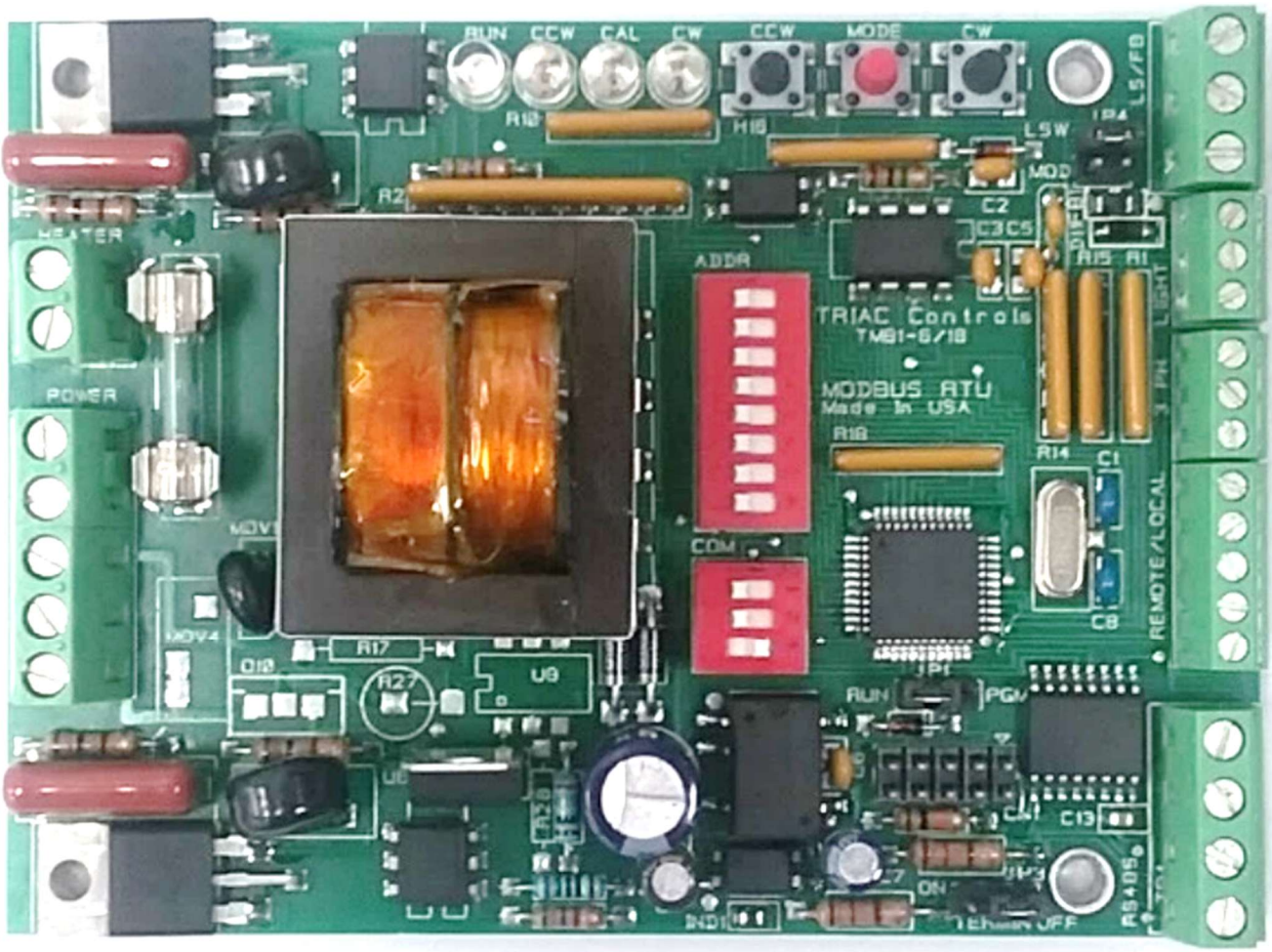
TMB1-RTU MODBUS CONTROL BOARD
USER MANUAL



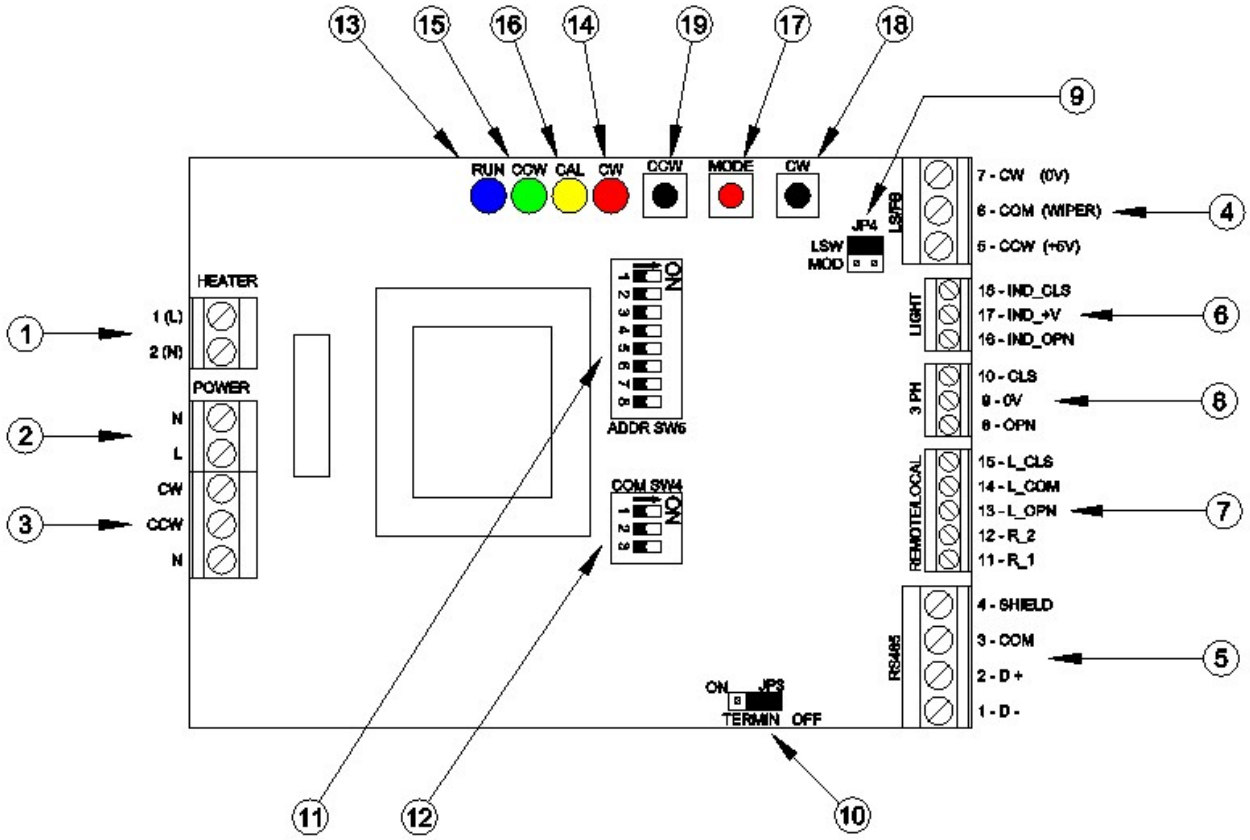
Contents

OVERVIEW

GENERAL DESCRIPTION

The TMB1-RTU control board is the successor to the TM-MODBUS-RTU control board with the addition of local/remote control capability and the added ability to control WE actuators with Semi-Integral Control Unit or BFS battery fail-safe actuators when specified. The TMB1-RTU is intended for use with AC actuators that require control by a Modbus RTU signal. It is available in two versions: 115VAC or 230VAC. The TMB1-RTU control board can be configured for two control modes: two-position on/off *Limit Switch Control*, or 0% - 100% *Modulation Control*. Actuator movements are initiated by and controlled from a Modbus RTU master over a three wire RS485 compliant bus.

CONTROL BOARD



1 Heater
2 Power
3 Motor
4 LS/FB Input
5 RS485
6 Open / Close Indicators (optional)
7 Local / Remote Switches (optional)
8 3 Phase & BFS Interface (optional)
9 Control Mode Selector (JP4)
10 120Ω Termination Resistor (JP3)
11 Address DIP Switches (SW5)
12 Communication DIP Switches (SW4)
13 Status/Run LED
14 CW LED
15 CCW LED
16 Calibration LED
17 Mode Button
18 CW manual control
19 CCW manual control

1 HEATER
Terminal block connection for external heater. Provides connections to supply power.

2 POWER
Terminal block connection for incoming supply power. Either 115VAC or 230VAC depending on board model.

3 MOTOR
Terminal block connection for motor control outputs.

4 LS/FB INPUT
Terminal block connection for position feedback input. Limit switch connections for on/off *Limit Switch Control* or feedback potentiometer for *Modulation Control*.

5 RS485
Terminal block connection for RS485 input signal.

A =	Non-inverting input	COM =	Signal reference
B =	Inverting input	S =	Cable shield

6 OPEN / CLOSE INDICATORS (OPTIONAL)
Connection for Open/Close indicators with local/remote control option -LR.

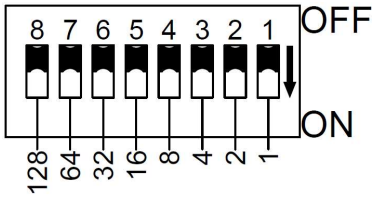
7 LOCAL / REMOTE SWITCHES (OPTIONAL)
Connection for Local/Remote control switches with local/remote control option -LR.

8 3 PHASE & BFS INTERFACE (OPTIONAL)
Connection for interface to Semi-Integral Control Unit or BFS battery backup failsafe actuators -CB.

9 CONTROL MODE SELECTOR (JP4)
Jumper to select between *Limit Switch Control* and *Modulation Control*. Jumper *MUST BE SET PRIOR* to applying power.

10 120Ω TERMINATION RESISTOR (JP3)
Jumper to select between using the on-board 120Ω termination resistor. It is recommended to set the termination resistor on the last board of the network.

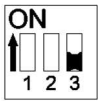
11 ADDRESS DIP SWITCHES (SW5)
DIP switches to set the network address of the board in binary. S1 is the least significant bit. S8 is the most significant bit. The address is the sum of the switch values in the on position. Refer to APPENDIX A



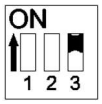
12 COMMUNICATION DIP SWITCHES (SW4)
DIP switches for setting the communication parity and baud rate.

PARITY

None



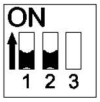
Even



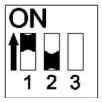
* Set stop bits to 2 for no parity

BAUD RATE

9.6k

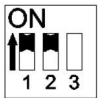


19.2k



57.6k

115.2k



13 STATUS/RUN LED (BLUE)
LED used to indicate board status. Refer to Table 2 for more information.

14 CW LED (RED)
LED used to indicate state of CW motor output or *Calibration* sub-mode. Refer to Table 2 for more information.

15 CCW LED (GREEN)
LED used to indicate state of CCW motor output or *Calibration* sub-mode. Refer to Table 2 for more information.

