



Technical Reference

Modbus Translator Module

Introduction

This document provides hardware and software protocol interface definition for the ModBus Translator board, hereafter referred to as the ModBus Translator.

The ModBus Translator is an electrical device powered from a nominal 12 VDC source that provides data exchange between the RS-232 port of a Capstone MicroTurbine System and an RS-485 ModBus network. The ModBus uses a microprocessor to communicate with the Capstone MicroTurbine System to provide data over a RS-485 ModBus network.

All devices on a bus must operate according to the same electrical standards (RS-232 or RS-485, not mixed). RS-232C standards specify that only two devices may be connected to a bus (i.e. only one slave is allowed). RS-485 specifications allow up to 32 devices (31 slaves) on a bus.



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Overview

The ModBus Translator is a self-contained pre-programmed unit, designed for instant connectivity with a Capstone MicroTurbine. There is no customer requirement to open the unit – all necessary connectors are on the exterior of the unit.

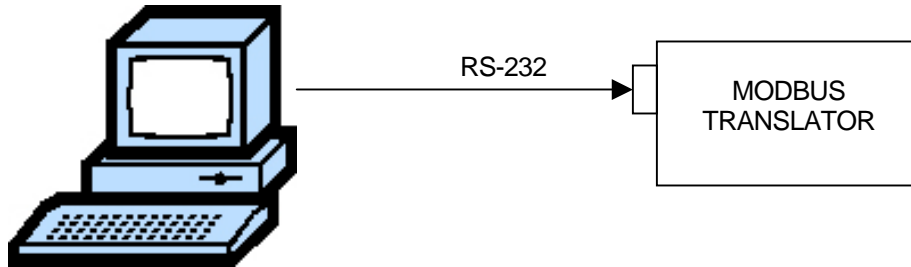
There are two steps required to prepare the ModBus Translator for use.

Step 1:

When the ModBus is first prepared for use at the Capstone factory, the ModBus codeset is downloaded from a local PC to the ModBus using a local RS-232 connection.

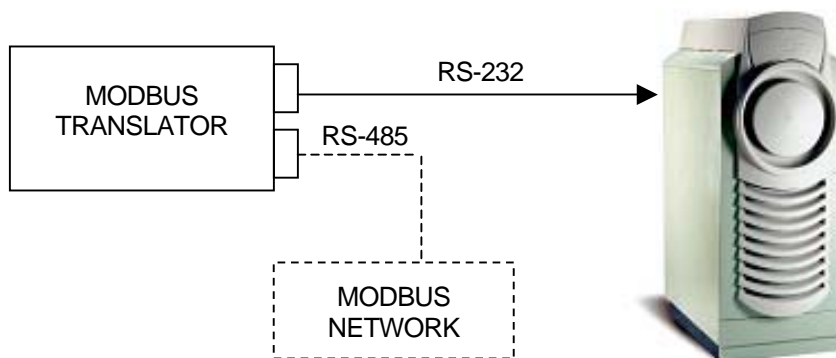
NOTE	This download does not need to be performed again by the user except under special circumstances ! If re-programming must be performed, see Appendix A, "ModBus Codeset Download," for the sequence of required steps.
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The figure below shows the hardware connection sequence for ModBus codeset download:



Step 2:

Perform RS-232 connections between the ModBus Translator and the (Model C30 or C60) MicroTurbine Connection Bay. These interconnections are shown on Figures 1 and 2.



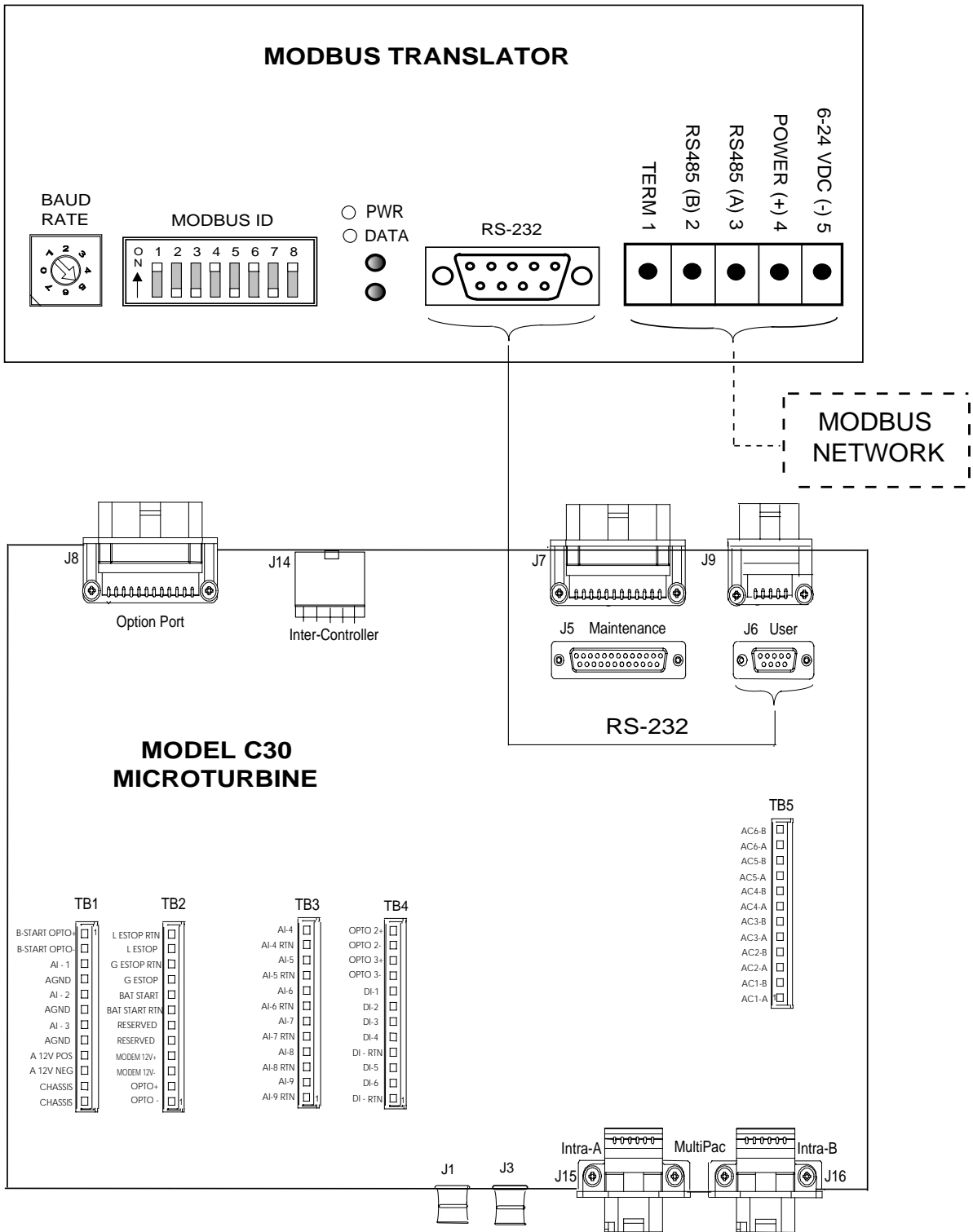


Figure 1. ModBus Connections to MicroTurbine (Model C30)

