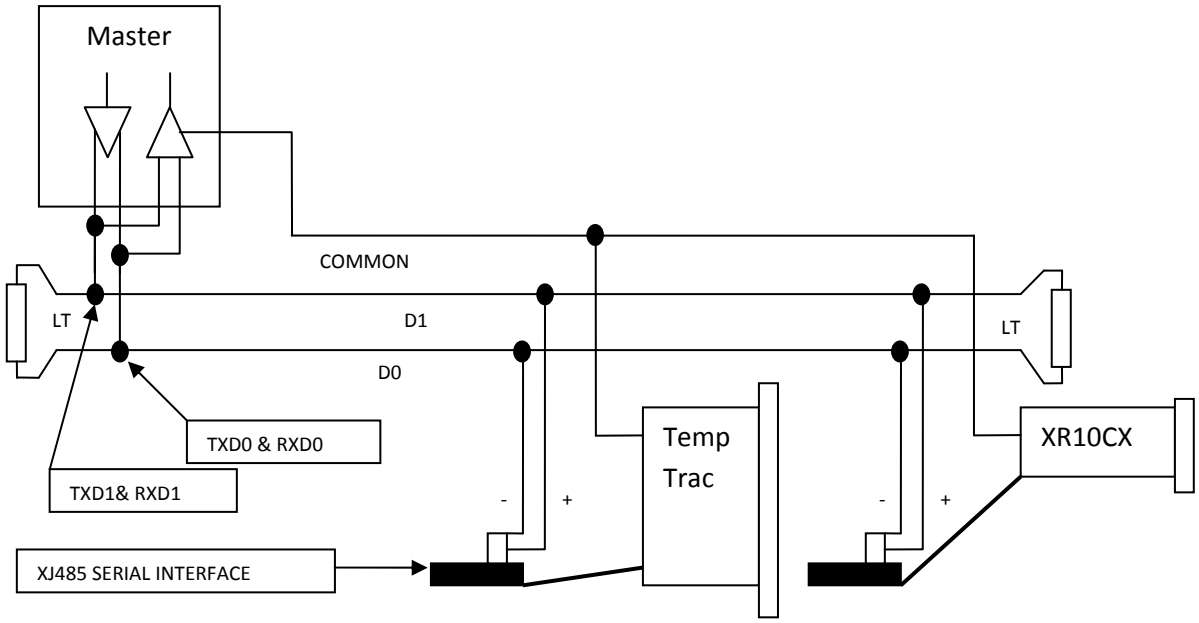
Signal Names	Recommended Color
D1-TXD1 (+)	Red
D0-TXD0 (-)	Black
Shield	Bare

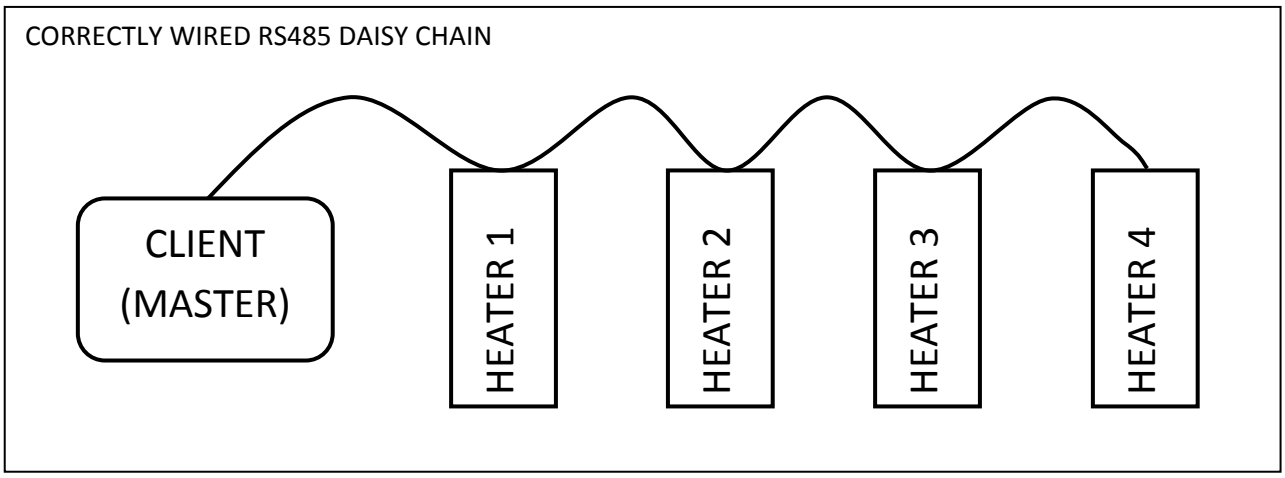
A MODBUS system over a serial line cable ***must be shielded/twisted pair***. At one end of each cable its shield must be connected to protective ground. If a connector is used at this end, the shell of the connector is connected to the shield of the cable.