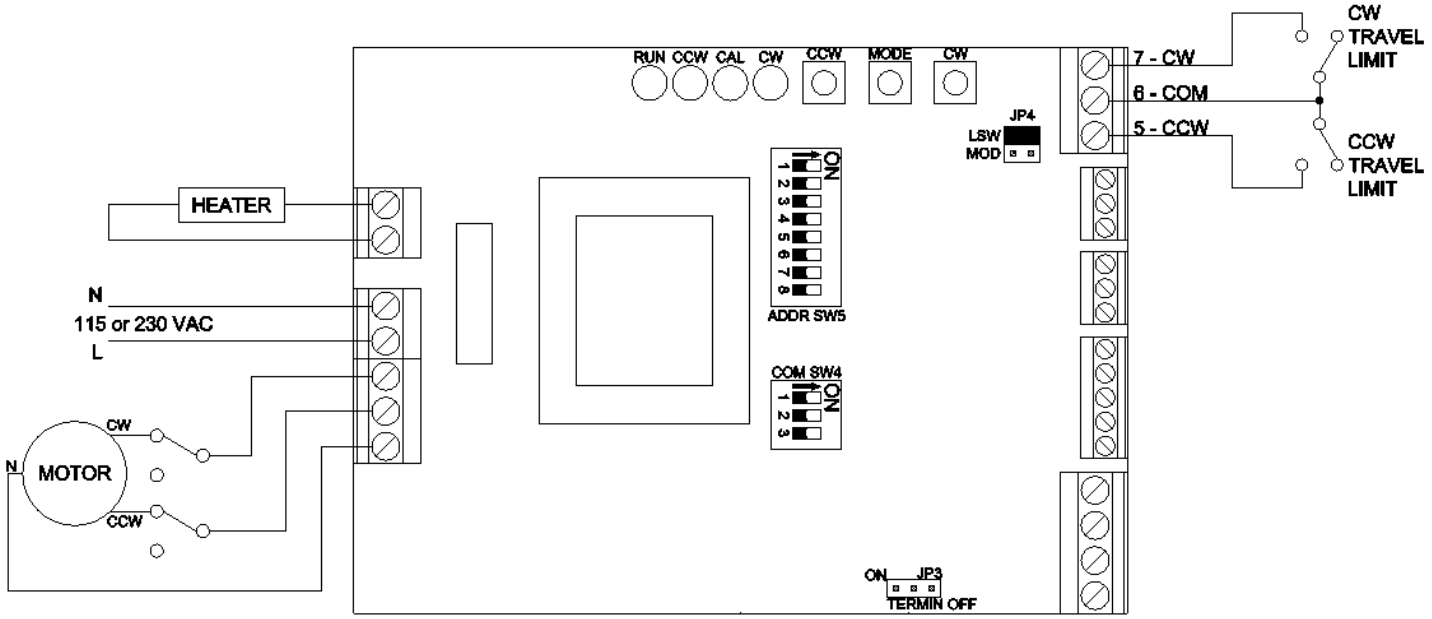
16 CALIBRATION LED (YELLOW)
LED used to indicate *Calibration* sub-mode. Refer to Table 2 for more information.

17 MODE BUTTON
Pushbutton to navigate through the operation modes. Used to enter/exit *Calibration Mode* and to cycle through *Calibration* sub-modes.

18 CW MANUAL CONTROL
Pushbutton to manually drive motor CW output when in *Calibration Mode*. Not enabled in *Calibration Sub-Mode 1* or *Run Mode*.

19 CCW MANUAL CONTROL
Pushbutton to manually drive motor CCW output when in *Calibration Mode*. Not enabled in *Calibration Sub-Mode 1* or *Run Mode*.

LIMIT SWITCH CONTROL



In *Limit Switch Control*, the travel span of the actuator is determined by two normally open limit switches; one for the CW travel limit, one for the CCW travel limit. These are the auxiliary close/open switches on the actuator. These are not the motor interrupt absolute limit travel switches in series with the CW and CCW motor connections.

The auxiliary limit switches used to control the TMB1-RTU must be engaged simultaneously or just prior to the absolute limit travel switches. If the absolute limit travel motor interrupt switches are engaged prior to the auxiliary travel limit switches, the TMB1-RTU will not recognize the end of travel and will not correctly provide indication of the position of the actuator.

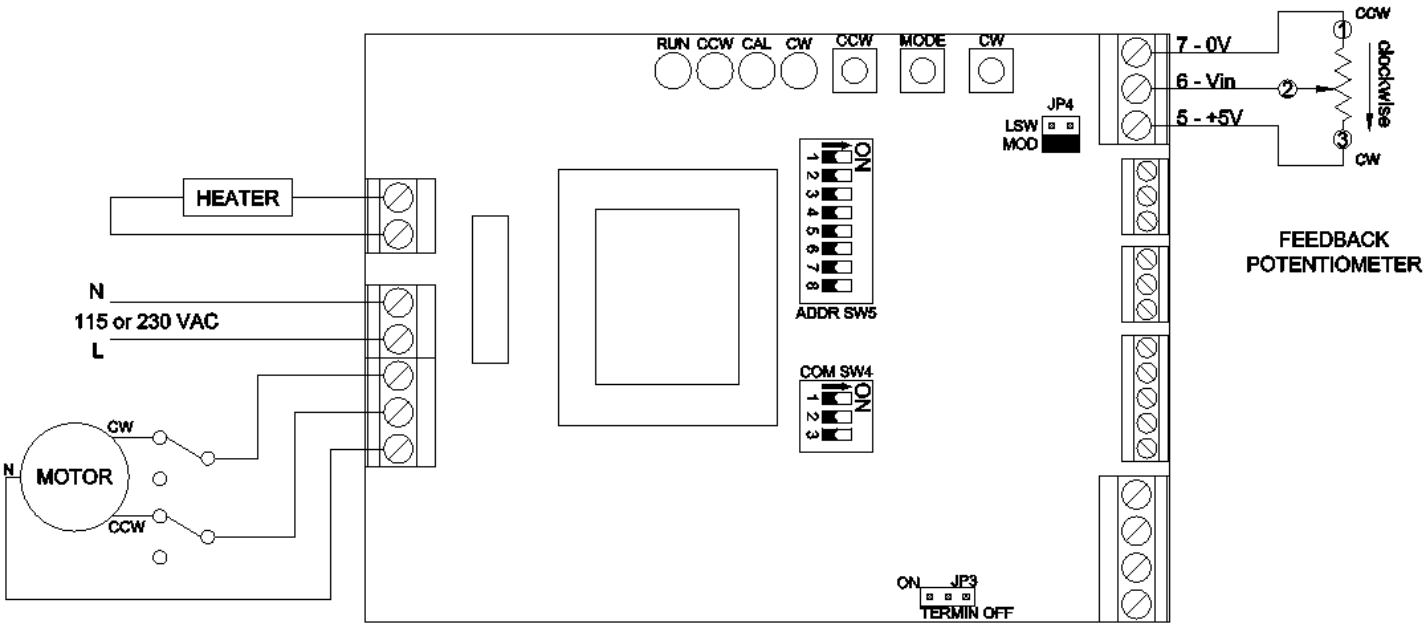
The two auxiliary travel limit switches are connected to the LS/FB terminal block. The CW travel limit switch NO contact must be connected to terminals 6 & 7. The CCW travel limit switch NO contact must be connected to terminals 5 & 6. Reversing the switch connections can result in the actuator not operating correctly and may cause the actuator to become unresponsive to issued travel commands.

WARNING! *DO NOT have both auxiliary switch contacts closed at the same time or connect a switch across terminals 5 & 7. This can damage the feedback input circuitry on the board.*

This control mode can be selected by positioning jumper JP4 in the LSW position as shown.

NOTE: *JP4 must be configured BEFORE power is supplied to the board to be recognized.*

MODULATION CONTROL



In *Modulation Control*, the travel span of the actuator is determined by a feedback potentiometer. In this control mode, the actuator can be accurately positioned at the fully CW position, the CCW position or any position in between. The motor interrupt absolute limit travel switches should be set just outside the 0% and 100% travel limits to avoid interfering with the feedback signal from the potentiometer.

The potentiometer must be connected to the LS/FB terminal block so the potentiometer wiper is connected to terminal 6. The potentiometer primary (0Ω) termination must be connected to terminal 7. The potentiometer resistance between terminals 6 & 7 should decrease as the actuator rotates CW, and increase as the actuator moves CCW if the potentiometer is connected properly. Reversing potentiometer connections (1) and (3) can result in the actuator not operating correctly and may cause the actuator to become unresponsive to issued travel commands.

WARNING! *DO NOT terminate potentiometer connections (1) & (2) or (2) & (3) across LS/FB terminals 5 & 7. This can damage the feedback input circuitry on the board.*

This control mode can be selected by positioning jumper JP4 in the MOD position as shown.

NOTE: *JP4 must be configured BEFORE power is supplied to the board to be recognized.*

PUSHBUTTONS

The Mode, CW manual control and CCW manual control pushbuttons are used to navigate through the various operating modes/sub-modes as well as manually control the actuator. A summary of their functionality is provided in Table 1.

TABLE 1: PUSHBUTTON FUNCTIONALITY

PUSHBUTTON	OPERATION MODE	DETAILS
MODE	Run	Press and release to enter *Calibration* Sub-Mode 1. (Only possible if in *Remote Operation*).
	Calibration 1	Press and release to enter *Calibration* Sub-Mode 2 and save current setting. Hold for 3 seconds to exit back to Run Mode and save current setting.
	Calibration 2	Press and release to enter *Calibration* Sub-Mode 3 and save current setting. Hold for 3 seconds to exit back to Run Mode and save current setting.
	Calibration 3	Press and release to enter *Calibration* Sub-Mode 4 and save current setting. Hold for 3 seconds to exit back to Run Mode and save current setting.
	Calibration 4	Press and release to enter *Calibration* Sub-Mode 1 and save current setting. Hold for 3 seconds to exit back to Run Mode and save current setting.
CW	Run	No functionality
	Calibration 1	
	Calibration 2	Energize CW motor output.
	Calibration 3	
	Calibration 4	
CCW	Run	No functionality
	Calibration 1	
	Calibration 2	Energize CCW motor output.
	Calibration 3	
	Calibration 4	

LED FUNCTIONALITY

The on-board LEDs are used to indicate which mode/sub-mode is currently active and provide feedback based on the different functionality of active the mode/sub-mode. A summary of LED status and function is provided in Table 2.

TABLE 2: LED FUNCTIONALITY

LED	COLOR	STATE	OPERATION MODE	DETAILS
Status/Run	**Blue**	ON	Calibration 1, 2, 3, 4	-
		Flash	Run (Loc. & Rem.)	• 1 sec. 10% ON, 90% OFF. Normal operation. • 1 sec. 80% ON, 20% OFF. Fault condition. Last communication exceeded time set in Register 40014.
Calibration	**Yellow**	ON	Calibration 3, 4	-
		OFF	Run (Rem.)	-
		Flash	Calibration 1 Run (Loc.)	1 sec. 50% ON, 50% OFF.
			Calibration 2	1 sec. 10% ON, 90% OFF.
CW	**Red**	ON	Run (Loc. & Rem.)	CW motor output energized.
			Calibration 2	• *Limit Switch Control*: Neither travel limit switch is engaged. • *Modulation Control*: Potentiometer wiper at center value.
			Calibration 3,4	*Limit Switch Control*: CW motor output energized.
		OFF	Run (Loc. & Rem.)	CW motor output NOT energized.
			Calibration 1	-
			Calibration 2	• *Limit Switch Control*: CCW travel limit switch engaged. • *Modulation Control*: Potentiometer wiper resistance greater than center value.
			Calibration 3, 4	*Limit Switch Control*: CW motor output NOT energized (even when CW button held).
			Calibration 4	*Modulation Control*: Sub-Mode 3 indication.
		Flash	Calibration 2	• *Limit Switch Control*: 1 sec. 10% ON, 90% OFF. CW travel limit switch engaged. • *Modulation Control*: Potentiometer wiper resistance less than center value. ON time increases as wiper approaches center value.
			Calibration 3	*Modulation Control*: 1 sec. 50% ON, 50% OFF. Sub-Mode 3 indication.
CCW	**Green**	ON	Run (Loc. & Rem.)	CCW motor output energized.
			Calibration 2	• *Limit Switch Control*: Neither travel limit switch is engaged. • *Modulation Control*: Potentiometer wiper at center value.
			Calibration 3,4	*Limit Switch Control*: CCW motor output energized.
		OFF	Run (Loc. & Rem.)	CW motor output NOT energized.
			Calibration 1	-
			Calibration 2	• *Limit Switch Control*: CW travel limit switch engaged. • *Modulation Control*: Potentiometer wiper resistance less than center value.
			Calibration 3, 4	*Limit Switch Control*: CCW motor output NOT energized (even when CCW button held).
			Calibration 3	*Modulation Control*: Sub-Mode 4 indication.
		Flash	Calibration 2	• *Limit Switch Control*: 1 sec. 10% ON, 90% OFF. CCW travel limit switch engaged. • *Modulation Control*: Potentiometer wiper resistance less than center value. ON time increases as wiper approaches center value.
			Calibration 4	*Modulation Control*: 1 sec. 50% ON, 50% OFF. Sub-Mode 4 indication.