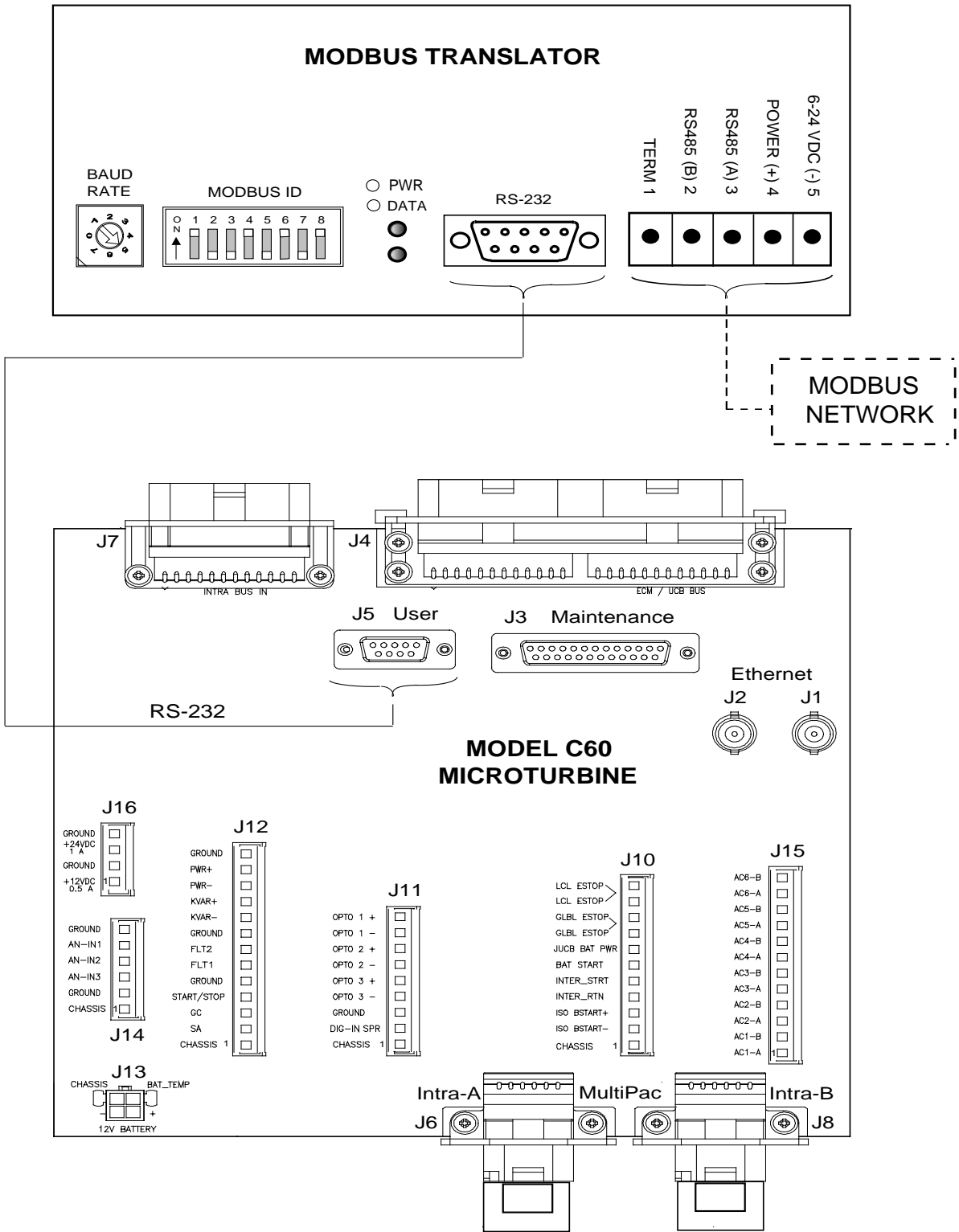


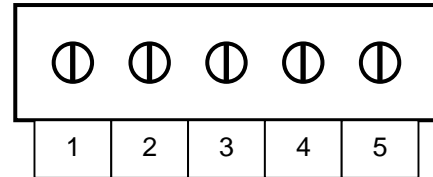
Figure 2. ModBus Connections to MicroTurbine (Model C60)

Hardware Interface

RS-485 Connector

- Connector - Terminal with Comm A, Comm B, Shield, and GND
- Communication - RTU Mode, 8 Data, 1 Stop, Even Parity, Half Duplex (Unless otherwise noted)
- Baud Rate - Selectable
- Distance - less than 4000 feet

Pin#	Description
1	RS-485 Termination
2	RS-485 Bus "B" Lead
3	RS-485 Bus "A" Lead
4	Positive Power Input (+6V to +24V DC)
5	Ground

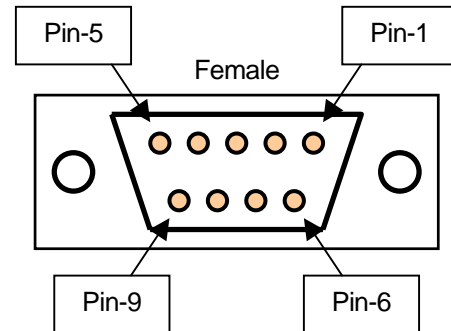


RS232 Connector

The connector between the Modbus Translator and the MicroTurbine system is a standard 9-pin straight-through serial cable.

- Connector - DB 9-pin (female) following DCE standard (see diagram below)
- Communication - 57,600 bps, 8 Data, 1 Stop, No Parity, Half Duplex
- Distance – less than 50 feet (in relatively noise-free environment)

Pin#	Description
1	DCD – Data Carrier Detect (output)
2	TXD – Transmit Data (output)
3	RXD – Receive Data (input)
4	DSR – Data Set Ready (input)
5	Signal Ground
6	DTR – Data Terminal Ready (output)
7	CTS – Clear To Send (input)
8	RTS – Request To Send (output)
9	RI – Ring Indicator (not used)



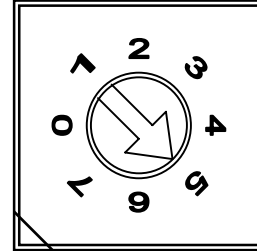
LED Operation

The ModBus Translator is equipped with two LEDs to provide status feedback about operation of the device. Illumination of the upper LED occurs when power is applied to the ModBus Translator. Software shall provide a 2ms pulse on the lower LED when a successful RS-485 ModBus communication packet is received.

Baud Rate Selector

An 8-position rotary switch is made available on the board for the purpose of selecting the baud rate communicated on the RS-485 ModBus link. See the table below for definition of position vs. baud rate selected. Note position 7 is “no parity” while all others are “even parity”.

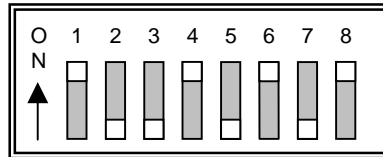
Position	Baud Rate (bps)
0	2400-E-8-1
1	4800-E-8-1
2	9600-E-8-1
3	14400-E-8-1
4	19200-E-8-1
5	28800-E-8-1
6	38400-E-8-1
7	9600-N-8-1



NOTE: Baud rate is set for 28800 bps.

Address Selector

On the side of the ModBus Translator, an 8-position DIP switch that appears as shown:



Each device in an RS-485 ModBus network must have a unique 8-bit address from 1 to 247. To set the Capstone ModBus Translator address, set the DIP switches to a unique 8-bit number. Flipping the switches up corresponds to a Logic-1, or “ON”. Flipping the switches down corresponds to a Logic-0, or “OFF”.

Each of the bit positions is numbered such that switch number one is assumed to be the MSB of the 8-bit address. Remember that for a RS-485 ModBus network to work, every device on the bus MUST have a different 8-bit address. An example for setting a ModBus address is shown below.

Address	Switch Number (Bit)							
	1 (7)	2 (6)	3 (5)	4 (4)	5 (3)	6 (2)	7 (1)	8 (0)
147 (93h)	ON	OFF	OFF	ON	OFF	OFF	ON	ON
90 (5Ah)	OFF	ON	OFF	ON	ON	OFF	ON	OFF

Specifications

Power Requirements

- Connector – Terminal block with +PWR, -PWR and GND
- Voltage – Nominal 13.8 VDC (+6 TO +24V)
- Amps – 300 mA continuous, 500mA peak @nominal voltage

Environmental Specifications

- Temperature: -20°C to +50°C operating
-25°C to +70°C storage
- Humidity: 100% Non-condensing

ModBus Interface

Description

The ModBus network is a “MASTER” to “SLAVE” network; that is to say, one node asks a question and a second node answers. A NODE is a ModBus device that is connected to the network. All communication is initiated selectively by the “MASTER” to other nodes by assigning each SLAVE NODE a unique address in the range of 1 to 247. Address 0 is a BROADCAST ADDRESS that can be used with certain ModBus functions to allow the MASTER to address all SLAVE NODES at one time. This device does not respond to BROADCAST messages.

ModBus Address

Each ModBus device responds to a single ModBus address. The address is in the range of 1 to 247, and each device must have a unique address.

Transaction Timing

Commands shall be processed and responded to by the ModBus Translator within 50ms. Write commands sent to the ModBus Translator are confirmed within 50ms, but updates to the Capstone MicroTurbine System may not occur for up to 500ms.

Read registers are updated by a polling operation in the converter. Several read registers may be updated by the ALLDAT command and are designated with an asterisk (*) in Table 8, RS232 Command column. ALLDAT is sent every 1 second. Other Read registers are updated in a “round robin” fashion at varying time intervals designated in the following table. Whenever a Write command is sent, the MicroTurbine will respond, causing certain Read registers to update. This will occur within 500ms in all cases.

Read Timing:

1	Response from Translator:	50ms
2	Read Register update from MicroTurbine:	See Table 8

Write Timing:

1	Response from Translator:	50ms
2	Response time from MicroTurbine:	Max 500ms
3	Update to Read register in Translator	Max 500ms

Data Format

Information regarding states and measurements made by the MicroTurbine are placed into a set of holding registers (4XXXX).

Registers are defined as READ ONLY (less than or equal to 47999) or WRITE and READ (greater than 48000) registers.

Both Read and Write Registers are converted to two byte values prior to transmission with the following formula:

$$\text{Register Number} - 40001$$

Example: To read Register 40008, first subtract 40001 resulting in 7. Convert this to two-byte hex: 0007h. This is the register value transmitted.

Similarly, when reading a Write register, such as 48507, the Register number returned would be 213Ah, which is $(48507 - 40001 = 8506 = 213Ah)$

All data from the ModBus registers is returned in either word (16-bits) or long word (32-bits) integer format. A long word integer format containing 2 words will always be transmitted high word first (lower address).

Integer data requires either translation or conversion to engineering units. Translations are described as an integer value representing some state or level. Integers may be converted to their corresponding floating-point representation with the units conversions provided. Information to perform the translation or conversion is described for each register in the Representation field of the tables.

ModBus Protocol

Introduction

The ModBus protocol is an open standard that defines a command-response method of communicating digital information between a master and slave device. The electrical connection between devices is known as a bus. In ModBus, two types of devices attach to the bus, master and slave devices. A master device issues commands to slaves. A slave device, such as the ModBus Translator device, issues responses to master commands that are addressed to them. Each bus must contain exactly one master and may contain as many slaves as the electrical standards permit.

