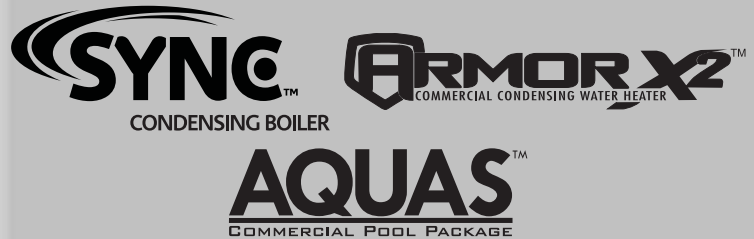
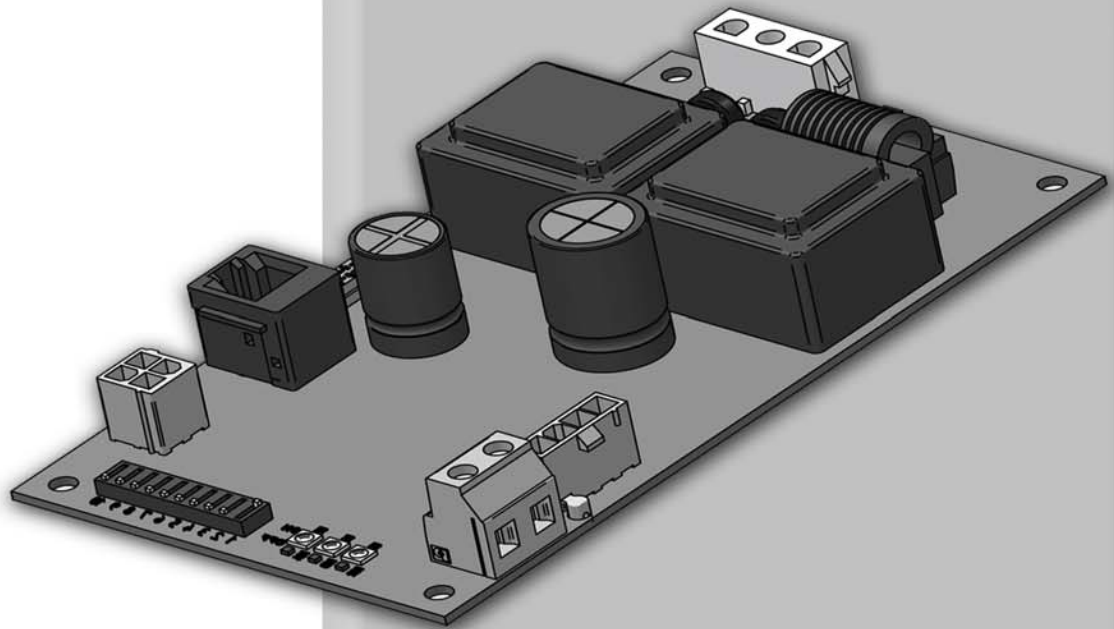


# MODBUS AND BACNET COMMUNICATION INSTRUCTIONS



**Models: 1.0 - 1.3 - 1.5**



**⚠ WARNING**

This manual must only be used by a qualified heating installer / service technician. Read all instructions, including this manual, the Installation and Operation Manual, and the Service Manual, before installing. Perform steps in the order given. Failure to comply could result in severe personal injury, death, or substantial property damage.