OPERATION

OPERATING MODE NAVIGATION

The TMB1-RTU has two main operating modes: *Run Mode* and *Calibration Mode*. *Run Mode* is the primary operating mode that allows the actuator to be controlled remotely by Modbus commands, or locally by switches. *Calibration Mode* is used to save settings for controlling the actuator and has four sub-modes. These sub-modes store the DIP switch settings, find the center position of the potentiometer, set the 0% position, and set the 100% position.

Each *Calibration* sub-mode setting is saved either when proceeding to the next sub-mode, or when exiting back out into *Run Mode*. To proceed to the next sub-mode, press and release the MODE pushbutton. To exit back out into the normal operating *Run Mode*, hold the MODE pushbutton for approximately 3 seconds until the blue LED begins its normal 10% on flash rate. The menu flow diagram is illustrated in Figure 1.

WARNING! *When exiting out of Calibration Mode back into the normal operating Run Mode, the actuator will return to the last command position issued in Register 40010.*

NOTE: *Calibration Mode* can only be entered if the TMB1-RTU is set for *Remote Operation*. It cannot be entered during *Local Operation*.

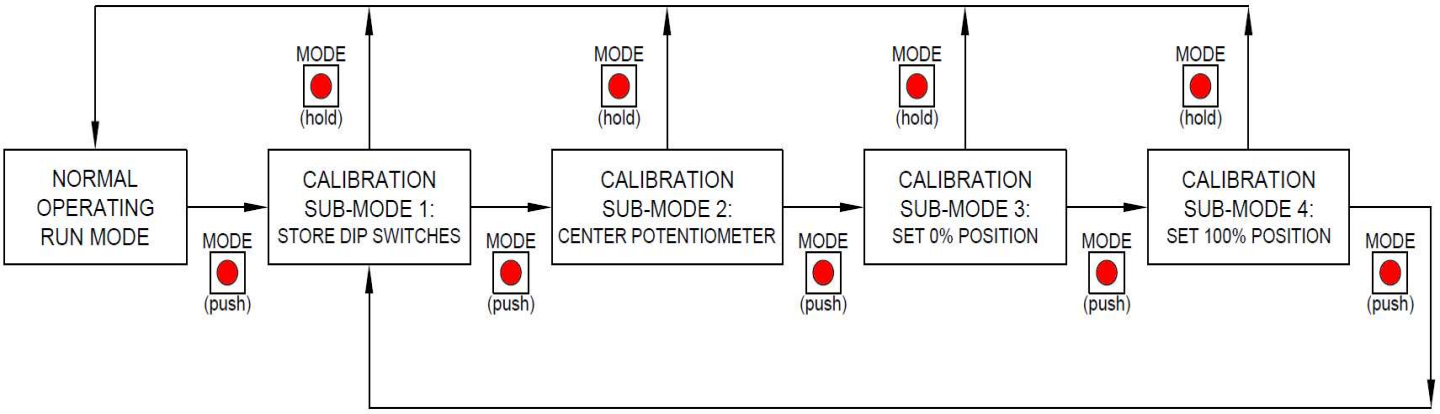


FIGURE 1: MENU FLOW DIAGRAM

RUN OPERATING MODE

When the board is powered up, it will default to its normal operating *Run Mode*. It is in this operating mode the actuator can be operated remotely with Modbus commands or locally with switches. The nature of the Modbus commands will differ depending on if the actuator is set for *Limit Switch Control* or *Modulation Control*. A description of each control scheme is provided below. In this operating mode the LEDs behave as indicated in Table 3.

TABLE 3: RUN OPERATING MODE LEDS

LED	DETAILS
STATUS/RUN (blue)	Flash 10% / 90%: Normal operation. Flash 80% / 20%: Fault condition. Last communication exceeded time set in Register 40014.
CALIBRATION (yellow)	OFF: Remote Operation Flash 50% / 50%: Local Operation
CW (red)	ON: CW motor output energized OFF: CW motor output NOT energized
CCW (green)	ON: CCW motor output energized OFF: CCW motor output NOT energized

LIMIT SWITCH CONTROL OPERATION

When operating in *Limit Switch Control*, Bit 1 and Bit 2 in Register 40009 control the actuator direction and movement. The actuator can also be controlled by writing specific values to Register 40010 as an alternative.

Bits 1 – 4 in Register 40001, provide the feedback information about the travel direction and end of travel position of the actuator. Operating details are provided in Table 4.

TABLE 4: LIMIT SWITCH CONTROL OPERATION

OPERATION Register 40009, *Action Bits/Flags 2*		
Bit 2	**Bit 1**	**Description**
0	x	De-energize motor outputs and stop actuator.
1	0	Energize motor outputs and drive actuator CW.
1	1	Energize motor outputs and drive actuator CCW.

OPERATION Register 40010, *Command Position*	
Value	**Description**
0	Energize motor outputs and drive actuator CW.
500	De-energize motor outputs and stop actuator.
1000	Energize motor outputs and drive actuator CCW.

FEEDBACK Register 40001, *Status Flags 1*						
Position			**Movement**		**Description**	
Bit 4	**Bit 3**		**Bit 2**	**Bit 1**	**Position**	**Movement**
0	0		0	0	Between limits	Stopped
0	0		0	1	Between limits	CCW
0	0		1	0	Between limits	CW
0	0		1	1	?	?
0	1		0	0	CCW limit	Stopped
0	1		0	1	?	?
0	1		1	0	CCW limit	CW (1)
0	1		1	1	?	?
1	0		0	0	CW limit	Stopped
1	0		0	1	CW limit	CCW (1)

(1) Could indicate jam condition.

Note that even though the motor stops when the destination travel limit switch is closed, the motor outputs of the TMB1-RTU control board remain energized until a stop command is written to Register 40009 or 40010.

In Register 40009, Bit 1 establishes the direction of actuator travel and Bit 2 energizes or de-energizes the motor output corresponding to the direction determined by Bit 1.

If Bit 1 = 0, the actuator is set to move in the CW direction. If Bit 1 = 1, the actuator is set to move in the CCW direction.

If Bit 2 = 0, the motor output is not energized. If Bit 2 = 1, the CW motor output is energized when Bit 1 = 0 and the CCW motor output is energized when Bit 1 = 1. Unless Bit 2 is cleared, the actuator will continue to move in the specified direction until the corresponding end of travel limit switch closes.

It is acceptable to change direction with Bit 1 while maintaining Bit 2 = 1. If the direction is changed while the actuator is moving, a short delay occurs before the actuator begins moving in the opposite direction.

Writing values shown in Table 4 into Register 40010 will automatically set Bit 1 and Bit 2 in Register 40009 according to the action specified.

CAUTION! *When writing to Bit 1 and Bit 2 of Register 40009, be careful not to change the other register bits.*

In Register 40001, Bit 1 and Bit 2 indicate the direction of travel. Bit 3 and Bit 4 indicate if the actuator is at the full CCW or full CW limit respectively.

While the actuator is moving in the CW direction, Bit 2 = 1. When the actuator reaches the CW end of travel limit switch, Bit 2 = 0 and Bit 4 = 1. The CW motor output is de-energized.

While the actuator is moving in the CCW direction, Bit 1 = 1. When the actuator reaches the CCW end of travel limit switch, Bit 1 = 0 and Bit 3 = 1. The CCW motor output is de-energized.

OBSTRUCTION OR JAM DETECTION

When a move command is given by either setting Bit 1 and Bit 2 in Register 40009, or by writing valid value to Register 40010, a timer is immediately started. The timer continues to increment once every second. After each increment, the timer value is compared to the value set in Register 40011 for the *Travel Timeout*.

If the destination travel limit switch closes before the timer value is greater than the value in Register 40011, the actuator is operating normally. Bit 1 or Bit 2 in Register 40001 is cleared. Bit 3 or Bit 4 in Register 40001 is set depending on the travel limit switch that is closed.

If the destination travel limit switch IS NOT closed before the timer value is greater than the value in Register 40011, a jam or obstruction has prevented the valve from operating properly. The active motor output is de-energized, and Bit 1 or Bit 2 in Register 40001 is cleared depending on the direction of travel.

OBSTRUCTION
An obstruction is indicated by the timeout occurring after the actuator has left the starting position, but before it has reached the destination position. Neither end of travel limit switches will be engaged for an obstruction. Bit 5 in Register 40001 will be set when an obstruction is detected.

JAM
A jam is indicated by the timeout occurring when the actuator has not left the starting position. In this case, the starting travel limit switch will remain engaged while Bit 1 or Bit 2 in Register 40001 show movement as indicated in Table 4. Bit 6 in Register 40001 will be set when a jam is detected.

Resuming normal operation from either an obstruction or a jam may be attempted by resetting the actuator using Bit 3 in Register 40009. In case of an obstruction, briefly reversing the direction may also allow operation to resume. This will clear Bit 5 or 6 depending on the condition. If the valve continues to show an obstruction or a jam condition, the cause may need to be manually cleared first.

MODULATION CONTROL OPERATION

When operating in *Modulation Control*, the actuator is controlled using the *Command Position* Register 40010, and the *Sensitivity* Register 40013. The actual location of the actuator is indicated by the *Current Position* Register 40008.

When a new command position value is written to Register 40010, the new value is compared to the current position value in Register 40008. If the difference between the two values is greater than the sensitivity value in Register 40010, the actuator begins moving towards the new command position. When the current position value is near the command position value, the actuator is stopped.

When one of the motor outputs is de-energized to stop the actuator, there will be some coasting due to load inertia and other factors. This coasting is measured by the TMB1-RTU Control Board. The extra travel due to the coasting is compensated for by de-energizing the motor output prematurely. This compensation for the coasting limits the response to small changes in the command position.

If the command position would result in a move that is less than the travel distance during coasting, the appropriate motor output will not be energized and there will be no actuator movement. This may even happen even if the sensitivity value in Register 40013 would normally allow the actuator movement.

Bit 1 and Bit 2 in Register 40001 are also used to indicate the direction of travel. If the actuator is moving in the CW direction, Bit 2 = 1. If the actuator is moving in the CCW direction, Bit 1 = 1. When the actuator reaches the command position value and is stopped, Bit 1 and Bit 2 will equal 0.

OBSTRUCTION OR JAM DETECTION

When a value is written to Register 40010 that would cause the actuator to move to a new position, a timer is simultaneously started when the motor output is energized. While the motor output remains energized, the timer is incremented 100 counts per second. When the value of the timer equals the value in the *Non-Movement Timeout* Register 40012, the feedback potentiometer is measured and compared to the beginning value when the timer was started.

If there is a change in the measure feedback potentiometer value, the timer is reset, and begins counting again. This procedure is repeated until either the destination command position is reached, or the measured position does not change within the time dictated by Register 40012. In either case, the active motor output is de-energized, and Bit 1 or Bit 2 in Register 40001 is cleared depending on the direction of travel.

OBSTRUCTION
An obstruction is indicated when no movement is detected at any position between the 0% or 100% positions. Bit 5 in Register 40001 will be set when an obstruction is detected.

JAM
A jam is indicated when no movement is detected from the 0% or 100% positions. Bit 6 in Register 40001 will be set when a jam is detected.

Resuming normal operation from either an obstruction or a jam may be attempted by resetting the actuator using Bit 3 in Register 40009. In case of an obstruction, briefly reversing the direction may also allow operation to resume. This will clear Bit 5 or 6 depending on the condition. If the valve continues to show an obstruction or a jam condition, the cause may need to be manually cleared first.

LOCAL/REMOTE CONTROL (OPTION)

The TMB1-RTU can be controlled locally by switches when used with a local/remote controls option for both *Limit Switch Control* and *Modulation Control*. The Open and Close position is determined according to which control mode the actuator is operating in. In *Limit Switch Control* this is by the actuator auxiliary switches. In *Modulation Control* this is by the feedback potentiometer.