When RS-485 ModBus queries are sent to the translator board, the board responds with data it has buffered from the MicroTurbine system. ModBus commands to write registers in the translator board are immediately queued up and transmitted to the MicroTurbine system over the RS-232 network. Both origination and user responses are buffered and can be read back.

The ModBus protocol specifications define two types of transmission modes: ASCII and RTU. This manual describes only the more common RTU mode.

ModBus RTU Message Framing

Each message from either a master or slave consists of a continuous stream of characters. A silent interval of 3.5 character times ($3.5 * 11 \text{ bits} / 9600 \text{ bps} = 3.5\text{ms}$) or more separates these communication streams. A typical response from this device would be:

- Enable the output interface drivers (RS-485)
- Wait 5 character times
- Send the response as a continuous stream
- Wait 3.5 character times
- Disable the output interface drivers (RS-485)

ModBus RTU Message Content

The ModBus RTU Message stream consists of an address byte, a function code byte, a number of message bytes, and two check bytes. The address byte, which is in the range 1 to 247, specifies the identity of the slave device. The function code byte in a master command indicates the operation that the slave is to perform. The function code byte in a slave response is the same value as the master command function code if no error occurs, otherwise it has 128 added to it.

The message bytes in a command contain additional information needed to perform the command. Message bytes in a response contain the data requested if no error has occurred or a one-byte exception code upon errors. The check bytes are generated using the CRC-16 polynomial generator sequence ($x^{16} + x^{15} + x^2 + 1$) with the remainder pre-initialized to all 1's. The least significant byte of the CRC is transmitted first.

ModBus Function and Exception Codes

The ModBus only supports the function codes shown below. Note that the values are shown in hexadecimal (base 16). The table below shows the value returned when an error occurs.

Table 1 – Error Response Function Codes

Master Function Code	Slave Error Code	Name	Meaning
03 ₁₆	83 ₁₆	Read Holding Registers	Read values from system run-time data
06 ₁₆	86 ₁₆	Preset Holding Registers	Set control values to command system
10 ₁₆	90 ₁₆	Preset Multiple Registers	Set control values of multiple register values

The ModBus will return exception codes back to the master upon certain conditions. All function codes greater than 127 decimal (7F₁₆) indicate a slave error response. The message byte indicates the exception code. The table below shows error code value definitions.

Table 2 - Error Code Value Definitions

Code	Name	Meaning
1	Illegal Function	Master command contained an unrecognized function code.
2	Illegal Data Address	Starting address is illegal. Note that some registers are read-only.
3	Illegal Data Value	Either the register count is invalid or an attempt to write an illegal register value was found. Note this can be caused by attempting to write fewer registers than are required for an operation.
4	Slave Device Failure	Some internal self-test of the device has failed.
6	Slave Device Busy	Not communicating with MicroTurbine system

Supported ModBus Commands

The ModBus supports one read and two write commands. Example transmissions are provided with the definition of each command below.

Read Holding Registers (Function Code 03)

This function reads a single or multiple holding register values. The command requires a Slave Address, Function Code, Start Address, Register Count, and CRC16. Attempting to read a non-existent or write-only register will cause an exception.

The example shown in the table below shows how to read the system Power Output value starting at register 42107 and ending with 42108.

Table 3 –Function Code 03 Command (Read Holding Registers)

Byte	Name	Example	Notes
1	Slave Address	01	
2	Function Code	03	
3	Start address high	08	Power Output at register 42107 (42107-40001 = 2106 = 083Ah)
4	Start address low	3A	
5	Register count high	00	
6	Register count low	02	Read 2 registers total
7	CRC-16 low	XX	
8	CRC-16 high	XX	

Table 4 – Function Code 03 Response (Read Holding Registers)

Byte	Name	Example	Notes
1	Slave Address	01	
2	Function Code	03	
3	Byte Count	04	2 registers, 2 bytes each
4	Data high (42107)	00	Power Output = 00006AAAh = 27306 decimal
5	Data low (42107)	00	Applying the units conversion = 149,996 Watts
6	Data high (42108)	6A	
7	Data low (42108)	AA	
8	CRC-16 low	XX	
9	CRC-16 high	XX	

Preset Single Register (Function Code 06)

This function writes to a single register. The command requires a Slave Address, Function Code, Start Address, Data, and CRC16. Attempting to write to a read-only register will cause an exception. The example shown in the table below shows how to set the Time of Use Event value at register 48507.

Table 5 – Function Code 06 Command and Response (Preset Single Register)

Byte	Name	Example	Notes
1	Slave Address	01	
2	Function Code	06	
3	Start address high	21	Time of Use Event at register 48507 (48507-40001 = 8506 = 213Ah)
4	Start address low	3A	
5	Data high	00	Set Event to number 5
6	Data low	05	
7	CRC-16 low	XX	
8	CRC-16 high	XX	

Preset Multiple Registers (Function Code 16)

This function writes to one or more contiguous registers. The command requires a Slave Address, Function Code, Start Address, Register count, Byte count, Data, and CRC16. Attempting to write to a read-only register will cause an exception. The table below shows how to enter a Time of Use Event value at register 48507.

Table 6 – Function Code 16 Command (Preset Multiple Registers)

Byte	Name	Example	Notes
1	Slave Address	01	
2	Function Code	10	
3	Start address high	21	Time of Use Event at register 48507 (48507-40001 = 8506 = 213Ah)
4	Start address low	3A	
5	Register count high	00	Writing to 6 registers (48507 – 48512)
6	Register count low	06	
7	Byte count	0C	6 registers, 2 bytes each
8	Data high	00	Time of Use Event = 5
9	Data low	05	
10	Data high	00	Event Day = 1 – Sunday
11	Data low	01	
12	Data high	08	Event Time = 080F hex (8:15AM)
13	Data low	0F	
14	Data high	00	Start Command = 1 – Start
15	Data low	01	
16	Data high	00	Power Demand = 159,000 Watts = 26D18 H
17	Data low	02	

Table 6 – Function Code 16 Command (Preset Multiple Registers) – Cont’d

Byte	Name	Example	Notes
18	Data high	6D	
19	Data low	18	
20	CRC-16 low	XX	
21	CRC-16 high	XX	

Table 7 – Function Code 16 Response (Preset Multiple Registers)

Byte	Name	Example	Notes
1	Slave Address	01	
2	Function Code	10	
3	Start address high	21	Time of Use Event at register 48507 (48507-40001 = 8506 = 213Ah)
4	Start address low	3A	
5	Register count high	00	Writing to 6 registers (48507 – 48512)
6	Register count low	06	
7	CRC-16 low	XX	
8	CRC-16 high	XX	

Read Registers

All read registers associated with a write register shall be updated within 500ms of a successful ModBus write operation. This provides time for the device to issue an RS-232 operation with the MicroTurbine system and verify the change has occurred.

NOTE	Read registers which may be updated with the ALLDAT command are indicated by an asterisk (“*”) following the RS232 command in the table below.
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Two modes of operation for Stationary and Hybrid Electric Vehicle (HEV) applications are provided with the ModBus Translator. These modes are mutually exclusive. Another mode of operation, for connections to a Capstone Power Server (CPS) is also provided. By selecting either mode (Write Register 48021), the system will provide different command options as described in the table below.

Table 8 - Holding Registers (Read Only)

Register	Mode	Description	Representation	RS232 Command	Timing (Sec)
General Communication Info					
40001	S,H	Selected Turbine (See Write Register 48001)	0 – This Turbine/Entire System 1 – Master Turbine 2 thru 10 – Specific Turbine	TURBNO,0	1
40002	S,H	Communication Status	Bit 0 – Unable to establish communication with the MicroTurbine system (Error = 1)	NA	NA
40003	S,H	Control Access	0 – Display 1 – User Port 2 – Maintenance Port	CNTACC	10
40004	S,H	Communication Configuration ¹	Bit 0 – 1: Mode Bits 0 = Stationary 1 = HEV 2 = CPS 3 = Reserved Bit 2 – 14: Not Used Bit 15: Comm Timeout Enable	NA	On Reg 48021 Update
40005	S,H	Comm Timeout Period ²	Units: 1 = 1 Seconds	NA	On Reg 48022 Update
40006	S,H	Password Access Level	0 – Base 1 – Protected	NA (prompt feedback)	NA
40007		ModBus Translator Software Version	Encoded (xx.yy) where, High Byte - (xx) Low Byte - (yy)	NA	NA

¹ User selects which mode of operation the ModBus Translator operates. Setting Bit 15 Comm Timeout Enable will cause a STRCMD=0 to be transmitted to the MicroTurbine™ system when a ModBus command has not been received within time defined by the Comm Timeout Period (addr 40005) and Start Command (addr 40101) is “Start”. Default setting is 0000h.

² Function is enabled when bit 15 of register 40004 is enabled. Default Comm Timeout Period is 10 seconds (can be changed at addr 48022). If the Comm Timeout Period setting exceeds 5 minutes, then the Comm Timeout Enable function will not work.