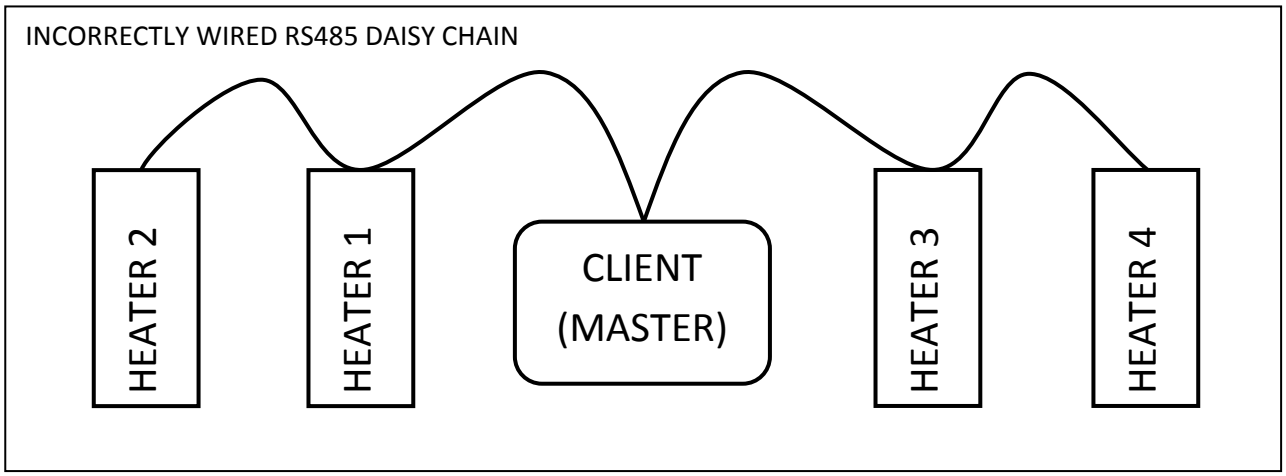
TWO WIRE MODBUS RS485 WIRING

A MODBUS solution over a serial line can use a “Two–Wire” electrical interface in accordance with EIA/TIA-485 standard. On such a 2W-bus, at any time one driver only has the right for transmitting. A third conductor must also interconnect all the devices of the bus: the common.

Typical “Two-Wire” Solution







Line Termination (TL). A reflection in a transmission line is the result of an impedance discontinuity that a travelling wave sees as it propagates down the line. To minimize the reflections from the end of the RS485-cable ist is required to place a Line Termination near each of the 2 ends of the Bus. It is important that the line be terminated at both ends since the propagation is bi-directional, but it is not allowed to place more than 2 LTs on one Passive D0-D1 balance pair. Never place any LT on a derivation cable.

- Each line termination must be connected between the two conductors of the balanced line: D0 and D1.
- Line termination may be a 150 ohms value (0.5 W) resistor.
- A serial capacitor (1nF, 10 V minimum) with a 120 Ohms (0.25 W) resistor is a better choice when a polarization of the pair must be implemented.
- In a 4 wire-system, each pair must be terminated at each end of the bus.
- In an RS232 interconnection, no termination should be wired.

Serial Termination. The XJ485 serial termination is a factory supplied RS485 to TTl connection device. The Temptrac control comes standard with a TTL communication port also used as the HOT KEY programming interface. The termination points are labeled as (+ and –) corresponding to (D1 and D0) The common circuit should be terminated at the common on the back of the Temptrac control.

TEMTRAC AND XR10CX REGISTRY ADDRESSES

The following table provides some of the most commonly used addresses for the Temptrac and XR10CR operating controls. If additional information is desired please contact the manufacturer for more information.

Control	Discription	Modbus Address
Temptrac	Set Point Read/Write	40769
Temptrac	Temp. Probe 1 Read Only	40257
Temptrac	Temp. Probe 2 Read Only	40259
Temptrac	Temp. Probe 3 Read Only	40261
Temptrac	On/Off Enable Read/Write	401281
XR10CX	Temp. Probe 1 Read Only	40257
XR10CX	Set Point Read/Write	40864

FULL REGISTER LIST FOR TEMPTRAC

All registers are function code 04 and analog/16bit Integers.