Terminals 11 & 12 determine if the actuator is operating locally, or remotely. When terminals 11 & 12 are connected, the TMB1-RTU is operated remotely with Modbus commands. When operated remotely, registers may be read or written to. When terminals 11 & 12 are not connected, the TMB1-RTU is operated locally with switches connected to terminals 13 thru 15. When operated locally, registers may only be read, and loss of Modbus communication has no effect.

Functionality of local/remote control in *Limit Switch Control* or *Modulating Control* is summarized in Table 5.

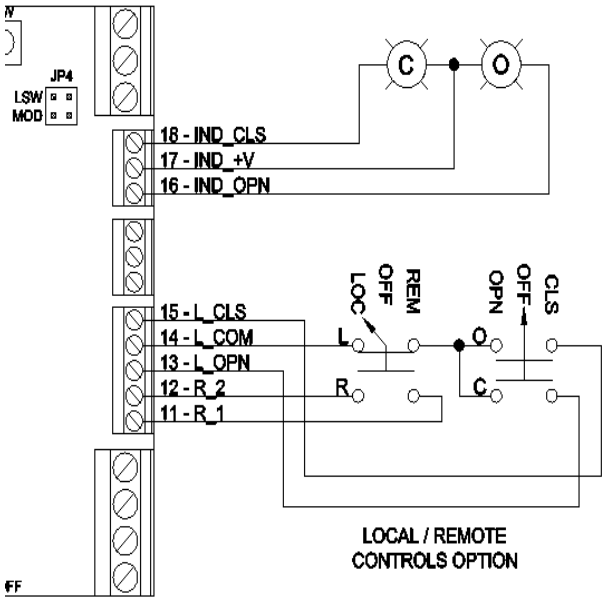


TABLE 5: LOCAL/REMOTE FUNCTIONALITY

Remote/Local Terminals					Description
11 R_1	12 R_2	13 L_OPN	14 L_COM	15 L_CLS	
NOT connected		NOT connected			Local Operation. No Open or Close input. No movement. Motor outputs are not energized.
		13 to 14			Local Operation. Open input. Move to Open position. *Limit Switch Control*: CCW motor output energized *Modulation Control,* Direct Acting: CCW motor output energized *Modulation Control*, Reverse Acting: CW motor output energized
		15 to 14			Local Operation. Close input. Move to Close position. *Limit Switch Control*: CW motor output energized *Modulation Control,* Direct Acting: CW motor output energized *Modulation Control*, Reverse Acting: CCW motor output energized
connected		n/a			Remote Operation. No switch control. Actuator controlled by Modbus commands only.

The corresponding indicator connected to terminals 16 thru 18 will light when the Open or Close position is reached in both local and remote operation. The CW LED and CCW LED on the TMB1-RTU board will also light when the corresponding motor output is energized.

NOTE: The TMB1-RTU can only enter local operation if it is in *Run Mode*. Local operation cannot be entered directly from *Calibration Mode* without first exiting back out to *Run Mode*.

NOTE: When changing from local to remote control, the current position will be stored in the *Command Position* Register 40010. If any motor output is energized when changing from local to remote control, it will be deenergized and the actuator will stop movement.

CALIBRATION

CALIBRATION OPERATING MODE

Calibration has the four steps / sub-mode listed below.

1. Store DIP Switch Settings
2. Center Potentiometer
3. Set 0% Position
4. Set 100% Position

Exiting each step saves the current setting for that step / sub-mode. When the calibration steps are finished, exit back into the *Run Mode* for normal operation by holding the red MODE push button. Press the MODE push button to cycle through the sub modes as illustrated in Figure 1 in the previous section.

In *Limit Switch Control*, only the first sub-mode needs to be entered to store the DIP switch setting. In *Modulation Control* cycle through all four sub-modes with the MODE push button following the information provided below for each sub-mode.

NOTE: *Actuator must be set for Remote operation when using Local/Remote controls to enter Calibration Mode.*

- *It is not possible to enter Calibration Mode if the Local/Remote inputs are set for Local operation.*
- *It is not possible to select Local operation while in Calibration Mode.*

WARNING! *When exiting out of Calibration Mode back into the normal operating Run Mode, the actuator will return to the last command position issued.*

NOTE: It is not possible to switch from remote operation to local operation while in *Calibration Mode*. To operate with local controls, it is necessary to first exit out to *Run Mode*.

SUB-MODE 1: STORE DIP SWITCH SETTINGS

The Store DIP Switch Settings *Calibration* sub-mode is used to store the Address and Communication DIP switch settings into non-volatile memory.

DIP switch settings can be saved after entering this *Calibration* sub-mode either by proceeding to the next *Calibration* sub-mode, or by exiting back out into *Run Mode*. While in this mode, the DIP switches can still be configured but any changes to the DIP switches are not recognized unless this *Calibration* sub-mode is subsequently exited after making the changes.

In this *Calibration* sub-mode the LEDs behave as indicated below.

LED	CONTROL MODE	DETAILS
STATUS/RUN (blue)	Limit Switch	ON
	Modulation	
CALIBRATION (yellow)	Limit Switch	Flash 50% / 50%
	Modulation	
CW (red)	Limit Switch	OFF
	Modulation	
CCW (green)	Limit Switch	OFF
	Modulation	

SUB-MODE 2: CENTER POTENTIOMETER

The Center Potentiometer *Calibration* sub-mode is used to locate the midrange of the feedback potentiometer resistance span. This is to ensure the potentiometer is capable of travelling in either direction without rotating outside of its operating range, thus providing unreliable position feedback. This *Calibration* sub-mode is only required for configuring the actuator in *Modulation Control*.

The red and green LEDs are used to find the midrange resistance of the feedback potentiometer. The status of each of the LEDs changes depending on the position of the potentiometer wiper arm. When the wiper is at the potentiometer center resistance value, both red and green LEDs will be solid. If the wiper resistance is less than the center value, the red LED will flash and the green LED will turn off. If the wiper resistance is greater than the center value, the red LED will turn off and the green LED will flash.

As the potentiometer wiper moves closer to the center value, the corresponding LED will begin to flash more rapidly depending on which side of the center value the wiper is approaching from. When the potentiometer is rotated so the wiper is at either limit, the corresponding LED will flash at approximately a 10% duty rate every second. Halfway between the potentiometer center point and either of the end values, the corresponding LED will flash at approximately a 50% duty rate every second. Just prior to the center point, the corresponding LED will flash at approximately a 90% duty rate every second.

In this *Calibration* sub-mode the LEDs behave as indicated below.

LED	CONTROL MODE	DETAILS
STATUS/RUN (blue)	Limit Switch	ON
	Modulation	
CALIBRATION (yellow)	Limit Switch	Flash 10% / 90%
	Modulation	
CW (red)	Limit Switch	ON: Neither travel limit switch engaged OFF: CCW travel limit switch engaged Flash 10% / 90%: CW travel limit switch engaged
	Modulation	ON: Potentiometer wiper at center value OFF: Potentiometer wiper resistance greater than center value Flash: Potentiometer wiper resistance less than center value. ON time increases as wiper approaches center value.
CCW (green)	Limit Switch	ON: Neither travel limit switch engaged OFF: CW travel limit switch engaged Flash 10% / 90%: CCW travel limit switch engaged
	Modulation	ON: Potentiometer wiper at center value OFF: Potentiometer wiper resistance less than center value Flash: Potentiometer wiper resistance greater than center value. ON time increases as wiper approaches center value.

SUB-MODE 3: SET 0% POSITION

This *Calibration* sub-mode is used to set the position of the actuator that corresponds to a 0% command input in *Modulation Control*. If the full CW position is set, the actuator is direct acting. If the full CCW position is set, the actuator is reverse acting. Register 40001 Bit 9 indicates the which action mode the actuator is set to.

In this *Calibration* sub-mode the LEDs behave as indicated below.

NOTE: *Both the 0% position in Sub-Mode 3 and 100% position in Sub-Mode 4 must be set at different positions for the actuator to operate properly.*

LED	CONTROL MODE	DETAILS
STATUS/RUN (blue)	Limit Switch	ON
	Modulation	
CALIBRATION (yellow)	Limit Switch	ON
	Modulation	
CW (red)	Limit Switch	ON: CW motor output energized OFF: CW motor output NOT energized (even when CW button held)
	Modulation	Flash 50% / 50%
CCW (green)	Limit Switch	ON: CCW motor output energized OFF: CCW motor output NOT energized (even when CCW button held)
	Modulation	OFF

SUB-MODE 4: SET 100% POSITION

This *Calibration* sub-mode is used to set the position of the actuator that corresponds to a 100% command input in *Modulation Control*. If the full CCW position is set, the actuator is direct acting. If the full CW position is set, the actuator is reverse acting. Register 40001 Bit 9 indicates the which action mode the actuator is set to.

NOTE: *Both the 0% position in Sub-Mode 3 and 100% position in Sub-Mode 4 must be set at different positions for the actuator to operate properly.*

In this *Calibration* sub-mode the LEDs behave as indicated below.

LED	CONTROL MODE	DETAILS
STATUS/RUN (blue)	Limit Switch	ON
	Modulation	
CALIBRATION (yellow)	Limit Switch	ON
	Modulation	
CW (red)	Limit Switch	ON: CW motor output energized OFF: CW motor output NOT energized (even when CW button held)
	Modulation	OFF
CCW (green)	Limit Switch	ON: CCW motor output energized OFF: CCW motor output NOT energized (even when CCW button held)
	Modulation	Flash 50% / 50%

MODBUS

FUNCTION CODES

The TMB1-RTU Controller is a Modbus slave that supports the following Modbus functions.

Code	Code (hex)	Code Definition
03	0x03	Read Holding Registers
08	0x08	Diagnostics
16	0x10	Write Multiple Registers

Function 03 reads the contents of a contiguous block of holding registers. All registers, 40001-40017 are readable with this function.

Function 16 writes values into a sequence of adjacent holding registers. Only registers, 40009-40017 can be written to with this function.

Function 08 currently only supports the Return Query Data sub-function. This is loopback test that verifies communication between a master and an actuator connected to the network.

FUNCTION 03 (0X03) – READ HOLDING REGISTERS

Modbus Function 03 reads the contents of a contiguous block of holding registers in a remote device. Fields besides the actuator address, function code and byte count are a 16-bit value divided into two 8-bit bytes. The high byte is communicated first, followed by the low byte. Additionally, data from the starting register is communicated first while data from the ending register is communicated last.

The query message from the master specifies the actuator to be read, the starting register address and the quantity of registers being read. The response from the actuator returns the actuator address, function code, quantity of bytes being returned and the register values that were requested.

EXAMPLE: Data from Registers 40004 to 40007 is requested to find the total motor run time and total number of motor starts. The actuator address is 5. For this example, the total motor run time is 555 hours (0x22B) and the total number of motor starts is 70,324 (0x112B4).

The master query:

Byte No.	Byte Description	Byte Data
0	Actuator Address	0x05
1	Function Code	0x03
2	Starting Register Address Hi	0x00
3	Starting Register Address Lo	0x03
4	No. of Registers Hi	0x00
5	No. of Registers Lo	0x04
6	Error Check Hi	??
7	Error Check Lo	??

The slave response:

Byte No.	Byte Description	Byte Data
0	Actuator Address	0x05
1	Function Code	0x03
2	Data Byte Count	0x08
3	Data (Register 40004) Hi	0x00
4	Data (Register 40004) Lo	0x00
5	Data (Register 40005) Hi	0x02
6	Data (Register 40005) Lo	0x2B
7	Data (Register 40006) Hi	0x00
8	Data (Register 40006) Lo	0x01
9	Data (Register 40007) Hi	0x12
10	Data (Register 40007) Lo	0xB4
11	Error Check Hi	??
12	Error Check Lo	??

FUNCTION 16 (0X10) – WRITE MULTIPLE REGISTERS

Modbus Function 16 writes values into a sequence of adjacent holding registers in a remote device. Fields besides the actuator address, function code and byte count are a 16-bit value divided into two 8-bit bytes. The high byte is communicated first, followed by the low byte. Additionally, data from the starting register is communicated first while data from the ending register is communicated last.