Register	Mode	Description	Representation	RS232 Command	Timing (Sec)
40008 – 40013		ModBus Translator Software Part Number	Each byte represents an ASCII character. String is NULL terminated.	NA	NA
		System Controls/Settings			
40101	S,H	Start Command (displays when the system is going to start)	0 – Stop, 1 – Start	CTRLDT*	1
40102	S	User Start (displays when user has commanded a start)	0 – Stop, 1 – Start	USRSTR	2
40103	S,H	Auto Restart	0 – Disabled, 1 – Enabled	AUTRST	10
40104	S	Restart Delay (GC)	Units: 1 = 0.1 Minutes	RDLYGC	10
40105	S	Restart Delay (SA)	Units: 1 = 0.1 Minutes	RDLYSA	10
40106	S	Remote Start Switch Enable	0 – User 1 – Remote 2 – GC User/SA Remote 3 – SA User/GC Remote	STRINP	10
40107	S	Remote Start Input Status (UCB Start Input)	0 – Stop, 1 – Start	UCBSTR	10
40108	S	Utility Connection	0 – Invalid, 1 – StandAlone, 2 – Grid Connect, 3 – Dual Mode	UTLCON	1
40109	S	Power Enable (SA only)	0 – Open, 1 – Closed	CTRLDT*	1
40110	S	Auto Load (SA only)	0 – Disabled, 1 – Enabled	AUTOLD	10
40111 – 40112	S,H	Power Demand	Units: 1 = 1 Watt	CTRLDT*	1
40113 – 40114	S,H	Store Power Demand	Units: 1 = 1 Watt	PWRDST	10
40115	S,H	Fuel Index 1	Units: 1 = 0.01 index	FUELI1	10
40116	S,H	Fuel Index 2	Units: 1 = 0.01 index	FUELI2	10
40117	S,H	Medium BTU Switch	0 – Normal 1 – Medium 2 – Low	MEDBTU	10
40118	S	MultiPac Enable	0 – Disabled, 1 – Enabled	MPENAB	10
40119	S	This Turbine's Number	Master: 1 Slave: 2 thru 10	STRBNO	10
		Grid Connect Relays			
40301	S	Under Voltage (GC)	Units: 1 = 1 VAC (line-to-line)	UNDVLT	10
40302	S	Under Voltage Time (GC)	Units: 1 = 0.01 Seconds	UVLTMM	10
40303	S	Over Voltage (GC)	Units: 1 = 1 VAC (line-to-line)	OVRVLT	10
40304	S	Over Voltage Time (GC)	Units: 1 = 0.01 Seconds	OVLTTM	10
40305	S	Fast Under Voltage (GC)	Units: 1 = 1 VAC (line-to-line)	FSTUVL	10
40306	S	Fast Over Voltage (GC)	Units: 1 = 1 VAC (line-to-line)	FSTOVL	10
40307	S	Under Frequency (GC)	Units: 1 = 0.1 Hz	UNDFRQ	10

Register	Mode	Description	Representation	RS232 Command	Timing (Sec)
40308	S	Under Frequency Time (GC)	Units: 1 = 0.01 Seconds	UFRQTM	10
40309	S	Over Frequency (GC)	Units: 1 = 0.1 Hz	OVRFRQ	10
40310	S	Over Frequency Time (GC)	Units: 1 = 0.01 Seconds	OFRQTM	10
		Stand Alone Relays			
40401	S	Output Voltage (SA)	Units: 1 = 1 VAC (line-to-line)	SAVOLT	10
40402	S	Voltage Start (SA)	Units: 1 = 1 VAC (line-to-line)	STVOLT	10
40403	S	Voltage Ramp (SA)	Units: 1 = 1 VAC/s (line-to-line)	STVTRT	10
40404	S	Under Voltage (SA)	Units: 1 = 1 VAC (line-to-line)	SAUVLT	10
40405	S	Under Voltage Time (SA)	Units: 1 = 0.01 Seconds	SAUVTM	10
40406	S	Over Voltage (SA)	Units: 1 = 1 VAC (line-to-line)	SAOVLT	10
40407	S	Over Voltage Time (SA)	Units: 1 = 0.01 Seconds	SAOVTM	10
40408	S	Output Frequency (SA)	Units: 1 = 0.1 Hz	SAFREQ	10
40409	S	Frequency Start (SA)	Units: 1 = 0.1 Hz	STFREQ	10
40410	S	Frequency Ramp (SA)	Units: 1 = 1 Hz/s	STFQRT	10
40411	S	Under Frequency (SA)	Units: 1 = 0.1 Hz	SAUFRQ	10
40412	S	Under Frequency Time (SA)	Units: 1 = 0.01 Seconds	SAUFTM	10
40413	S	Over Frequency (SA)	Units: 1 = 0.1 Hz	SAOFRQ	10
40414	S	Over Frequency Time (SA)	Units: 1 = 0.01 Seconds	SAOFTM	10
		Load Management Settings			
40501	S	Load Management Mode	0 – Disabled 2 – Load Following 3 – Time-of-Use	LMMODE	10
40502	S	Meter Constant	Units: 1 = 0.001 Wh/pulse	LMMTRC	10
40503	S	Utility Power Setpoint	Units: 1 = 0.1 kW	LMUTPW	10
40504	S	Load Following Response Time	Units: 1 = 1 Second	LMRSPT	10
40505 – 40506	S	Minimum Power Shutoff	Units: 1 = 0.1 kW	LMMPWR	10
40507	S	Minimum Power Shutoff Time	Units: 1 = 1 Minute	LMPWTM	10
40508	S	Time of Use Event (See Write register 48507 to Set)	Min: 1 Max: 20	N/A	On Reg 48507 Update
40509	S	TOU Event Day	0 – Inactive 1 – Sunday 7 – Saturday	LMTOUE	On Reg 48507 Update
40510	S	TOU Event Hour	High Byte – Hour Low Byte – Minute	LMTOUE	On Reg 48507 Update
40511	S	TOU Event Start Command	0 – Stop, 1 – Start	LMTOUE	On Reg 48507 Update
40512 – 40513	S	TOU Event Power Demand	Units: 1 = 1 Watt	LMTOUE	On Reg 48507 Update

Register	Mode	Description	Representation	RS232 Command	Timing (Sec)
40514	S	Reverse Power Protect	0 – Disabled, 1 – Enabled	LMRPFPP	10
40515	S	Reverse Power Protect Time	Units: 1 = 1 Seconds	LMRPTM	10
40551	S	Load Management Start/Stop	0 – Stop, 1 – Start	LMDATA	5
40552 – 40553	S	Power Meter +Pwr	Units: 1 = 1 Watt	LMDATA	5
40554 – 40555	S	Power Meter –Pwr	Units: 1 = 1 Watt	LMDATA	5
40556 – 40557	S	Power Meter +VAR	Units: 1 = 1 VAR	LMDATA	5
40558 – 40559	S	Power Meter –VAR	Units: 1 = 1 VAR	LMDATA	5
		UCB Relays			
40601	S	Relay Number (See Write register 48507 to Set)	Min: 1 Max: 6	N/A	On Reg 48601 Update
40602	S	Relay Function	0 – Standby 1 – Run 2 – Load 3 – Fault 4 – Standalone 5 – Dual Mode 6 – Disable 7 – Fuel On 8 – Purge	OUTRLY	On Reg 48601 Update
40603	S	Relay Active State	0 – Open, 1 – Close	OUTRLY	On Reg 48601 Update
		Battery Information			
40701	S	Battery Enabled	0 – Disabled, 1 – Enabled	BATENA	2
40702	S	Battery Auto Sleep	Units: 1 = 0.1 Hours Min: 1 = 0.1 Hours Max: 239 = 23.9 Hours	ATOSLP	10
40703	S	Battery Charge	0 – Disabled, 1 – Enabled	BATCHG	5
40704	S	Battery Recharge Enable (SA only)	0 – Disabled, 1 – Enabled	RCHENA	2
40705 – 40706	S	Last Equalization Charge Date	Word 1, High Byte – Month Word 1, Low Byte – Day Word 2 - Year	BATEQL	30
40707	S	Charge Permission Day (See Write register 48507 to Set)	1 – Sunday 2 – Monday 7 – Saturday	N/A	On Reg 48707 Update
40708	S	Charge Permission Active	0 – Inactive, 1 - Active	CHGEQP	On Reg 48707 Update
40709	S	Charge Permission Start Time	High Byte – Hour Low Byte – Minute	CHGEQP	On Reg 48707 Update