# Contents

1. INTRODUCTION		Timing Specifications.....	10
Definitions.....	2	Communication Board Diagnostics .....	10
Minimum System Requirements.....	2	Internal Faults.....	10
2. MODBUS CONFIGURATION		5. BACNET MEMORY MAP	
Addressing.....	3	Primary Data Tables.....	11
Timing Specifications.....	4	Appliance Map.....	11-12
Parity.....	4	Input Registers .....	12
Data Transmission Mode.....	4	Holding Registers.....	12
Modbus Board Diagnostics.....	4	6. WIRING REQUIREMENTS	
Internal Faults.....	4	Physical Wiring .....	13
Modbus Function Set .....	5	Typical System Wiring .....	14-17
Modbus Exception Codes.....	6	7. UNIT OPERATION	
3. MODBUS MEMORY MAP		Unit Operation with Modbus Communications .....	18-21
Primary Data Tables.....	7	8. TROUBLESHOOTING.....	22-23
Appliance Map.....	7-8	9. DIAGRAMS	
Input Registers.....	8	Ladder Diagram Part 1 & 2 .....	24-25
Holding Registers.....	8	Wiring Diagram.....	26
Configuration Bits .....	8	Notes.....	27
4. BACNET CONFIGURATION		Revision Notes .....	Back Cover
Addressing.....	9		

## 1 Introduction

The information contained in this manual provides general guidelines for the implementation of Modbus and BACnet communication with the Lochinvar appliance.

All Modbus networks are implemented utilizing a master-slave arrangement where all appliances are slaves and the master is a building automation system capable of communicating over a RS-485 serial connection. BACnet networks are implemented using a token passing process where multiple masters and slaves share a common RS-485 bus. The Lochinvar BACnet interface is a master only.

### Definitions

Abbreviation or Acronym	Meaning
ASCII	American Standard Code for Information Interchange
BACnet	A data communication protocol for Building Automation and Control Networks
BAS	Building Automation System
Baud (Baud Rate)	Number of data bits transmitted per second (bps)
EMS	Energy Management System
FDX	Full-Duplex
HDX	Half-Duplex
Hex	Hexadecimal Number (0 - 9, A - F)
I/O Box	Input/Output (I/O)
LSB	Least Significant Byte
Modbus®	A serial, half-duplex data transmission protocol developed by AEG Modicon
MSB	Most Significant Byte
RS232	A standard for serial, full-duplex (FDX) transmission of data based on the RS232 Standard
RS485	A standard for serial transmission of data based on the RS-485 Standard
RTU	Remote Terminal Unit