The query message from the master specifies the actuator to be written to, the starting register address, the quantity of registers being written to, the quantity of bytes being written, and finally the actual bytes to be written in the registers. The response from the actuator returns the actuator address, function code, starting register address and finally the quantity of registers that were written to.

EXAMPLE: An actuator with address 5 is to be moved to the 25% position. A value of 250 must be written to Register 40010.

The master query:

Byte No.	Byte Description	Byte Data
0	Actuator Address	0x05
1	Function Code	0x10
2	Starting Register Address Hi	0x00
3	Starting Register Address Lo	0x09
4	No. of Registers Hi	0x00
5	No. of Registers Lo	0x01
6	Byte Count	0x02
7	Data Hi	0x00
8	Data Lo	0xFA
9	Error Check MSB	??
10	Error Check LSB	??

The slave response:

Byte No.	Byte Description	Byte Data
0	Actuator Address	0x05
1	Function Code	0x10
2	Starting Register Address Hi	0x00
3	Starting Register Address Lo	0x09
4	No. of Registers Hi	0x00
5	No. of Registers Lo	0x01
6	Error Check MSB	??
7	Error Check LSB	??

FUNCTION 08 (0X08) – DIAGNOSTICS

Modbus Function 08 provides numerous options for checking and controlling the communication system between the Modbus master and connected slave devices. The TMB1-RTU control board currently only supports the diagnostics sub-functions listed.

Code	Code (hex)	Sub-function Definition	Sub-Function Description
00	0x0000	Return Query Data	Loopback test. Data passed in the query data field from the master is to be returned in the response from the actuator. The entire response message should be identical to the query.

Fields besides the actuator address and function code are a 16-bit value divided into two 8-bit bytes. The high byte is communicated first, followed by the low byte. The query message from the master specifies the actuator to be written to, the starting register address, the quantity of registers being written to, the quantity of bytes being written, and finally the actual bytes to be written in the registers. The response from the actuator returns the actuator address, function code, starting register address and finally the quantity of registers that were written to.

EXAMPLE: Communication to actuator with address 5 is being verified using the loopback test (sub-function code 00). The data being used is 0xA537.

The master query:

Byte No.	Byte Description	Byte Data
0	Actuator Address	0x05
1	Function Code	0x08
2	Sub-function Hi	0x00
3	Sub-function Lo	0x00
4	Data Hi	0xA5
5	Data Lo	0x37
6	Error Check MSB	??
7	Error Check LSB	??

The slave response:

Byte No.	Byte Description	Byte Data
0	Actuator Address	0x05
1	Function Code	0x08
2	Sub-function Hi	0x00
3	Sub-function Lo	0x00
4	Data Hi	0xA5
5	Data Lo	0x37
6	Error Check MSB	??
7	Error Check LSB	??

REGISTERS

All registers are 16 bits in length. When the register is addressed in the data communications, the register is assigned a hexadecimal value starting with 0x00. Therefore, registers numbered 40001-40017 are addressed as 0-16 in decimal, or 0x00 to 0x10 in hexadecimal resulting in the register always addressed one value below the specified decimal register number.

The following table provides a list of all registers used by the TMB1-RTU control board.

Register No.	Register Address	Address Name	16 bit / Digital Name	Unit	Scale	Range	Default	Read / Write
40001	0x00	STATUS FLAGS 1	INT					
		bit 1	CCW Movement	Bit	N/A	True/False	N/A	Read
		bit 2	CW Movement	Bit	N/A	True/False	N/A	Read
		bit 3	CCW Travel Limit	Bit	N/A	True/False	N/A	Read
		bit 4	CW Travel Limit	Bit	N/A	True/False	N/A	Read
		bit 5	Actuator Obstructed	Bit	N/A	True/False	N/A	Read
		bit 6	Actuator Jammed	Bit	N/A	True/False	N/A	Read
		bit 7	Control Mode	Bit	N/A	True/False	N/A	Read
		bit 8	Operating Mode	Bit	N/A	True/False	N/A	Read
		bit 9	Action Direction	Bit	N/A	True/False	N/A	Read
		bit 10	Local / Remote	Bit	N/A	True/False	N/A	Read
		bit 11	EEPROM Error	Bit	N/A	True/False	N/A	Read
		bit 12	-	-	-	-	-	-
		bit 13	-	-	-	-	-	-
		bit 14	-	-	-	-	-	-
		bit 15	-	-	-	-	-	-
		bit 16	-	-	-	-	-	-
40002	0x01	TOTAL POWER ON TIME HI / FIRMWARE VERSION	INT					
		bit 1-8	Total Power On Time (Upper Byte)	Hour	1	65,536 – 16,711,680 (0 – 16,777,215 when used with Register 40003)	0	Read
		bit 9-16	Firmware Version	Int.	1	0-255	N/A	Read
40003	0x02	TOTAL POWER ON TIME LO	INT	Hour	1	0 – 65,535 (0 – 16,777,215 when used with Register 40002 bits 1-8)	0	Read
40004	0x03	TOTAL MOTOR RUN TIME HI	INT					
		bit 1-8	Total Motor Run Time (Upper Byte)	Count	1	65,536 – 16,711,680 (0 – 16,777,215 when used with Register 40005)	0	Read
		bit 9-16	-	-	-	-	-	-
40005	0x04	TOTAL MOTOR RUN TIME LO	INT	Count	1	0 – 65,535 (0 – 16,777,215 when used with Register 40004 bits 1-8)	0	Read

Register No.	Register Address	Address Name	16 bit / Digital Name	Unit	Scale	Range	Default	Read / Write
40006	0x05	TOTAL MOTOR STARTS HI	INT					
		bit 1-8	Total Motor Starts (Upper Byte)	Count	1	65,536 – 16,711,680 (0 – 16,777,215 when used with Register 40007)	0	Read
		bit 9-16	-	-	-	-	-	-
40007	0x06	TOTAL MOTOR STARTS LO	INT	Count	1	0 – 65,535 (0 – 16,777,215 when used with Register 40006 bits 1-8)	0	Read
40008	0x07	CURRENT POSITION	INT	%	0.1	0-1000	N/A	Read
40009	0x08	ACTION BITS / STATUS FLAGS 2	INT					
		bit 1	Direction	Bit	N/A	True/False	N/A	Read / Write
		bit 2	Motor Output	Bit	N/A	True/False	N/A	Read / Write
		bit 3	Reset Actuator	Bit	N/A	True/False	N/A	Read / Write
		bit 4	Emergency Shut Down (ESD)	Bit	N/A	True/False	N/A	Read / Write
		bit 5 bit 6	ESD Action	Bit	N/A	0,0 – In Place 0,1 – CCW 1,0 – CS 1,1 – To Position (40017)	0,0	Read / Write
		bit 7 bit 8	Fault Action	Bit	N/A	0,0 – In Place 0,1 – CCW 1,0 – CS 1,1 – To Position (40017)	0,0	Read / Write
		bit 9	Power Interrupt Flag	Bit	N/A	True/False	N/A	Read / Write
		bit 10	Reset Flag	Bit	N/A	True/False	N/A	Read / Write
		bit 11	Brownout Flag	Bit	N/A	True/False	N/A	Read / Write
		bit 12	Save To EEPROM	Bit	N/A	True/False	N/A	Read / Write
		bit 13	Fault Flag	Bit	N/A	True/False	N/A	Read / Write
		bit 14	-	-	-	-	-	-
		bit 15	-	-	-	-	-	-
		bit 16	-	-	-	-	-	-
40010	0x09	COMMAND POSITION	INT	%	0.1	0 – 1000 (Modulating) 0, 500, 1000 (Limit Switch)	N/A	Read / Write
40011	0x0A	TRAVEL TIMEOUT	INT	sec	1	5 - 255	60	Read / Write
40012	0x0B	NON-MOVEMENT TIMEOUT	INT	sec	0.01	50 - 1000	300	Read / Write
40013	0x0C	SENSITIVITY	INT	%	0.1	1 - 25	5	Read / Write
40014	0x0D	COMMUNICATION TIMEOUT	INT	sec	0.01	100 - 10,000	1000	Read / Write
40015	0x0E	RESERVE	-	-	-	-	-	-
40016	0x0F	SLAVE RESPONSE DELAY	INT	sec	0.01	1 - 255	1	Read / Write
40017	0x10	FAULT POSITION	INT	%	0.1	0 - 1000	N/A	Read / Write

STATUS FLAGS 1 REGISTER

Register Number	Register Address	Read/ Write	Save to EEPROM		Unit	Scale	Range	Default
40001	0x00	R	No		n/a	n/a	n/a	n/a

The *Status Flags 1* register provides flags to indicate various status and operating conditions. The first 11 bits of the register are assigned the functionality provided below. It is indicated if the bit is detected in either *Limit Switch Control* or *Modulation Control* mode, or in *Run* or *Calibration* operating mode.

Bit 1	CCW Movement			
	This bit indicates if the CCW motor output terminal is energized and is used to detect CCW movement of the actuator. This bit is cleared when the actuator is reset.			
	0 = Motor CCW output not on	(Y) Limit Switch Control	(Y) Run Mode	
	1 = Motor CCW output on	(Y) Modulation Control	(N) Calibration Mode	
Bit 2	CW Movement			
	This bit indicates if the CW motor output terminal is energized and is used to detect CW movement of the actuator. This bit is cleared when the actuator is reset.			
	0 = Motor CW output not on	(Y) Limit Switch Control	(Y) Run Mode	
	1 = Motor CW output on	(Y) Modulation Control	(N) Calibration Mode	
Bit 3	CCW Travel Limit			
	This bit indicates if the travel limit switch connected to terminals 5 & 6 of the LS/FB terminal is closed. This bit is cleared when the actuator is reset.			
	0 = CCW limit switch not closed	(Y) Limit Switch Control	(Y) Run Mode	
	1 = CCW limit switch closed	(N) Modulation Control	(N) Calibration Mode	
Bit 4	CW Travel Limit			
	This bit indicates if the travel limit switch connected to terminals 6 & 7 of the LS/FB terminal is closed. This bit is cleared when the actuator is reset.			
	0 = CW limit switch not closed	(Y) Limit Switch Control	(Y) Run Mode	
	1 = CW limit switch closed	(N) Modulation Control	(N) Calibration Mode	
Bit 5	Actuator Obstructed			
	This bit indicates if the actuator has encountered an obstruction during its travel to the specified position. This bit turns on if the time set in either Register 40011 or 40012 has been exceeded before the actuator reaches its appropriate end of travel position after having left its starting position. This bit is cleared when the actuator is reset.			
	0 = No obstruction detected	(Y) Limit Switch Control	(Y) Run Mode	
	1 = Obstruction detected	(Y) Modulation Control	(N) Calibration Mode	

Bit 6	Actuator Jammed				
	This bit indicates if the actuator has encountered a jam when trying to leave its current position. This bit turns on if the time set in either Register 40011 or 40012 has been exceeded with the actuator remaining at its starting position. This bit is cleared when the actuator is reset.				
	0 =	No jam detected	(Y)	Limit Switch Control	(Y) Run Mode
	1 =	Jam detected	(Y)	Modulation Control	(N) Calibration Mode
Bit 7	Actuator Control Mode				
	This bit indicates if the actuator is set to *Limit Switch Control* or *Modulation Control* depending on the position of the jumper on JP4.				
	0 =	Limit Switch Control (LSW)	(Y)	Limit Switch Control	(Y) Run Mode
	1 =	Modulation Control (MOD)	(Y)	Modulation Control	(Y) Calibration Mode
Bit 8	Actuator Operating Mode				
	This bit indicates if the actuator is in *Run* operating mode, or in any of the *Calibration* sub-modes. Note that the actuator will not perform *Run Mode* related commands while in *Calibration Mode*.				
	0 =	Run Mode	(Y)	Limit Switch Control	(Y) Run Mode
	1 =	Calibration Mode	(Y)	Modulation Control	(Y) Calibration Mode
Bit 9	Action Direction				
	This bit indicates if the actuator is configured for either Direct Acting or Reverse Acting. This is determined based on the positions set in *Calibration* sub-mode 3 and 4 for the 0% and 100% positions. If the 0% position is set to CW, the actuator is Direct Acting. If the 0% position is set to CCW, the actuator is Reverse Acting.				
	0 =	Direct Acting	(N)	Limit Switch Control	(Y) Run Mode
	1 =	Reverse Acting	(Y)	Modulation Control	(N) Calibration Mode
Bit 10	Local/Remote				
	This bit indicates the local or remote status based on if terminals 11 & 12 of the REM/LOC terminal are connected or not. This bit is cleared when the actuator is reset.				
	0 =	Remote Control (11-12 connected)	(Y)	Limit Switch Control	(Y) Run Mode
	1 =	Local Control (11-12 NOT connected)	(Y)	Modulation Control	(N) Calibration Mode
Bit 11	EEPROM Error				
	This bit indicates if the actuator has detected corrupted EEPROM data on power up, indicating data recovered from EEPROM may not be reliable. This bit is cleared when the actuator is reset.				
	0 =	No error detected	(Y)	Limit Switch Control	(Y) Run Mode
	1 =	Error detected	(Y)	Modulation Control	(Y) Calibration Mode

TOTAL POWER ON TIME / FIRMWARE

Register Number	Register Address	Read/ Write	Save to EEPROM		Unit	Scale	Range	Default
40002 40003	0x01 0x02	R	Yes		Hour Ver.	1 1	0 – 16,777,216 0x00000000 – 0x00FFFFFF 0 – 255 0x00 – 0xFF	n/a

Register 40002		Register 40003	
Upper Byte	Lower Byte	Upper Byte	Lower Byte
Firmware	Total Powered On Time		
0 – 255	0 – 16,777,216		

The *Total Power on Time/Firmware* registers store the total time (in hours) the board has been powered on as well as the current version of the firmware. The firmware version is stored in the upper 8 bits of Register 40002. The lower 8 bits of Register 40002 and all 16 bits of Register 40003 contain the 24-bit value representing the time the board has been powered on, providing for between 0 and 16,777,216 hours.