Register	Mode	Description	Representation	RS232 Command	Timing (Sec)
40710	S	Charge Permission End Time	High Byte – Hour Low Byte – Minute	CHGEQP	On Reg 48707 Update
40711	S	Battery Temperature	1 = 1°C	BCDAT1*	1
40712	S	Battery Base SOC	% Battery state of charge	BCDAT1	10
40713	S	Number of Equalization Charges	Integer number	BATDAT	10
		Hybrid Vehicle Relays			
40801	H	Under Voltage (HEV)	Units: 1 = 1 V _{DC}	UNDVLT	10
40802	H	Under Voltage Time (HEV)	Units: 1 = 0.01 Seconds	UVLTMM	10
40803	H	Over Voltage (HEV)	Units: 1 = 1 V _{DC}	OVRVLT	10
40804	H	Over Voltage Time (HEV)	Units: 1 = 0.01 Seconds	OVLTTM	10
40805	H	Fast Under Voltage (HEV)	Units: 1 = 1 V _{DC}	FSTUVL	10
40806	H	Fast Over Voltage (HEV)	Units: 1 = 1 V _{DC}	FSTOVL	10
40807	H	Battery Current Limit	Units: 1 = 1 A _{DC} Min: 0 = 0 A _{DC} Max: 195 = 195 A _{DC}	BATILM	10
		Capstone Power Server CPS)			
40808	C	Min Power Capacity, Grid Connect	Units: 1 = 1 Watt Min: 0 Watts Max: 2,000,000,000 Watts	MPCPGC	1
40810	C	Min Power Capacity, Stand Alone	Units: 1 = 1 Watt Min: 0 Watts Max: 2,000,000,000 Watts	MPCPSA	1
40812	C	Spinning Reserve, Grid Connect	Units: 1 = 1 Watt Min: 0 Watts Max: 2,000,000,000 Watts	MPSRGC	1
40814	C	Spinning Reserve, Stand Alone	Units: 1 = 1 Watt Min: 0 Watts Max: 2,000,000,000 Watts	MPSRSA	1
40816	C	Multipac Mode	0 – Load Balancing, 1 – Max Efficiency	MPMODE	1
40817		System Type	0 – Capstone Power Server, 1 – C30 MicroTurbine, 2 – C60 MicroTurbine	SYSTYP	1
		Data Acquisition			
42001 – 42002	S,H	System Date	Word 1, High Byte – Month Word 1, Low Byte – Day Word 2 – Year	ENGDT1*	1
42003 – 42004	S,H	System Time	Word 1 – Hour Word 2, High Byte – Minute Word 2, Low Byte – Second	ENGDT1*	1

Register	Mode	Description	Representation	RS232 Command	Timing (Sec)
42005	S,H	High Fault Identification Number	Integer Fault Number	ENGDT2*	1
42006	S,H	System Severity Level	0 – System Ok 1 – Information 2 – Warning 3 – Shutdown 4 – Inverter Loss 5 – Warmdown 6 – Estop 7 – Disable	ENGDT2*	1
42007	S,H	System State and Mode	Mode Bits 15-12 0 – Invalid 1 – Reserved 2 – Standalone 3 – Grid-Connect 4 – Reserved State Bits 11 – 0 0 – Not Connected 1 – StandBy 2 – Prepare to Start 3 – Lift-off 4 – Prepare to Light 5 – Start Acceleration 6 – Run 7 – Load 8 – Re-charge 9 – Cooldown 10 – Warmdown 11 – Re-start 12 – Shutdown 13 – Fault 14 – Disable 15 – Bad Configuration 16 – Download 17 – Idle Re-charge	CTRLDT*	1
42008 - 42009	S,H	Bitmapped System State and Mode. (Only 1 bit each for Mode and State can be set at any time. Register 42009 contains the lower order bits – Bit 0 through Bit 15, Bits 16 – 31 are in register 42008)	Mode Bits 28 - 31 Bit 28 – Invalid Bit 29 – Reserved Bit 30 – Standalone Bit 31 – Grid-Connect State Bits 0 - 27 Bit 0 – Not Connected Bit 1 – StandBy Bit 2 – Prepare to Start Bit 3 – Lift-off Bit 4 – Prepare to Light Bit 5 – Start Acceleration Bit 6 – Run Bit 7 – Load	CTRLDT*	1

Register	Mode	Description	Representation	RS232 Command	Timing (Sec)
			Bit 8 – Re-charge Bit 9 – Cooldown Bit 10 – Warmdown Bit 11 – Re-start Bit 12 – Shutdown Bit 13 – Fault Bit 14 – Disable Bit 15 – Bad Configuration Bit 16 – Download Bit 17 – Idle Re-charge		
42101 – 42102	S,H	Phase A Power Average	Units: 1 = 2.7465820 Watts	INVDT2*	1
42103 – 42104	S,H	Phase B Power Average	Units: 1 = 2.7465820 Watts	INVDT2*	1
42105 – 42106	S,H	Phase C Power Average	Units: 1 = 2.7465820 Watts	INVDT2*	1
42107 – 42108	S,H	Power Output	Units: 1 = 5.4931641 Watts	INVDT2*	1
42109 – 42110	S H	Output Phase A Current	Units: 1 = 1.8310547e-02 A _{RMS} Units: 1 = 1.8310547e-02 A _{DC}	INVDT1*	1
42111 – 42112	S H	Output Phase B Current	Units: 1 = 1.8310547e-02 A _{RMS} Units: 1 = 1.8310547e-02 A _{DC}	INVDT1*	1
42113 – 42114	S H	Output Phase C Current	Units: 1 = 1.8310547e-02 A _{RMS} Units: 1 = 1.8310547e-02 A _{DC}	INVDT1*	1
42115 – 42116	S H	Output Neutral Current	Units: 1 = 1.8310547e-02 A _{RMS} Units: 1 = 1.8310547e-02 A _{DC}	INVDT2*	1
42117 – 42118	S H	Total 3 Phase Current	Units: 1 = 1.8310547e-02 A _{RMS} Units: 1 = 1.8310547e-02 A _{DC}	Sum of currents from regs 42109 thru 42114	With registers listed
42119	S H	Output Phase A Voltage	Units: 1 = 1.8310547e-02 V _{RMS} Units: 1 = 1.8310547e-02 V _{DC}	INVDT2*	1
42120	S H	Output Phase B Voltage	Units: 1 = 1.8310547e-02 V _{RMS} Units: 1 = 1.8310547e-02 V _{DC}	INVDT2*	1
42121	S H	Output Phase C Voltage	Units: 1 = 1.8310547e-02 V _{RMS} Units: 1 = 1.8310547e-02 V _{DC}	INVDT2*	1
42122	S	Output AC Frequency	Units: 1 = 0.0625 Hz	INVDT1*	1
42123	S,H	Power Supply Voltage	Units: 1 = 0.0625 Volts	CTRLDT*	1
42124		Reserved			
42125		Reserved			
42201	S,H	Ambient Pressure	Units: 1 = 0.01 kpa	ENGDT1*	1
42202	S,H	Compressor Inlet Temperature	Units: 1 = 0.125°C	ENGDT1*	1

Register	Mode	Description	Representation	RS232 Command	Timing (Sec)
42203 – 42204	S,H	Engine Speed	Units: 1 = 1 RPM	ENGDT1*	1
42205		Reserved			
42206	S,H	Turbine Exhaust Temp Avg.	Units: 1 = 0.125°C	ENGDT1*	1
42207	S,H	Percent Fuel Command	Units: 1 = 0.1% Cmd	PRFUEL	2
42208		Fuel Pressure (Reserved)			
42209	C	Present Min Power Capacity	Units: 1 = 1 Watt Min: 0 Watts Max: 2,000,000,000 Watts	CURMPC	1
42211	C	Present Spinning Reserve	Units: 1 = 1 Watt Min: 0 Watts Max: 2,000,000,000 Watts	CURSPR	1
42213	S,H	Inlet Fuel Pressure		SPVDAT	1
		Fault Information			
46000 – 46001		Fault Summary Register (Bitmapped. Lower Order bits, 0 through 15 are contained in register 46001 and bits 16 – 31 in register 46000)	Bit 0 – Any System Fault Bit 1 – Category 1000 Fault Bit 2 – Category 2000 Fault ... Bit 20 – Category 20000 Fault Bits 21 – 31 - Unused	FLTLST	10
46002 – 46003		Faults 1000 – 1031 from Fault Category 1000	Bit 0 – Fault 1000 Bit 1 – Fault 1001 Bit 2 – Fault 1002 ... Bit 31 – Fault 1031	FLTLST	1
46004 – 46005		Faults 1032 – 1063	Bit 0 – Fault 1032 Bit 1 – Fault 1033 ... Bit 31 – Fault 1063	FLTLST	1
46006 – 46007		Faults 1064 – 1095	Bit 0 – Fault 1064 Bit 1 – Fault 1065 ... Bit 31 – Fault 1095	FLTLST	1
46008 – 46009		Faults 1096 – 1127	Bit 0 – Fault 1096 Bit 1 – Fault 1097 ... Bit 31 – Fault 1127	FLTLST	1
46010 – 46011		Faults 2000 – 2031 from Fault Category 2000	First 32 faults in Category 2000 Similar to registers 46002 – 46003 for Fault Category 1000	FLTLST	1
...					
46016 – 46017		Faults 2096 – 2127 from Fault Category 2000	Similar to registers 46008 – 46009 for Fault Category 1000	FLTLST	1
46018 – 46025		Faults in Category 3000	Similar to registers 46002 – 46009 for Fault Category 1000	FLTLST	1

Register	Mode	Description	Representation	RS232 Command	Timing (Sec)
46026 – 46033		Faults in Category 4000	Similar to registers 46002 – 46009 for Fault Category 1000	FTLST	1
...					
46146 – 46153		Faults in Category 19000	Similar to registers 46002 – 46009 for Fault Category 1000	FTLST	1
46154 – 46161		Faults in Category 20000	Similar to registers 46002 – 46009 for Fault Category 1000	FTLST	1
		Warranty Information			
47001 – 47002	S,H	Commission Date	Word 1, High Byte – Month Word 1, Low Byte – Day Word 2 – Year	WARNTY	30
47003 – 47005	S,H	Operating Time (Hours High)	Word 1 – Hours High Word 2 – Hours Low Word 3, High Byte – Minute Word 3, Low Byte – Second	WARNTY	30
47006 – 47007	S,H	Number of Starts	Units: 1 = 1 Start	WARNTY	30
47008 – 47010	S	RFC Low Psi Time	Word 1 – Hours High Word 2 – Hours Low Word 3, High Byte – Minute Word 3, Low Byte - Second	WARNTY	30

Write Registers

Some write registers may be written into without entering a password. However, most do require password access in order to change the values. Write Registers 48001, 48003 – 48008, and 48021 – 48022 may be written without password access. All other Write Registers will require entering a valid password in register 48004 through 48008 before modifying a value. Successful entry of the password may be verified by reading back the value at register 40006 as 1, indicating protected password access has been granted.