Control Label	Discription	Range	Modbus Address Temptrac	Alternate Protocol Address
St1	Set point1	LS1÷US1	40769	1
St2	Set point2	LS2÷US2	40770	2
St3	Set point3	LS3÷US3	40771	3
St5	Set point5 Set point 3 alternate	-20÷70°F	40772	4
Hy1	Differential for set1	-22÷22°F	40773	5
LS1	Minimum set point1	-40°F÷SET	40774	6
US1	Maximum set point1	SET ÷ 230°F	40775	7
AC1	Anti-short cycle delay for output 1	0÷30 min.	40776	8
S2c	Configuration of Set2: dependent on set1 or independent	diP; ind	40777	9
Hy2	Differential for set2	-22÷22°F	40778	10
LS2	Minimum set point2	-40°F÷SET2	40779	11
US2	Maximum set point2	SET2 ÷ 230°F	40780	12
AC2	Anti-short cycle delay for output 2	0÷30 min.	40781	13
S3c	Configuration of Set3: dependent on set1 or independent	diP; ind	40782	14
Hy3	Differential for set3	-22÷22°F	40783	15
LS3	Minimum set point3	-40°F÷SET3	40784	16
US3	Maximum set point3	SET3 ÷ 230°F	40785	17
AC3	Anti-short cycle delay for output 3	0÷30 min.	40786	18
o3P	Probe selection for output 3	Pb1 / Pb2	40787	19
SSE	Set point shift for output 3 enable disable	Yes / No	40788	20
Hy5	Differential for set point 5	-22÷22°F	40789	21
AC5	Anti-short cycle delay for output 3 alternate set point	0÷30 min.	40790	22
ACA	Time delay between the St3 to St5 set point shift	0÷15 min.	40791	23
S4c	Configuration of Set4: dependent on set1 or independent	diP; ind	40792	24
St4	Analogue output set point	-100÷100°F	40793	25
SR	Analogue output band width	-100÷100°F	40794	26
TH4	Outlet temperature threshold for forcing to 4ma the analog output	-40°F ÷ 230°F	40795	27
HY4	Differential for restart working of analog output	-45 ÷ -1 °F	40796	28
Ac4	Anti-short cycle delay for output 4	0÷30 min.	40797	29
PS4	Analog output percentage LSB=101 for (nu)	0÷100, nu	40798	30
PP4	Analog output percentage with fault probe 1	0÷100, nu	40799	31
tt	Outdoor temperature threshold for dynamic reset of SET1	-40÷230°F	40800	32
rr2	Outdoor temperature band width	-100÷100°F	40801	33
rr1	Maximum shift of SET1	-100÷100°F	40802	34
tt2	Outdoor temperature threshold to open all the loads	-40÷230°F	40803	35
Ht2	Differential for restart working of controller	-45 ÷ -1 °F	40804	36
i1P	Digital input 1 polarity	CL÷OP	40805	37
i2P	Digital input 2 polarity	CL÷OP	40806	38
i2d	Digital input 2 alarm delay	0÷255 min.	40807	39
i3P	Digital input 3 polarity	CL÷OP	40808	40
i3d	Digital input 3 alarm delay	0÷255 min.	40809	41
CF	Temperature measurement unit	°C ÷ °F	40810	42
rES	Resolution (integer/decimal point) only for °C	in ÷ de	40811	43
dS2	Default showing for display #2	Pb2, Pb3	40812	44
dS1	Default showing for display #1	Pb1; tiM	40813	45
ALC	Temperature alarms configuration: dependent on SET1 or independent	rE÷Ab	40814	46
ALL	minimum temperature alarm, referred to TP1	-40÷230°F	40815	47
ALU	MAXIMUM temperature alarm, referred to TP1	-40÷230°F	40816	48