When reading the registers, the 8 bits in Register 40002 represent the most significant bits of the time, while all 16 bits in Register 40003 represent the least significant bits of the time. It is recommended to read both registers with the same command. In order to extract the length of time the board has been powered on, the upper 8 bits of Register 40002 must be masked off. In order to extract the firmware version, the lower 8 bits of Register 40002 must be masked off

.

TOTAL MOTOR RUN TIME

Register Number	Register Address	Read/ Write	Save to EEPROM		Unit	Scale	Range	Default
40004 40005	0x03 0x04	R	Yes		Hour	1	0 – 16,777,216 0x00000000 – 0x00FFFFFF	n/a

Register 40004		Register 40005	
Upper Byte	Lower Byte	Upper Byte	Lower Byte
-	Total Motor Run Time		
-	0 – 16,777,216		

The *Total Motor Run Time* registers store the total combined time (in hours) the CW and CCW motor outputs of the board have been energized. The lower 8 bits of Register 40004 and all 16 bits of Register 40005 contain the 24-bit value, providing for between 0 and 16,777,216 hours.

When reading the registers, the 8 bits in Register 40004 represent the most significant bits of the time, while all 16 bits in Register 40005 represent the least significant bits of the time. It is recommended to read both registers with the same command.

TOTAL MOTOR STARTS

Register Number	Register Address	Read/ Write	Save to EEPROM		Unit	Scale	Range	Default
40006 40007	0x05 0x06	R	Yes		Count	1	0 – 16,777,216 0x00000000 – 0x00FFFFFF	n/a

Register 40006		Register 40007	
Upper Byte	Lower Byte	Upper Byte	Lower Byte
-	Total Motor Starts		
-	0 – 16,777,216		

The *Total Motor Starts* registers store the total count for number of times the CW and CCW motor outputs of the board have been energized. The lower 8 bits of Register 40006 and all 16 bits of Register 40007 contain the 24-bit value, providing for between 0 and 16,777,216 total number of starts.

When reading the registers, the 8 bits in Register 40006 represent the most significant bits of the count, while all 16 bits in Register 40007 represent the least significant bits of the count. It is recommended to read both registers with the same command.

CURRENT POSITION

Register Number	Register Address	Read/ Write	Save to EEPROM		Unit	Scale	Range	Default
40008	0x07	R	No		%	0.1	0 – 1000 0x0000 – 0x03E8	n/a

The *Current Position* register is used to track the current actuator position in *Modulation Control* using the feedback potentiometer connected to the LS/FB input terminal. The range is automatically scaled based on the 0% and 100% positions set in *Calibration* sub-modes 3 and 4.

The values in the register span from 0 to 1000, which corresponds to 0.0% and 100.0% respectively. With 0.0% representing a fully closed actuator, and 100.0% representing a fully open actuator, a value of 674 represents the actuators is 67.4% open.

ACTION BITS/FLAGS 2 REGISTER

Register Number	Register Address	Read/ Write	Save to EEPROM		Unit	Scale	Range	Default
40009	0x08	R / W	Bits 5-8		n/a	n/a	n/a	n/a

The *Action Bits/Flags 2* register provides individual bits for multiple operation settings as well as resettable flags used to indicate various status changes.

Bit 1 Actuator Direction

This bit sets the direction to move the actuator in *Limit Switch Control*. Use this bit in conjunction with Bit 2 to move the actuator in on/off applications. The status of this bit determines which motor output is energized when Bit 2 is set. This bit is cleared when the actuator is reset.

0 =	Move CW	(Y)	Limit Switch Control	(Y)	Run Mode
1 =	Move CCW	(N)	Modulation Control	(N)	Calibration Mode

Bit 2 Actuator Output Status

This bit energizes the motor output determined by the direction set by Bit 1 in *Limit Switch Control*. Set the desired direction of travel with Bit 1, and either turn on or off the motor output by either setting or resetting this bit. This bit is cleared when the actuator is reset.

0 =	Motor output not energized	(Y)	Limit Switch Control	(Y)	Run Mode
1 =	Motor output energized	(N)	Modulation Control	(N)	Calibration Mode

Bit 3 Actuator Reset

This bit resets the actuator and is subsequently reset afterwards. When this bit is set, the following registers and bits are affected.

- Register 40001: Bit 1 – Bit 6 and Bit 11 are cleared.
- Register 40009: Bit 1 – Bit 4 are cleared.
- Register 40010: Bit 16 is set to disable actuator movement.

0 =	No effect	(Y)	Limit Switch Control	(Y)	Run Mode
1 =	Reset actuator	(Y)	Modulation Control	(N)	Calibration Mode

Bit 4 Emergency Shut Down

This bit initiates an Emergency Shut Down (ESD) and forces the actuator to move to the position set by Bit 5 and Bit 6 as indicated below. This bit must be cleared before any other command input can be recognized. This bit is automatically cleared when the actuator is reset.

0 =	No effect	(Y)	Limit Switch Control	(Y)	Run Mode
1 =	Issue ESD	(Y)	Modulation Control	(N)	Calibration Mode

Bit 6,5 ESD Action

These two bits determine the movement of the actuator when an ESD command is issued using Bit 3. The ESD Action setting will override the Fault Action setting should an ESD occur simultaneously with a fault condition.

0,0 = Stay in place (default)	(Y) Limit Switch Control	(Y) Run Mode
0,1 = Move full CCW	(Y) Modulation Control	(N) Calibration Mode
1,0 = Move full CW		
1,1 = Move to position (*Modulation Control*)		

Bit 8,7 Fault Action

These two bits determine the movement of the actuator when a lack of communication, as determined by the length of time set by Register 40014, is encountered. Issuing a ESD command with Bit 4 will override the actuator movement to the Fault Action position set using these two bits, and will instead move the actuator to the position set by the ESD Action bits 5 and 6.

0,0 = Fail in place (default)	(Y) Limit Switch Control	(Y) Run Mode
0,1 = Fail full CCW	(Y) Modulation Control	(N) Calibration Mode
1,0 = Fail full CW		
1,1 = Fail to position (*Modulation Control*)		

Bit 9 Power Interrupt Flag

This bit indicates if supply power has been interrupted since the last time this bit was cleared. This bit must be cleared manually by writing to this register.

0 = No power interruption detected	(Y) Limit Switch Control	(Y) Run Mode
1 = Power interruption detected	(Y) Modulation Control	(Y) Calibration Mode

Bit 10 Reset Flag

This bit indicates if the actuator was reset since the last time this bit was cleared. This bit must be cleared manually by writing to this register.

0 = Actuator has not been reset	(Y) Limit Switch Control	(Y) Run Mode
1 = Actuator has been reset	(Y) Modulation Control	(N) Calibration Mode

Bit 11 Brownout Flag

This bit indicates if the actuator experienced a brownout since the last time this bit was cleared. This bit must be cleared manually by writing to this register.

0 = No brownout detected	(Y) Limit Switch Control	(Y) Run Mode
1 = Brownout detected	(Y) Modulation Control	(Y) Calibration Mode

Bit 12 Save to EEPROM

This bit is used to force a save of register data to the built in non-volatile EEPROM memory. This bit is automatically cleared after a save. Specific register data is automatically saved to memory once every hour, however setting this bit will immediately save newly written data.

It must be noted that due to limitations on the number of saves the EEPROM can endure, consistently saving more than once per hour is not recommended. This bit should NEVER be continuously set as a default.

The following registers and bits are saved.

- Register 40002 – 40007
- Register 40011 – 40017
- Register 40009, Bits 5 – 8

0 =	No effect	(Y)	Limit Switch Control	(Y)	Run Mode
1 =	Save data to EEPROM	(Y)	Modulation Control	(N)	Calibration Mode

Bit 13 Fault Flag

This bit indicates if there has been a loss of communications once communication is restored.

0 =	No loss in communication	(Y)	Limit Switch Control	(Y)	Run Mode
1 =	Loss in communication	(Y)	Modulation Control	(N)	Calibration Mode

COMMAND POSITION

Register Number	Register Address	Read/ Write	Save to EEPROM	Unit	Scale	Range	Default
40010	0x09	R / W	No	%	0.1	0 – 1000 (32,768 – 33,768) 0x0000 – 0x03E8 (0x8000 – 0x83E8)	n/a

If a value outside of the acceptable range of 0 to 1000 is written, the actuator will not move. When the TMB1-RTU control board has power applied, or is reset using Bit 3 in Register 40009, Bit 16 is set to 1 resulting in a value of 32,768 added to the value currently in the register. Setting Bit 16 forces the *Command Position* register value outside of the acceptable 0 to 1000 range and therefore prevents the actuator from moving. The actuator can be controlled again by writing another value between 0 and 1000.

The *Command Position* register is used to initiate an actuator move. When the board is set to *Modulation Control*, the values span from 0 to 1000, corresponding to 0.0% and 100.0% respectively. Therefore, with 0.0% representing a fully closed actuator, and 100.0% representing a fully open actuator, a written value of 674 indicates a command to move the actuator to 67.4% open.

When the board is set to *Limit Switch Control*, a 0 will move the actuator CW, a 500 will stop the actuator, and 1000 will move the actuator CCW.

Value	Description
0	Energize motor outputs and drive actuator CW.
500	De-energize motor outputs and stop actuator.
1000	Energize motor outputs and drive actuator CCW.

TRAVEL TIMEOUT

Register Number	Register Address	Read/ Write	Save to EEPROM		Unit	Scale	Range	Default
40011	0x0A	R / W	Yes		Sec.	1	5 – 255 0x0005 – 0x00FF	60 (60 sec)

The *Travel Timeout* register is used in *Limit Switch Control* to determine a stall or obstruction condition identified by Bit 5 or Bit 6 in Register 40001. The value stored in this register represents the maximum time allowed between energizing a motor output and the closing of the expected limit switch before identifying either a jam or an obstruction. This value should be set greater than the typical travel time of the actuator from full open to full close.

Values in this register can be between 5 and 255 with each integer representing 1 second. The default value is set to 60 representing a time of 60 seconds.

NON-MOVEMENT TIMEOUT

Register Number	Register Address	Read/ Write	Save to EEPROM		Unit	Scale	Range	Default
40012	0x0B	R / W	Yes		Sec.	0.01	50 – 1000 0x0032 – 0x03EB	300 (3 sec)

The *Non-Movement Timeout* register is used in *Modulation Control* to determine a stall or obstruction condition identified by Bit 5 or Bit 6 in Register 40001. The value stored in this register represents the maximum time allowed where no movement of the potentiometer detected before the desired command position has not been reached.