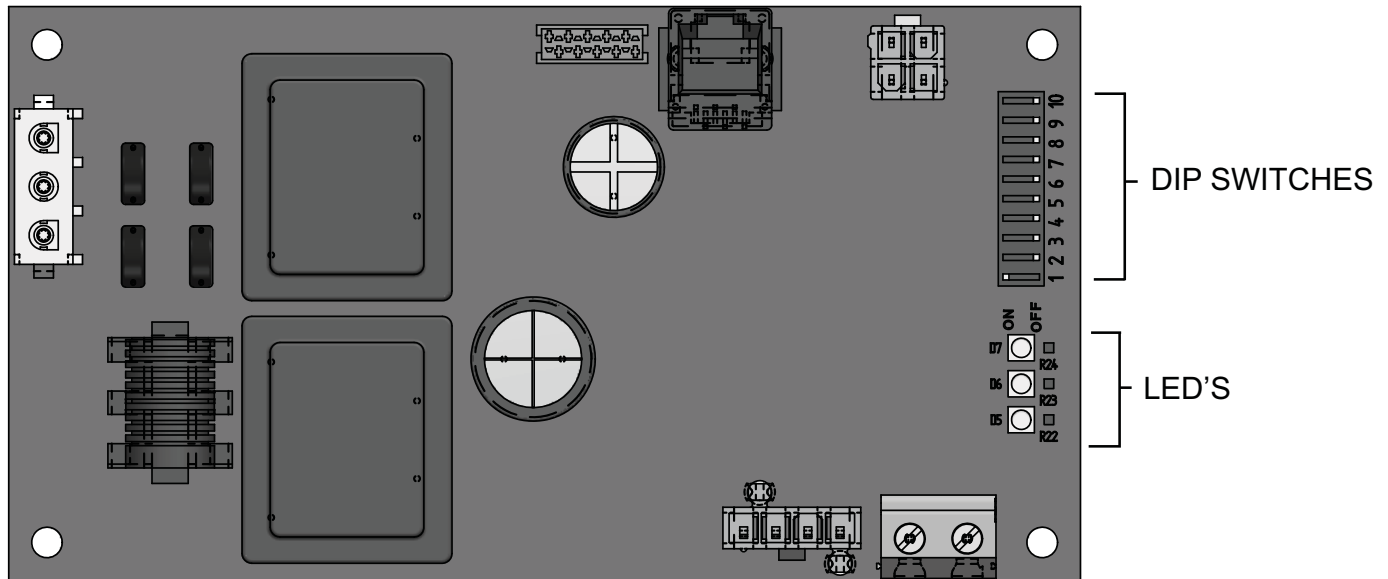
### Minimum System Requirements

- BAS system or computer with a serial or USB port with a converter to RS-485.
- Appliance equipped with Modbus / BACnet communication board.
- Shielded twisted pair communication cable.

## 2 ModBus Configuration

The Modbus communication board is equipped with a set of ten dip switches that are used to set the board configuration (address, baud rate, and parity settings). The first eight are used to set the address of each board. The ninth baud rate. The tenth is parity.

**Figure 2-1**\_Modbus Communication Board



### Addressing

The Modbus addressing space is comprised of 256 different addresses.

- 0 is reserved for broadcast messages from the master device
- 1 - 247 are free to use for each unique device
- 248 - 255 are reserved

To set the Modbus address the dip switches can be set in either the 0 position or the 1 position. For switches set to the 1 position their value will be added together to determine the address.

Each switch set to the 1 position has the following value:

- Dip switch 1 = 1
- Dip switch 2 = 2
- Dip switch 3 = 4
- Dip switch 4 = 8
- Dip switch 5 = 16
- Dip switch 6 = 32
- Dip switch 7 = 64
- Dip switch 8 = 128

Any dip switch set to 0 has a value equal to 0.

*Example:*

To set the address of the Modbus board to 50, dip switches 2, 5, and 6 have to be set to the 1 position. The address is determined by adding the values of all the dip switches together.

Address = Value of Dip switch 1 + Value of Dip switch 2 + Value of Dip switch 3 + Value of Dip switch 4 + Value of Dip switch 5 + Value of Dip switch 6 + Value of Dip switch 7 + Value of Dip switch 8

In this example:

$$\text{Address} = 0 + 2 + 0 + 0 + 16 + 32 + 0 + 0 = 50$$

## 2 ModBus Configuration

### Timing Specifications

The baud rate for the Modbus board is selectable with Dip switch #9.

1 = 19200 bps

0 = 9600 bps

Each message is started by at least 3.5 character times of silence. The maximum delay between frames is 1.5 character times.

When the system temperature, tank temperature, and/or 0-10V BMS voltage is provided by the BAS to the boiler or water heater, it is critical that the values be updated every few seconds. If the appliance does not receive updated values within a timeout period (installer adjustable), the control will revert to using its own readings (if connected). The timeout is programmable by pressing the MAIN>>SETUP>>BMS buttons. The timeout is adjustable between 5 and 120 seconds. The default timeout is 10 seconds.

When the BAS is not providing any of these values, but is still controlling the boiler or water heater (such as providing an enable command), the BAS must refresh these commands at least every 4 minutes. If the commands are not refreshed, the appliance will revert to operating based on its own inputs.

### Parity

Parity is set by the position of Dip switch #10.

0 = No Parity

1 = Even Parity

If No Parity is selected there will be two stop bits, otherwise there will be one.

### Data Transmission Mode

Many Modbus bus master devices can be configured to transmit data in either Modbus RTU or Modbus ASCII modes. Since RTU messages can be formatted to use fewer data bits and are therefore more efficient, RTU has been chosen to be used with all Lochinvar Modbus communication. Please ensure that the master device is transmitting Modbus RTU.