REGISTER LIST FOR TEMPTRAC continued

Control Label	Discription	Range	Modbus Address Temptrac	Alternate Protocol Address
AFH	Differential for temperature alarm recovery	1÷45°F	40817	49
ALd	Temperature alarm delay	0÷255 min.	40818	50
dAO	Delay of temperature alarm at start up	0 ÷ 23h 50 min.	40819	51
oF1	First probe calibration	-21÷21°F	40820	52
P2P	Second probe presence	yES; no	40821	53
oF2	Second probe calibration	-21÷21°F	40822	54
P3P	Third probe presence	yES; no	40823	55
oF3	Third probe calibration	-21÷21°F	40824	56
Hur	Current hour	0 ÷ 23	40825	57
Min	Current minute	0 ÷ 59	40826	58
dAY	Current day	Sun ÷ SAt	40827	59
E1	Energy saving start on Sunday	0 ÷ 23h 50 min. - nu	40828	60
S1	Energy saving stop on Sunday	0 ÷ 23h 50 min. - nu	40829	61
Sb1	Set back temperature on Sunday	-40÷40°F	40830	62
E2	Energy saving start on Monday	0 ÷ 23h 50 min. - nu	40831	63
S2	Energy saving stop on Monday	0 ÷ 23h 50 min. - nu	40832	64
Sb2	Set back temperature on Monday	-40÷40°F	40833	65
E3	Energy saving start on Tuesday	0 ÷ 23h 50 min. - nu	40834	66
S3	Energy saving stop on Tuesday	0 ÷ 23h 50 min. - nu	40835	67
Sb3	Set back temperature on Tuesday	-40÷40°F	40836	68
E4	Energy saving start on Wednesday	0 ÷ 23h 50 min. - nu	40837	69
S4	Energy saving stop on Wednesday	0 ÷ 23h 50 min. - nu	40838	70
Sb4	Set back temperature on Wednesday	-40÷40°F	40839	71
E5	Energy saving start on Thursday	0 ÷ 23h 50 min. - nu	40840	72
S5	Energy saving stop on Thursday	0 ÷ 23h 50 min. - nu	40841	73
Sb5	Set back temperature on Thursday	-40÷40°F	40842	74
E6	Energy saving start on Friday	0 ÷ 23h 50 min. - nu	40843	75
S6	Energy saving stop on Friday	0 ÷ 23h 50 min. - nu	40844	76
Sb6	Set back temperature on Friday	-40÷40°F	40845	77
E7	Energy saving start on Saturday	0 ÷ 23h 50 min. - nu	40846	78
S7	Energy saving stop on Saturday	0 ÷ 23h 50 min. - nu	40847	79
Sb7	Set back temperature on Saturday	-40÷40°F	40848	80
oP1	working hours limit of relay 1 (set to 0 to disable)	0÷9999h	40849	81
oP2	working hours limit of relay 2 (set to 0 to disable)	0÷9999h	40850	82
oP3	working hours limit of relay 3 (set to 0 to disable)	0÷9999h	40851	83
ou1	working hours actual of relay 1	0÷9999h; when enabled	40852	84
ou2	working hours actual of relay 2	0÷9999h; when enabled	40853	85
ou3	working hours actual of relay 3	0÷9999h; when enabled	40854	86
1on	The output 1 is always on or depending on temperature	rEG=1,1;YES=0,1; no=0,0	40855	87
2on	The output 2 is always on or depending on temperature	rEG=1,1;YES=0,1; no=0,0	40856	88
3on	The output 3 is always on or depending on temperature	rEG=1,1;YES=0,1; no=0,0	40857	89
	Probe 1 temperature (return water or tank control sensor)	Degrees F/C (read only)	40257	90
	Probe 2 temperature (supply water or tank outlet)	Degrees F/C (read only)	40259	91
	Probe 3 temperature (outdoor temp or system temp with Ontrac)	Degrees F/C (read only)	40261	92
	States of Relays 1,2&3	Bit 0,1 and 2 (read only)	42050	93
	Digital input alarms	Bit 5 (read only)	43329	94
	On/Off (bit 0 of MS 1on 0off, LS 1enable 0 disable)		41281	95
	Keyboard Lock (bit 4 of MS 1lock 0un, LS 1enable 0 disable)		41281	95
	Reset audible alarm (bit 5 of MS 1reset. LS 1enable 0 disable)		41281	95
Adr	Serial address	1 to 248	40858	96
rEL	Software release	(read only)	40859	97
Ptb	Parameter map code	(read only)	40860	98

REFERENCES

This document is not intended to be a comprehensive guide for application or installation of a MODBUS solution. The following are some additional resources:

- ANSI/TIA/EIA-232 Interface between data terminal equipment and data circuit-terminating equipment employing serial binary data interchange.
- ANSI/TIA/EIA-485 Electrical characteristics of generators and receivers for use in balanced digital multipoint systems.
- MODBUS.org MODBUS applications protocol specification.