Values in this register can be between 50 and 1000 with each integer representing 0.01 seconds. The default value is set to 300 representing a time of 3 seconds.

SENSITIVITY

Register Number	Register Address	Read/ Write	Save to EEPROM		Unit	Scale	Range	Default
40013	0x0C	R / W	Yes		%	0.1	1 – 25 0x0001 – 0x0019	5 (0.5%)

The *Sensitivity* register stores the necessary change between the value written to Register 40010 and the current value in Register 40008 before an actuator movement is initiated.

Values in this register can be between 1 and 25 with each integer representing 0.1%. The default value is set to 5 representing 0.5%. Using the default value of 0.5%, if the actuator position is at 50.0%, indicated by a value of 500 in Register 40008, the value written to Register 40010 must be greater than 505 or less than 495.

COMMUNICATION TIMEOUT

Register Number	Register Address	Read/ Write	Save to EEPROM		Unit	Scale	Range	Default
40014	0x0D	R / W	Yes		Sec.	0.01	100 – 10,000 0x0064 – 0x2710	1000 (10 sec)

The *Communication Timeout* register stores the maximum time allowed with no communication received from the master device before entering into a fault condition indicated by the blue LED changing its flash rate from a 10% to an 80% duty cycle. When this time is exceeded, the actuator will move to the position set by Bit 7 and Bit 8 in Register 40009.

The master should communicate with each actuator on the bus within the time set in this register. If no data is required to be read from, or written to a specific actuator, it is recommended that a loopback test using Modbus Function code 08 is used. Doing so will ensure the actuator moves to the fault position determined by Bit 7 and Bit 8 in Register 40009 only when an unintended lapse in communication is encountered.

Values in this register can be between 100 and 10,000 with each integer representing 0.01 seconds. The default value is set to 1000 representing 10 seconds.

RESERVED

Register Number	Register Address	Read/ Write	Save to EEPROM		Unit	Scale	Range	Default
40015	0x0E	R / W	Yes		n/a	n/a	n/a	n/a

This register is currently not used.

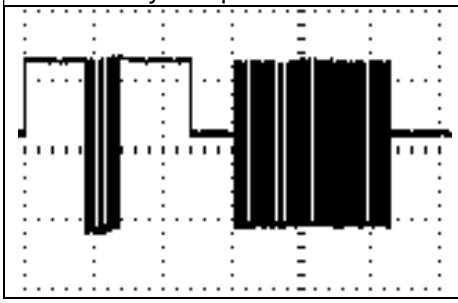
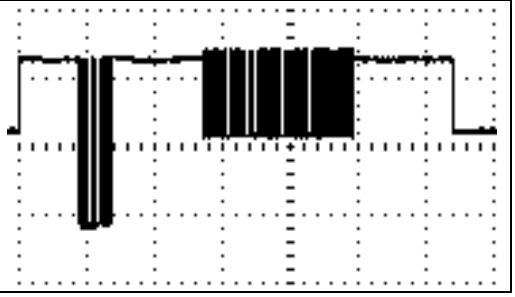
SLAVE RESPONSE DELAY

Register Number	Register Address	Read/ Write	Save to EEPROM		Unit	Scale	Range	Default
40016	0x0F	R / W	Yes		Sec.	0.01	1 – 255 0x0001 – 0x00FF	1 (0.01 sec)

The *Slave Response Delay* stores the minimum time before the start of a response to a message from the master device. The specific delay may be up to 0.01 seconds more than the set value. This is because there is an internal loop time of 0.01 seconds, and depending on when in the loop cycle the message from the master device arrives, there can be a 0.01 second variation in the response time.

Values in this register can be between 1 and 255 with each integer representing 0.01 seconds. Thus the actual range is 0.01 to 2.55 seconds. The default value is set to 1 representing 0.01 seconds.

If the master device communication port allows a RTS delay time to be set, or some other transmit delay, the value in this register should be greater than whatever value is set in the master communication port. If the value in this register is less than the delay set by the master communication port, the response may not be considered a valid response as shown below.

Slave response delay = 10 ms Master RTS off delay = 10 ms Slave response is after the master communication port delay. Reply is successfully interpreted.		Slave response delay = 10 ms Master RTS off delay = 50 ms Slave response is not after the master communication port delay. Replay is not recognized by the master.
		

FAULT POSITION

Register Number	Register Address	Read/ Write	Save to EEPROM		Unit	Scale	Range	Default
40017	0x10	R / W	Yes		%	0.1	0 – 1000 0x000 – 0x03E8	n/a

The *Fault Position* register is used in *Modulation Control* to set a position to move the actuator for a fault or Emergency Shut Down. The values in the register span from 0 to 1000, which corresponds to 0.0% and 100.0% respectively. With 0.0% representing a fully closed actuator, and 100.0% representing a fully open actuator, a value of 674 represents the actuator will fail to the 67.4% open position either from fault, or from an Emergency Shut Down operation.

Moving to the position specified in this register for an Emergency Shut Down is achieved by setting both Bit 5 and Bit 6 in Register 40009 high.

Failing to the position specified in this register when a fault condition occurs is achieved by setting both Bit 7 and Bit 8 in Register 40009 high.

APPENDIX A

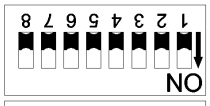
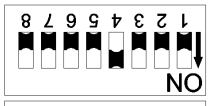
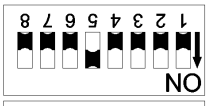
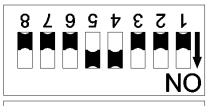
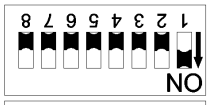
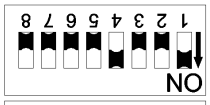
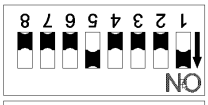
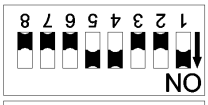
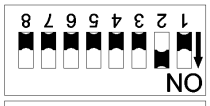
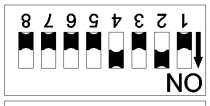
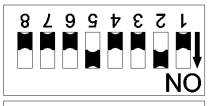
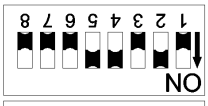
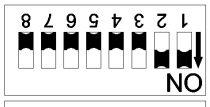
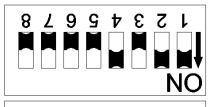
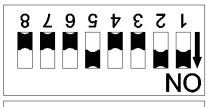
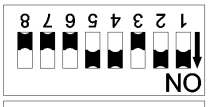
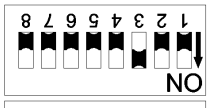
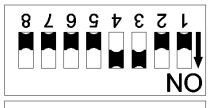
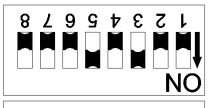
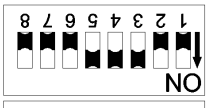
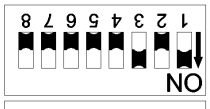
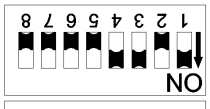
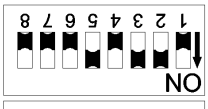
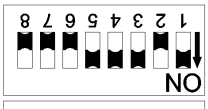
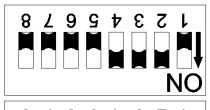
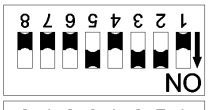
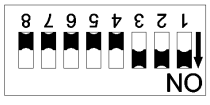
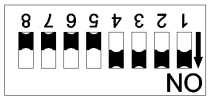
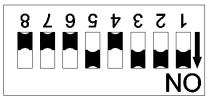
ADDRESS DIP SWITCH SETTINGS (ADDR SW5)

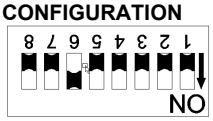
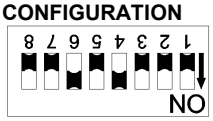
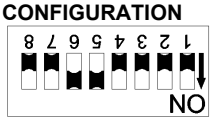
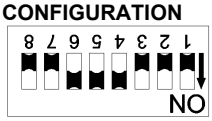
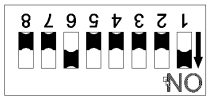
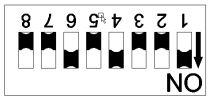
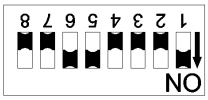
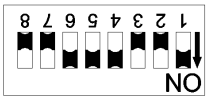
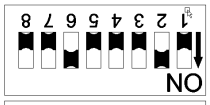
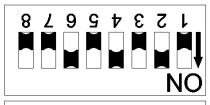
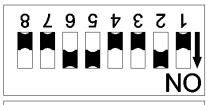
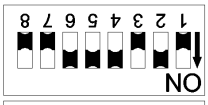
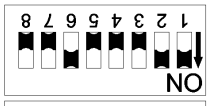
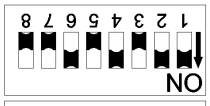
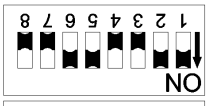
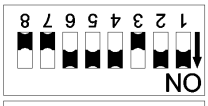
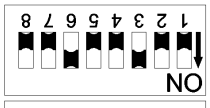
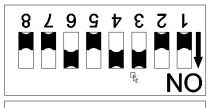
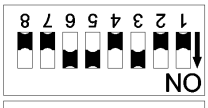
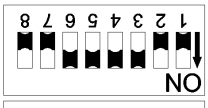
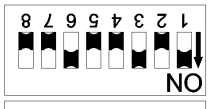
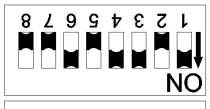
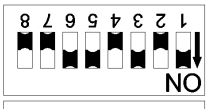
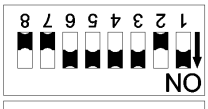
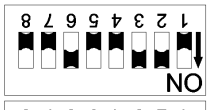
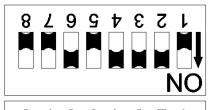
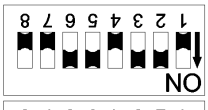
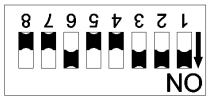
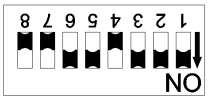
Addresses are represented in 8-bit binary where each DIP switch on ADDR SW 5 represents a single bit. A binary '1' is represented by the DIP switch being in the ON position. A binary '0' is represented by the DIP switch being in the OFF position.

Only addresses 1-247 are considered valid addresses. Addresses 0 and 248-255 are restricted. If any of the restricted addresses are set by the switches, the nearest valid address will be assigned. If address 0 is set, the board will be recognized as address 1. If address 248-255 is set, the board will be recognized as address 247.

Please note, the DIP switches as shown below are read with switch 1 being the least significant bit on the right, and switch 8 being the most significant bit on the left. This results in the DIP switch being read upside down, where the switch being down is ON, and the switch being up is OFF.

DIP switch positions for the first 64 addresses are provided in the table below. See the **Error! Reference source not found.** table below for more information on binary for the switch positioning for addresses 64 thru 255.