### Modbus Board Diagnostics

The Modbus board is equipped with three LED's for visual diagnostics: Two yellow LED's and one green. One yellow LED (D5) is used to indicate transmission of data. The other yellow LED (D6) is used to indicate reception of data. The green LED (D7) is used to show internal faults.

Internal Faults:

Normal Operation = 1 second on, 1 second off

Controller Fault = Continuously on

No Burner Control Communication = 0.5 seconds on, 1.5 seconds off

No Modbus Communication = 1.5 seconds on, 0.5 seconds off

### Modbus Communication

The Modbus communication commands and exception codes that are supported by the Modbus communication board can be found on pages 5 and 6 of this manual.

## 2 ModBus Configuration *(continued)*

### Modbus Function Set

Function		Sub Function	HEX	Description
Dec	HEX	Dec		
1	01			Read Coil Status
2	02			Read Input Status
3	03			Read Holding Registers
4	04			Read Input Registers
5	05			Force Single Coil
6	06			Preset Single Register
7	07			Read Exception Status
8	08	0	00	Diagnostic - Return Query Data
		1	01	Diagnostic - Restart Communication
		2	02	Diagnostic - Return Diagnostic Register
		4	04	Diagnostic - Force Listen Mode
		10	0A	Diagnostic - Clear Counters and Diagnostic Registers
		11	0B	Diagnostic - Return Bus Message Count
		12	0C	Diagnostic - Bus Communication Error Count
		13	0D	Diagnostic - Bus Exception Error Count
		14	0E	Diagnostic - Return Slave Message Count
		15	0F	Diagnostic - Return Communication Error Count
		16	10	Diagnostic - Return Slave NAK Count
		17	11	Diagnostic - Return Slave Busy Count
		18	12	Diagnostic - Return Bus Character Overrun Count
		20	14	Diagnostic - Clear Overrun Counter and Flag
11	0B			Get Communication Event Counter
12	0C			Get Communication Event Log
15	0F			Write Multiple Coils
16	10			Write Multiple Registers
17	11			Report Slave ID
23	17			Read / Write Multiple Registers

## 2 ModBus Configuration

### Modbus Exception Codes

MODBUS Exception Codes		
Code	Name	Meaning
01	ILLEGAL FUNCTION	The function code received in the query is not an allowable action for the server (or slave). This may be because the function code is only applicable to newer devices, and was not implemented in the unit selected. It could also indicate that the server (or slave) is in the wrong state to process a request of this type, for example because it is unconfigured and is being asked to return register values.
02	ILLEGAL DATA ADDRESS	The data address received in the query is not an allowable address for the server (or slave). More specifically, the combination of reference number and transfer length is invalid. For a controller with 100 registers, the PDU addresses the first register as 0, and the last one as 99. If a request is submitted with a starting register address of 96 and a quantity of registers of 4, then this request will successfully operate (address-wise at least) on registers 96, 97, 98, 99. If a request is submitted with a starting register address of 96 and a quantity of registers of 5, then this request will fail with Exception Code 0x02 "Illegal Data Address" since it attempts to operate on registers 96, 97, 98, 99 and 100, and there is no register with address 100.
03	ILLEGAL DATA VALUE	A value contained in the query data field is not an allowable value for server (or slave). This indicates a fault in the structure of the remainder of a complex request, such as that the implied length is incorrect. It specifically does NOT mean that a data item submitted for storage in a register has a value outside the expectation of the application program, since the MODBUS protocol is unaware of the significance of any particular value of any particular register.
04	SLAVE DEVICE FAILURE	An unrecoverable error occurred while the server (or slave) was attempting to perform the requested action.
05	ACKNOWLEDGE	Specialized use in conjunction with programming commands. The server (or slave) has accepted the request and is processing it, but a long duration of time will be required to do so. This response is returned to prevent a timeout error from occurring in the client (or master). The client (or master) can next issue a Poll Program Complete message to determine if processing is completed.
06	SLAVE DEVICE BUSY	Specialized use in conjunction with programming commands. The server (or slave) is engaged in processing a long -- duration program command. The client (or master) should re-transmit the message later when the server (or slave) is free.
08	MEMORY PARITY ERROR	Specialized use in conjunction with function codes 20 and 21 and reference type 6, to indicate that the extended file area failed to pass a consistency check. The server (or slave) attempted to read record file, but detected a parity error in the memory. The client (or master) can retry the request, but service may be required on the server (or slave) device.
0A	GATEWAY PATH UNAVAILABLE	Specialized use in conjunction with gateways, indicates that the gateway was unable to allocate an internal communication path from the input port to the output port for processing as the request. Usually means that the gateway is misconfigured or overloaded.
0B	GATEWAY TARGET DEVICE FAILED TO RESPOND	Specialized use in conjunction with gateways, indicates that no response was obtained from the target device. Usually means that the device is not present on the network.