The paragraph below demonstrates how to enter a user password.

Entering a User Password

- Passwords may be no more than 9 characters (see Appendix A for character - hex translation)
- An additional character is required for a NULL terminator (0x00)
- Two characters make up one 16-bit register location
- Passwords must be entered starting in location 48004
- Fill any remaining register bytes with NULL (0x00)

The example below shows how to enter the default password:

Register Location	Byte Contents	
48004	0x55h (“U”)	0x53h (“S”)
48005	0x52h (“R”)	0x31h (“1”)
48006	0x32h (“2”)	0x33h (“3”)
48007	0x50h (“P”)	0x00h (NULL)
48008	0x00 (NULL)	0x00h (NULL)

Several write registers require multiple registers to be updated simultaneously in order to complete the operation. These registers will be identified with footnotes.

All values written into the write registers can be read back using the standard ModBus read procedure. This allows verification that the value that was attempted to be written into a specific register, can be read back from that register. However, this value may be different from the value of the corresponding read register, which could happen if the host device does not or was not able to accept the command issued to it. In that case, the command value remains unchanged and the corresponding read register on the ModBus Translator would still contain the old value.

WARNING	Several of the registers in this section access MicroTurbine commands that write to Non-Volatile Memory (NVM) locations. The NVM memory device has limited number of writes (10,000 writes) that can be executed before the device fails. All registers that apply (see below) are denoted with an asterisk (*) character preceding the description name.
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Table 9 - Holding Register (Write Only)

Register	Mode	Description	Representation	RS232 Command
General Communication Info				
48001	S	Selected Turbine ³	0 – This Turbine/Entire System 1 – Master Turbine 2 thru 10 – Specific Turbine	TURBNO,0
48002		Reserved		
48003	S,H	Logoff ⁴	Send 1 to logoff	LOGOFF
48004 – 48008	S,H	Enter Password ^{4,5}	Each byte represents an ASCII character for the password. String must be NULL terminated. (Default: USR123P)	PSSWRD
48009 – 48013	S,H	Change Password ⁶	Each byte represents an ASCII character for the password. String must be NULL terminated.	CPTPSW
48014 – 48018	S,H	*Verify Password ⁷	Each byte represents an ASCII character for the password. String must be NULL terminated.	VPTPSW
48020	S,H	Reboot	Send 1 to reboot system	REBOOT
48021	S,H	Communication Configuration ¹	Bit 0 – 1: Mode Bits 0 = Stationary 1 = HEV 2 = Reserved 3 = Reserved Bit 2 – 14: Not Used Bit 15: Comm Timeout Enable	NA
48022	S,H	Comm Timeout Period ²	Units: 1 = 1 Seconds Min: 1 Seconds Max: 65535 Seconds	NA
System Controls/Settings				
48101	S,H	*Start Command	0 – Stop, 1 – Start	STRCMD
48102	S	*User Start	0 – Stop, 1 – Start	USRSTR
48103	S,H	*Auto Restart	0 – Disabled, 1 – Enabled	AUTRST
48104	S	*Restart Delay (GC)	Units: 1 = 0.1 Minutes Min: 0.0 Minutes Max: 60.0 Minutes	RDLYGC

³ Updating this parameter will make all registers reflect data from system number selected. All read registers would be invalidated until the ModBus device has been able to query data from the new turbine number.

⁴ Logoff command is automatically issued after 5 minutes of no ModBus communication.

⁵ Changes Port Access Level (see Reg 40006) so that write commands can be processed. When no ModBus communication is received within 5 minutes, the LOGOFF command will be issued.

⁶ Changes the password for the Enter Password (see Reg 48004 - 48008). Must be followed by a write to the Verify Password registers (see Reg 48014 – 48018) with the same password data.

⁷ Must follow a write to the Change Password registers (see Reg 48009 - 48013) to have the new password (Enter Password, see Reg 48004 – 48008) become valid.

Register	Mode	Description	Representation	RS232 Command
48105	S	*Restart Delay (SA)	Units: 1 = 0.1 Minutes Min: 0.0 Minutes Max: 60.0 Minutes	RDLYSA
48106	S	*Remote Start Switch Enable	0 – User 1 – Remote 2 – GC User/SA Remote 3 – SA User/GC Remote	STRINP
48107		Reserved		
48108	S	*Utility Connection	0 – Invalid, 1 – Stand Alone, 2 – Grid Connect, 3 – Dual Mode	UTLCON
48109	S	Power Enable (SA only)	0 – Open, 1 – Closed	PWRENA
48110	S	*Auto Load (SA only)	0 – Disabled, 1 – Enabled	AUTOLD
48111 – 48112	S,H	Power Demand	Units: 1 = 1 Watt Min: 0 Watts Max: 2,000,000,000 Watts	PWRDMD
48113 – 48114	S,H	*Store Power Demand ⁸	Units: 1 = 1 Watt Min: 0 Watts Max: 2,000,000,000 Watts	PWRDST
48115	S,H	*Fuel Index 1	Units: 1 = 0.01 index Min: 0.10 Max: 14.00 (see Installation Guide for details)	FUEL11
48116	S,H	*Fuel Index 2	Units: 1 = 0.01 index Min: 0.10 Max: 2.00 (see Installation Guide for details)	FUEL12
48117	S,H	*Medium BTU Switch	0 – Normal 1 – Medium 2 – Low (see Installation Guide for details)	MEDBTU
48118	S	*MultiPac Enable	0 – Disabled, 1 – Enabled	MPENAB
48119	S	*This Turbine's Number	Master: 1 Slave: 2 thru 10	STRBNO
		Grid Connect and HEV Relays		
48301	S	*Under Voltage (GC)	Units: 1 = 1 VAC (line-to-line) Min: 360 VAC Max: 528 VAC	UNDVLT
48302	S	*Under Voltage Time (GC)	Units: 1 = 0.01 Seconds Min: 0.01 Second Max: 10.00 Seconds	UVLTTM

⁸ For continuous power command updates use registers 48111 - 48112 Power Demand.

Register	Mode	Description	Representation	RS232 Command
48303	S	*Over Voltage (GC)	Units: 1 = 1 VAC (line-to-line) Min: 360 VAC Max: 528 VAC	OVRVLT
48304	S	*Over Voltage Time (GC)	Units: 1 = 0.01 Seconds Min: 0.01 Second Max: 10.00 Seconds	OVLTTM
48305	S	*Fast Under Voltage (GC)	Units: 1 = 1 VAC (line-to-line) Min: 0 VAC Max: 528 VAC	FSTUVL
48306	S	*Fast Over Voltage (GC)	Units: 1 = 1 VAC (line-to-line) Min: 360 VAC Max: 635 VAC	FSTOVL
48307	S	*Under Frequency (GC)	Units: 1 = 0.1 Hz Min: 45.0 Hz Max: 65.0 Hz	UNDFRQ
48308	S	*Under Frequency Time (GC)	Units: 1 = 0.01 Seconds Min: 0.01 Second Max: 10.00 Seconds	UFRQTM
48309	S	*Over Frequency (GC)	Units: 1 = 0.1 Hz Min: 45.0 Hz Max: 65.0 Hz	OVRFRQ
48310	S	*Over Frequency Time (GC)	Units: 1 = 0.01 Seconds Min: 0.01 Second Max: 10.00 Seconds	OFRQTM
		Stand Alone Relays		
48401	S	*Output Voltage (SA)	Units: 1 = 1 VAC (line-to-line) Min: 150 VAC Max: 480 VAC	SAVOLT
48402	S	*Voltage Start (SA)	Units: 1 = 1 VAC (line-to-line) Min: 0 VAC Max: 480 VAC	STVOLT
48403	S	*Voltage Ramp (SA)	Units: 1 = 1 VAC/s (line-to-line) Min: 3 VAC/s Max: 6000 VAC/s	STVTRT
48404	S	*Under Voltage (SA)	Units: 1 = 1 VAC (line-to-line) Min: 0 VAC Max: 480 VAC	SAUVLT
48405	S	*Under Voltage Time (SA)	Units: 1 = 0.01 Seconds Min: 0.01 Second Max: 10.00 Seconds	SAUVTM
48406	S	*Over Voltage (SA)	Units: 1 = 1 VAC (line-to-line) Min: 150 VAC Max: 528 VAC	SAOVL