ADDRESS (decimal)	SWITCH CONFIGURATION	ADDRESS (decimal)	SWITCH CONFIGURATION	ADDRESS (decimal)	SWITCH CONFIGURATION	ADDRESS (decimal)	SWITCH CONFIGURATION
0		8		16		24	
1		9		17		25	
2		10		18		26	
3		11		19		27	
4		12		20		28	
5		13		21		29	
6		14		22		30	
7		15		23		31	

ADDRESS (decimal)	SWITCH CONFIGURATION	ADDRESS (decimal)	SWITCH CONFIGURATION	ADDRESS (decimal)	SWITCH CONFIGURATION	ADDRESS (decimal)	SWITCH CONFIGURATION
32		40		48		56	
33		41		49		57	
34		42		50		58	
35		43		51		59	
36		44		52		60	
37		45		53		61	
38		46		54		62	
39		47		55		63	

APPENDIX B

NUMBER SYSTEM CONVERSION

DEC	OCT	HEX	BIN	DEC	OCT	HEX	BIN	DEC	OCT	HEX	BIN	DEC	OCT	HEX	BIN
0	000	00	0000 0000	16	020	10	0001 0000	32	040	20	0010 0000	48	060	30	0011 0000
1	001	01	0000 0001	17	021	11	0001 0001	33	041	21	0010 0001	49	061	31	0011 0001
2	002	02	0000 0010	18	022	12	0001 0010	34	042	22	0010 0010	50	062	32	0011 0010
3	003	03	0000 0011	19	023	13	0001 0011	35	043	23	0010 0011	51	063	33	0011 0011
4	004	04	0000 0100	20	024	14	0001 0100	36	044	24	0010 0100	52	064	34	0011 0100
5	005	05	0000 0101	21	025	15	0001 0101	37	045	25	0010 0101	53	065	35	0011 0101
6	006	06	0000 0110	22	026	16	0001 0110	38	046	26	0010 0110	54	066	36	0011 0110
7	007	07	0000 0111	23	027	17	0001 0111	39	047	27	0010 0111	55	067	37	0011 0111
8	010	08	0000 1000	24	030	18	0001 1000	40	050	28	0010 1000	56	070	38	0011 1000
9	011	09	0000 1001	25	031	19	0001 1001	41	051	29	0010 1001	57	071	39	0011 1001
10	012	0A	0000 1010	26	032	1A	0001 1010	42	052	2A	0010 1010	58	072	3A	0011 1010
11	013	0B	0000 1011	27	033	1B	0001 1011	43	053	2B	0010 1011	59	073	3B	0011 1011
12	014	0C	0000 1100	28	034	1C	0001 1100	44	054	2C	0010 1100	60	074	3C	0011 1100
13	015	0D	0000 1101	29	035	1D	0001 1101	45	055	2D	0010 1101	61	075	3D	0011 1101
14	016	0E	0000 1110	30	036	1E	0001 1110	46	056	2E	0010 1110	62	076	3E	0011 1110
15	017	0F	0000 1111	31	037	1F	0001 1111	47	057	2F	0010 1111	63	077	3F	0011 1111
64	100	40	0100 0000	80	120	50	0101 0000	96	140	60	0110 0000	112	160	70	0111 0000
65	101	41	0100 0001	81	121	51	0101 0001	97	141	61	0110 0001	113	161	71	0111 0001
66	102	42	0100 0010	82	122	52	0101 0010	98	142	62	0110 0010	114	162	72	0111 0010
67	103	43	0100 0011	83	123	53	0101 0011	99	143	63	0110 0011	115	163	73	0111 0011
68	104	44	0100 0100	84	124	54	0101 0100	100	144	64	0110 0100	116	164	74	0111 0100
69	105	45	0100 0101	85	125	55	0101 0101	101	145	65	0110 0101	117	165	75	0111 0101
70	106	46	0100 0110	86	126	56	0101 0110	102	146	66	0110 0110	118	166	76	0111 0110
71	107	47	0100 0111	87	127	57	0101 0111	103	147	67	0110 0111	119	167	77	0111 0111
72	110	48	0100 1000	88	130	58	0101 1000	104	150	68	0110 1000	120	170	78	0111 1000
73	111	49	0100 1001	89	131	59	0101 1001	105	151	69	0110 1001	121	171	79	0111 1001
74	112	4A	0100 1010	90	132	5A	0101 1010	106	152	6A	0110 1010	122	172	7A	0111 1010
75	113	4B	0100 1011	91	133	5B	0101 1011	107	153	6B	0110 1011	123	173	7B	0111 1011
76	114	4C	0100 1100	92	134	5C	0101 1100	108	154	6C	0110 1100	124	174	7C	0111 1100
77	115	4D	0100 1101	93	135	5D	0101 1101	109	155	6D	0110 1101	125	175	7D	0111 1101
78	116	4E	0100 1110	94	136	5E	0101 1110	110	156	6E	0110 1110	126	176	7E	0111 1110
79	117	4F	0100 1111	95	137	5F	0101 1111	111	157	6F	0110 1111	127	177	7F	0111 1111

DEC	OCT	HEX	BIN	DEC	OCT	HEX	BIN	DEC	OCT	HEX	BIN	DEC	OCT	HEX	BIN
128	200	80	1000 0000	144	220	90	1001 0000	160	240	A0	1010 0000	176	260	B0	1011 0000
129	201	81	1000 0001	145	221	91	1001 0001	161	241	A1	1010 0001	177	261	B1	1011 0001
130	202	82	1000 0010	146	222	92	1001 0010	162	242	A2	1010 0010	178	262	B2	1011 0010
131	203	83	1000 0011	147	223	93	1001 0011	163	243	A3	1010 0011	179	263	B3	1011 0011
132	204	84	1000 0100	148	224	94	1001 0100	164	244	A4	1010 0100	180	264	B4	1011 0100
133	205	85	1000 0101	149	225	95	1001 0101	165	245	A5	1010 0101	181	265	B5	1011 0101
134	206	86	1000 0110	150	226	96	1001 0110	166	246	A6	1010 0110	182	266	B6	1011 0110
135	207	87	1000 0111	151	227	97	1001 0111	167	247	A7	1010 0111	183	267	B7	1011 0111
136	210	88	1000 1000	152	230	98	1001 1000	168	250	A8	1010 1000	184	270	B8	1011 1000
137	211	89	1000 1001	153	231	99	1001 1001	169	251	A9	1010 1001	185	271	B9	1011 1001
138	212	8A	1000 1010	154	232	9A	1001 1010	170	252	AA	1010 1010	186	272	BA	1011 1010
139	213	8B	1000 1011	155	233	9B	1001 1011	171	253	AB	1010 1011	187	273	BB	1011 1011
140	214	8C	1000 1100	156	234	9C	1001 1100	172	254	AC	1010 1100	188	274	BC	1011 1100
141	215	8D	1000 1101	157	235	9D	1001 1101	173	255	AD	1010 1101	189	275	BD	1011 1101
142	216	8E	1000 1110	158	236	9E	1001 1110	174	256	AE	1010 1110	190	276	BE	1011 1110
143	217	8F	1000 1111	159	237	9F	1001 1111	175	257	AF	1010 1111	191	277	BF	1011 1111
192	300	C0	1100 0000	208	320	D0	1101 0000	224	340	E0	1110 0000	240	360	F0	1111 0000
193	301	C1	1100 0001	209	321	D1	1101 0001	225	341	E1	1110 0001	241	361	F1	1111 0001
194	302	C2	1100 0010	210	322	D2	1101 0010	226	342	E2	1110 0010	242	362	F2	1111 0010
195	303	C3	1100 0011	211	323	D3	1101 0011	227	343	E3	1110 0011	243	363	F3	1111 0011
196	304	C4	1100 0100	212	324	D4	1101 0100	228	344	E4	1110 0100	244	364	F4	1111 0100
197	305	C5	1100 0101	213	325	D5	1101 0101	229	345	E5	1110 0101	245	365	F5	1111 0101
198	306	C6	1100 0110	214	326	D6	1101 0110	230	346	E6	1110 0110	246	366	F6	1111 0110
199	307	C7	1100 0111	215	327	D7	1101 0111	231	347	E7	1110 0111	247	367	F7	1111 0111
200	310	C8	1100 1000	216	330	D8	1101 1000	232	350	E8	1110 1000	248	370	F8	1111 1000
201	311	C9	1100 1001	217	331	D9	1101 1001	233	351	E9	1110 1001	249	371	F9	1111 1001
202	312	CA	1100 1010	218	332	DA	1101 1010	234	352	EA	1110 1010	250	372	FA	1111 1010
203	313	CB	1100 1011	219	333	DB	1101 1011	235	353	EB	1110 1011	251	373	FB	1111 1011
204	314	CC	1100 1100	220	334	DC	1101 1100	236	354	EC	1110 1100	252	374	FC	1111 1100
205	315	CD	1100 1101	221	335	DD	1101 1101	237	355	ED	1110 1101	253	375	FD	1111 1101
206	316	CE	1100 1110	222	336	DE	1101 1110	238	356	EE	1110 1110	254	376	FE	1111 1110
207	317	CF	1100 1111	223	337	DF	1101 1111	239	357	EF	1110 1111	255	377	FF	1111 1111

APPENDIX C

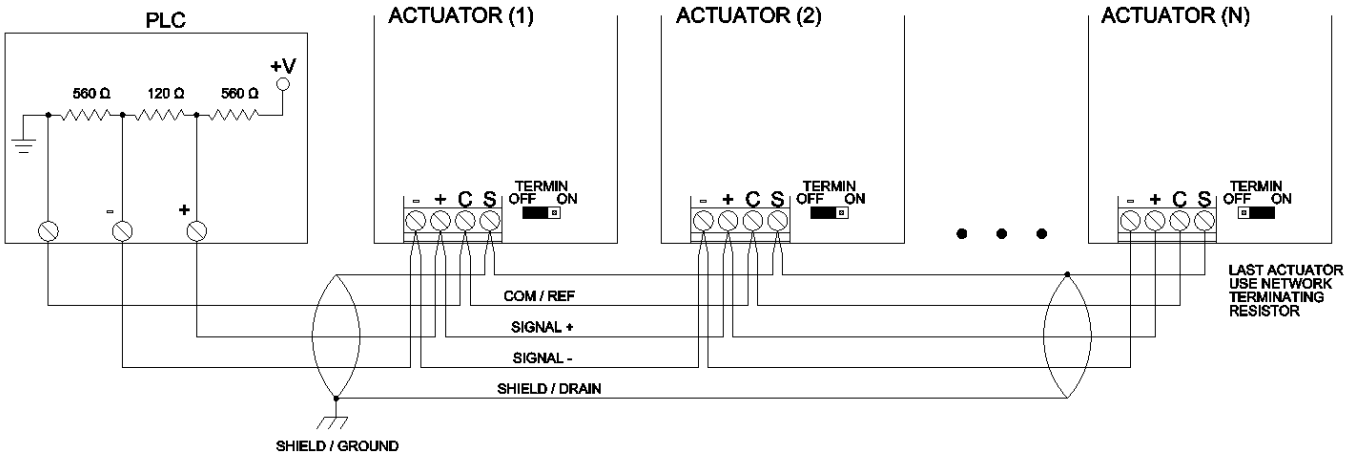
MODBUS NETWORK WIRING

TMB1-RTU control boards can be chained together as shown below. The RS485 differential pair should be appropriately connected to the (D+) and (D-) terminals. Reversing the (D+) and (D-) connections may prevent communication. The DC reference or common of the differential signal should be connected to the COM terminals.

The SHIELD terminal on the board can be used to connect the cable drain connections to extend the shield connection between boards. This terminal is not connected to anything and should not be relied on to ground the cable shield or drain wire.

The final actuator on the network should move the termination resistor jumper to the ON position. The termination resistor at the end of the network is needed to prevent losses due to signal reflections.

A typical biasing network in the PLC is shown. This network defines a consistent start state when the bus goes from idle to active. Without it, the data transfer may be unreliable.



A-T Controls product, when properly selected, is designed to perform its intended function safely during its useful life. However, the purchaser or user of A-T Controls products should be aware that A-T Controls products might be used in numerous applications under a wide variety of industrial service conditions. Although A-T Controls can provide general guidelines, it cannot provide specific data and warnings for all possible applications. The purchaser / user must therefore assume the ultimate responsibility for the proper sizing and selection, installation, operation, and maintenance of A-T Controls products. The user should read and understand the installation operation maintenance (IOM) instructions included with the product, and train its employees and contractors in the safe use of A-T Controls products in connection with the specific application.

While the information and specifications contained in this literature are believed to be accurate, they are supplied for informative purposes only. Because A-T Controls is continually improving and upgrading its product design, the specifications, dimensions and information contained in this literature are subject to change without notice. Should any question arise concerning these specifications, the purchaser/user should contact A-T Controls.

For product specifications go to http://download.a-tcontrols.com/

A-T Controls, Inc. • 9955 International Boulevard, Cincinnati, OH 45246 • Phone: (513) 530-5175 • Fax: (513) 247-5462 • www.atcontrols.com