Register	Mode	Description	Representation	RS232 Command
48407	S	*Over Voltage Time (SA)	Units: 1 = 0.01 Seconds Min: 0.01 Second Max: 10.00 Seconds	SAOVTM
48408	S	*Output Frequency (SA)	Units: 1 = 0.1 Hz Min: 10.0 Hz Max: 60.0 Hz	SAFREQ
48409	S	*Frequency Start (SA)	Units: 1 = 0.1 Hz Min: 0.0 Hz Max: 60.0 Hz	STFREQ
48410	S	*Frequency Ramp (SA)	Units: 1 = 1 Hz/s Min: 3 Hz/s Max: 6000 Hz/s	STFQRT
48411	S	*Under Frequency (SA)	Units: 1 = 0.1 Hz Min: 5.0 Hz Max: 60.0 Hz	SAUFRQ
48412	S	*Under Frequency Time (SA)	Units: 1 = 0.01 Seconds Min: 0.01 Second Max: 10.00 Seconds	SAUFTM
48413	S	*Over Frequency (SA)	Units: 1 = 0.1 Hz Min: 10.0 Hz Max: 65.0 Hz	SAOFRQ
48414	S	*Over Frequency Time (SA)	Units: 1 = 0.01 Seconds Min: 0.01 Second Max: 10.00 Seconds	SAOFTM
		Load Management Settings		
48501	S	*Load Management Mode	0 – Disabled 2 – Load Following 3 – Time-of-Use	LMMODE
48502	S	*Meter Constant	Units: 1 = 0.001 Wh/pulse Min: 0.000 Wh/pulse Max: 50.000 Wh/pulse	LMMTRC
48503	S	*Utility Power Setpoint	Units: 1 = 0.1 kW Min: -1000.0 kW Max: +1000.0 kW	LMUTPW
48504	S	*Load Following Response Time	Units: 1 = 1 Second Min: 1 Second Max: 120 Seconds	LMRSPT
48505 – 48506	S	*Minimum Power Shutoff	Units: 1 = 0.1 kW Min: 0.0 kW Max: 2,000,000.0 kW	LMMPWR
48507	S	*Minimum Power Shutoff Time	Units 1 = 1 Minutes Min: 1 Minute Max: 15 Minutes	LMPWTM

Register	Mode	Description	Representation	RS232 Command
48508 ^{9,10}	S	Time of Use Event	Min: 1 Max: 20 Update of Holding Registers will be delayed 1 second	N/A
48509 ¹⁰	S	*TOU Event Day	0 – Inactive 1 – Sunday ... 7 – Saturday	LMTOUE
48510 ¹⁰	S	*TOU Event Time	High Byte – Hour Low Byte – Minute	LMTOUE
48511 ¹⁰	S	*TOU Event Start Command	0 – Stop, 1 – Start	LMTOUE
48512 ¹⁰ – 48513	S	*TOU Event Power Demand	Units: 1 = 1 Watt Min: 0 Watts Max: 2,000,000,000 Watts	LMTOUE
48514	S	*Reverse Power Protect	0 – Disabled, 1 - Enabled	LMRPFPP
48515	S	*Reverse Power Protect Time	Units 1 = 1 Seconds Min: 1 Second Max: 120 Seconds	LMRPTM
		UCB Relays		
48601 ^{11,12}	S	Selected Relay Number	Min: 1 Max: 6 Update of Holding Registers will be delayed 1 second	N/A
48602 ¹²	S	*Relay Function	0 – Standby 1 – Run 2 – Load 3 – Fault 4 – Standalone 5 – Dual Mode 6 – Disable 7 – Fuel On 8 – Purge	OUTRLY
48603 ¹²	S	*Relay Active State	0 – Open, 1 – Close	OUTRLY
		Battery Information		
48701	S	Battery Enable	0 – Disabled, 1 – Enabled	BATENA

⁹ Writing to only this register will query the information for a specific Time-of-Use event. Read registers 40508 through 40513 will be updated within 500ms with the requested information.

¹⁰ All of these registers must be written simultaneously to update a Time-of-Use event.

¹¹ Writing to only this register will query the information for a specific UCB Relay. Read registers 40601 through 40603 will be updated within 500ms with the requested information.

¹² All of these registers must be written simultaneously to update UCB Relay settings.

Register	Mode	Description	Representation	RS232 Command
48702	S	*Battery Auto Sleep	Units: 1 = 0.1 Hours Min: 1 = 0.1 Hours Max: 239 = 23.9 Hours	ATOSLP
48703	S	Battery Charge	0 – Disabled, 1 – Enabled	BATCHG
48704	S	Battery Recharge Enable (SA only)	0 – Disabled, 1 – Enabled	RCHENA
48705		Reserved		
48706		Reserved		
48707 ^{13,14}	S	Selected Charge Permission Day	1 – Sunday 2 – Monday ... 7 – Saturday Update of Holding Registers will be delayed 1 second	N/A
48708 ¹⁴	S	*Charge Permission Active	0 – Inactive, 1 – Active	CHGEQP
48709 ¹⁴	S	*Charge Permission Start Time. Must be earlier than 40710.	High Byte – Hour (0 – 23) Low Byte – Minute (Ignored)	CHGEQP
48710 ¹⁴	S	*Charge Permission End Time. Must be later than 40709.	High Byte – Hour (0 – 23) Low Byte – Minute (Ignored)	CHGEQP
48711		Reserved		
		Hybrid Vehicle Relays		
48801	H	*Under Voltage (HEV)	Units: 1 = 1 V _{DC} Min: 40 V _{DC} Max: 740 V _{DC}	UNDVLT
48802	H	*Under Voltage Time (HEV)	Units: 1 = 0.01 Seconds Min: 0.01 Second Max: 10.00 Seconds	UVLTTM
48803	H	*Over Voltage (HEV)	Units: 1 = 1 V _{DC} Min: 40 V _{DC} Max: 740 V _{DC}	OVRVLT
48804	H	*Over Voltage Time (HEV)	Units: 1 = 0.01 Seconds Min: 0.01 Second Max: 10.00 Seconds	OVLTTM
48805	H	*Fast Under Voltage (HEV)	Units: 1 = 1 V _{DC} Min: 40 V _{DC} Max: 740 V _{DC}	FSTUVL
48806	H	*Fast Over Voltage (HEV)	Units: 1 = 1 V _{DC} Min: 40 V _{DC} Max: 740 V _{DC}	FSTOVL
48807	H	*Battery Current Limit	Units: 1 = 1 A _{DC} Min: 0 = 0 A _{DC} Max: 195 = 195 A _{DC}	BATILM

¹³ Writing to only this register will query the information for a specific Charge Permission Day. Read registers 40707 through 40710 will be updated within 500ms with the requested information.

¹⁴ All of these registers must be written simultaneously to update Charge Permission Day settings.

Register	Mode	Description	Representation	RS232 Command
		Capstone Power Server		
48808	C	Min Power Capacity, Grid Connect	Units: 1 = 1 Watt Min: 0 Watts Max: 2,000,000,000 Watts	MPCPGC
48810	C	Min Power Capacity, Stand Alone	Units: 1 = 1 Watt Min: 0 Watts Max: 2,000,000,000 Watts	MPCPSA
48812	C	Spinning Reserve, Grid Connect	Units: 1 = 1 Watt Min: 0 Watts Max: 2,000,000,000 Watts	MPSRGC
48814	C	Spinning Reserve, Stand Alone	Units: 1 = 1 Watt Min: 0 Watts Max: 2,000,000,000 Watts	MPSRSA
48816	C	Multipac Mode	0 – Load Balancing, 1 – Max Efficiency	MPMODE
		Data Acquisition		
49001 – 49002	S,H	*System Date	Word 1, High Byte – Month Word 1, Low Byte – Day Word 2 – Year	DATESC
49003 – 49004	S,H	*System Time	Word 1 – Hour Word 2, High Byte – Minute Word 2, Low Byte – Second	TIMESC

Loopback Diagnostic Test (Function Code 08)

This function performs a communication test. The command requires a Slave Address, Function Code, Sub function Code, two bytes of user-supplied data bytes, and CRC16. The entire response should be identical to the command. This command is typically used to verify the existence of a device at a ModBus address. The example shown in the table below shows the user data transmission to perform the Loopback communication.

Table 10– Function Code 08 Command and Response (Loopback Diagnostic Test)

Byte	Name	Example	Notes
1	Slave Address	01	
2	Function Code	08	
3	Sub function high	00	Only legal sub function is 00,00
4	Sub function low	00	
5	Data high	55	Any two data bytes are allowed
6	Data low	AA	
7	CRC-16 low	XX	
8	CRC-16 high	XX	

Troubleshooting

In the event that there is a ModBus problem, attempt the following solutions provided below:

Symptom: Cannot communicate with the device through the ModBus Translator.

Solutions:

- Verify that the ModBus Translator Power Indicator light is ON.
- Verify that the device that the ModBus Translator is hooked to (MicroTurbine) is powered up. This can be verified by looking for lights on the display panel.
- Verify that the DB-9 serial cable from the MicroTurbine is properly plugged into both the Turbine unit, and the ModBus Translator.
- Verify that the Data Activity Indicator light on the ModBus Translator blinks occasionally.
- Verify that the RS-485 Bus wires are properly terminated, and the screws tightened into terminals 2 and 3 of the ModBus RS-485 connector. The A-Bus wire MUST connect to Terminal 3, and the B-Bus wire MUST connect to Terminal 2.
- Change the ModBus Translator to a different address.
- Change the baud rates of the entire system to a slower baud to verify. It is possible that by adding a new node to the RS-485 system, a previously achieved baud rate can no longer be supported. This occurs because the length of the cable and number of nodes may have changed.

Symptom: The Power Indicator light on the ModBus Translator is not ON.

Solutions:

- Verify that the power is correctly hooked to the ModBus Translator. The positive (+) power wire MUST hook to Pin-4. The negative (-) power wire MUST hook to Pin-5.

NOTE	If these wires are hooked up backwards, permanent damage to the ModBus Translator could occur!
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- Verify with a voltmeter, that the voltage at power terminals is DC, and is between +6.0V and +25.0V.

Symptom: The Data Activity Indicator light on the ModBus Translator is not lit. This light should never be solidly ON, but should blink ON and OFF periodically. When this light blinks, it shows that a valid ModBus command was received on the RS-485 Bus.

Solutions:

- Verify that the Power Indicator light is ON. The Data Activity light will not work if there is inadequate power to the ModBus Translator.
- Verify that the baud rate selector switch is set to the same baud rate your ModBus master system is communicating. If data rates are not the same, bit timing will be off and data will not be understood properly by the ModBus Translator.
- If there are still communications problems, then either the address should be changed, or the host device connected to the ModBus Translator over the DB-9 connector is not communicating.

Symptom: Unable to read back value from a read register that was previously written to a corresponding write register.

Solutions:

- Note that because this is a translator, there may be a 0.5sec to 1.0sec delay before the write operation is actually processed. Slow down the time between writing a Write Register and trying to read back the value from the corresponding Read Register.
- Verify access to write the register has been granted by reading register 40006. If a zero is read back, a password must first be entered by writing registers 48004 through 48008.
- Verify the connected port has control access by reading register 40003.
- A write operation may require update to multiple registers - rather than just one. If only one register is written to, the entire entry may be ignored.

Test Modes

Invalid address settings and the baud rate selector shall be used to place the system into various modes. In addition to normal operation, test modes will be made available for the Golden System board test operator and Unit-Under Test (UUT) functions.

The table below shows mode selections and corresponding address settings:

Table 11 - Mode Selection (Address)

Mode	Address Setting
Normal	1 – 247
Unit Under Test	0 and 248-254
Golden System	255

Golden System

The Baud Rate selector switch provided on the ModBus Translator Board will determine the RS-485 baud rate.

A Golden System (address set to 255), when powered up will:

1. Delay for 2 seconds in order for UUT to power up. The lower LED shall be ON during this process.
2. Begin blinking lower LED 250 msec ON, then 250 msec OFF, repeatedly, to indicate test in progress.
3. Test RS-232 communications by executing a command to the UUT.
4. Send an RS-232 command to initiate execution of a Loopback Command on the UUT.
5. Verify RS-485 command was received from UUT address (245_d).
6. Respond to the UUT's Loopback Command (08_h).
7. Verify the RS-232 response contains the correct data from the Loopback Command.
8. Execute steps 4 through 7 for nine (9) more iterations to verify operation.
9. Report that the test was successful by leaving the lower LED turned ON. When a failure has occurred, the lower LED shall be turned OFF for 2 seconds. This OFF period will be followed by a continued blink of the lower LED to indicate the Test Code below followed by a 2 second OFF break. The blink rate shall be 50 msec ON followed by 250 msec OFF.

The table below shows reported test codes:

Table 12 – Reported Test Codes

Test Code	Description
1	Test Successfully Complete
2	RS-232 Communication Failure
3	RS-485 Communication Failure

Unit Under Test Mode

When powered up, the UUT will respond to commands issued by the Golden System, and utilize functionality already implemented by the Debug Mode. The Baud Rate selector switch provided on the ModBus Translator Board will determine RS-485 baud rate. The system will be capable of receiving RS-232 commands that execute functions over the RS-485 ModBus interface.

The table below shows RS-232 debug commands that may be performed:

Table 13 - Debug RS-232 Commands

Command	Description	Arguments
MBADDR		
MBTEST		
MBRD10		
MBWR10		
MBRD16		
MBWR16		
MBECHO		

Remapping ModBus Registers

In some implementations, it may be desirable to re-map the ModBus register assignments. This may be done to “fill in the gaps” in the standard table, allowing for longer multi-byte read operations. It can be accomplished by using the following Relocate commands.

1. The commands to assign both read and write registers are MBASGN and MBSAVE and are available at the Capstone prompt (which is enabled by setting all address dip switches to “off” and connecting the RS232 program to the RS232 port). When new firmware is installed, the assignments are reset. A “batch” file can be created to load all the changes at once.

The command MBASGN works as follows:

MBASGN <enter>: lists all current assignments stored in memory (not NVM)

MBASGN =0 <enter>: clears all current assignments in memory (does not Write to NVM)

MBASGN =<ModBus addr>, <capstone addr>: assigns default capstone register to new ModBus Address

MBASGN =<ModBus addr>, 0: deletes ModBus assignment in memory – restore default

MBASGN =<ModBus addr>: displays current assignment for specified ModBus Address – shows assigned default

MBSAVE: saves current assignment list to NVM to be loaded on next boot

2. When a new ModBus address is assigned to a Capstone default register, that Capstone register will no longer be valid at its original address and may not be assigned to another ModBus address. In other words, it is not possible to have a Capstone default register (read or write) appear at more than one ModBus address; nor is it possible to have more than the original number of valid registers available at one time.
3. When re-assigning multi-word registers, only the first register location needs be assigned; the others will follow automatically. If an attempt is made to assign a register in the middle of a multi-word bank, a warning is generated and the command is ignored. For write registers, the multi-word banks are obvious, may be up to 6 words long, and are indicated as such in the documentation. For the read registers, the multi-word registers are only those returning pure 32-bit values and may only be 2 words long. To remap multi-word registers more than 2 words long, the user needs to reassign each word of the multi-word register. For ex., in case of the fault register, register 46002 will need to be remapped separately from register 46000, and that separately from register 46004, etc.
4. The MBSAVE command actually writes the assignment list from RAM to flash memory. The next time the ModBus controller is booted, the new assignments are loaded back into RAM and used. The MBASGN=0 command can be used to clear the RAM copy of the assignments; to reload the assignments from NVM use the REBOOT command.
5. By using the MBASGN command to list assignments and RS232 program's "W" command to save this to disk, a verified batch file for assigning the registers in a production situation can be created.

NOTE	A register re-assignment map may become invalid after a software upgrade. The registers per the new software will need to be reassigned once again after an upgrade.
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Table 14 – Relocate ModBus Register RS-232 Commands

Command	Description	Arguments
MBASGN	Assign new ModBus addresses	See text
MBSAVE	Save ModBus changes	See text

Capstone Technical Information

If questions arise regarding ModBus operation for your Capstone MicroTurbine, please contact Capstone Turbine Technical Support for assistance and information.

Capstone Technical Support

Toll Free Telephone: (877) 282-8966

Service Telephone: (818) 407-3600 • Fax: (818) 734-1080

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Appendix A - ModBus Codeset Download

Perform the following steps to download the ModBus Codeset:

1. Copy the MODBUS software file (ex: 512620-002.crc) to your hard drive, and rename the file to MODBUS.crc.
2. Ensure that the power to the MODBUS Translator Board is off.
3. The ADDRESS selector must be set with all switches in the ON position. This represents address 255. The position of the rotary switch does not matter.
4. Connect the MODBUS to the COM port of a PC.
5. With CRMS inactive, run the RS232.exe program.
6. Within the RS232.exe interface, enter the command F1 PSSWRD=A4D5M6N!
7. Turn on power to the MODBUS translator. As soon as the Capstone Turbine logo is seen, press the F1 key.
8. The prompt MNTADM>> should appear. If the prompt does not appear, there is an apparent failure and earlier steps should be repeated.
9. At the prompt, type LB C:\MODBUS.CRC 70000 10000 (this will actually be the directory of the copied crc file)
10. The next activity seen at the screen will be several lines of dots or periods; otherwise, a series of ones and zeroes will appear. When the sequence finishes, you will receive a 'Downloading Complete and Verified' message.
11. Enter the command DLTEST to query the checksum of this MODBUS Application Code segment. This checksum should match that of the version description document.
12. Enter the command DLBURN to burn the MODBUS Application Code into flash memory.
13. Upon completion of the burn operation, type the command FLEXEC to execute the MODBUS Application Code.
14. Upon completion of this execute operation, the message MECHO 25 is seen.
15. At this point, shut off power to the MODBUS. However, leave the RS232.exe program active.
16. The ADDRESS selector must be set to an address in the range 1-247. The recommended address is 55H.
17. Turn power on to the MODBUS.
18. Watch for the Capstone Turbine logo, the Boot Code version string, and the MODBUS Application Code version string at the screen.
19. The MNT> prompt should appear.
20. Verify the Boot Code version string has the correct version number.
21. Verify the MODBUS Application Code version string has the correct version number.