### 3 ModBus Memory Map

#### Primary Data Tables

Table	Data Type	Read / Write
Discrete Inputs	Single Bit	Read Only
Coils	Single Bit	Read / Write
Input Registers	16-Bit Word	Read Only
Holding Registers	16 Bit Word	Read / Write

#### Appliance Memory Map

Coils						
Address	Description	Default	Unit	Min.	Max.	Resolution
00001	Unit Enable	0	1=ON / 0=OFF	0	1	1
00005	Tank Thermostat	0	1=ON / 0=OFF	0	1	1
Discrete Inputs						
10001	Manual Reset High Limit 1	0	1=ON / 0=OFF	0	1	1
10002	Flow Switch 1	0	1=ON / 0=OFF	0	1	1
10003	Gas Pressure Switch 1	0	1=ON / 0=OFF	0	1	1
10004	Louver Proving Switch 1	0	1=ON / 0=OFF	0	1	1
10005	Flap Valve 1	0	1=ON / 0=OFF	0	1	1
10006	Blocked Drain Switch 1	0	1=ON / 0=OFF	0	1	1
10007	Auto Reset High Limit 1	0	1=ON / 0=OFF	0	1	1
10008	Flame 1	0	1=ON / 0=OFF	0	1	1
10009	Enable	0	1=ON / 0=OFF	0	1	1
10010	Tank Thermostat	0	1=ON / 0=OFF	0	1	1
10017	Manual Reset High Limit 2	0	1=ON / 0=OFF	0	1	1
10018	Flow Switch 2	0	1=ON / 0=OFF	0	1	1
10019	Gas Pressure Switch 2	0	1=ON / 0=OFF	0	1	1
10020	Louver Proving Switch 2	0	1=ON / 0=OFF	0	1	1
10021	Flap Valve 2	0	1=ON / 0=OFF	0	1	1
10022	Blocked Drain Switch 2	0	1=ON / 0=OFF	0	1	1
10023	Flame 2	0	1=ON / 0=OFF	0	1	1
10033	Run-time Contacts 1	0	1=ON / 0=OFF	0	1	1
10034	Alarm Contacts 1	0	1=ON / 0=OFF	0	1	1
10035	Boiler Pump 1	0	1=ON / 0=OFF	0	1	1
10036	DHW Pump 1	0	1=ON / 0=OFF	0	1	1
10038	Gas Valve 1	0	1=ON / 0=OFF	0	1	1
10039	System Pump	0	1=ON / 0=OFF	0	1	1
10041	Run-time Contacts 2	0	1=ON / 0=OFF	0	1	1
10042	Alarm Contacts 2	0	1=ON / 0=OFF	0	1	1
10043	Boiler Pump 2	0	1=ON / 0=OFF	0	1	1
10046	Gas Valve 2	0	1=ON / 0=OFF	0	1	1
10049	Fan Power 1	0	1=ON / 0=OFF	0	1	1
10050	Fan Power 2	0	1=ON / 0=OFF	0	1	1

## 3 ModBus Memory Map

### Appliance Memory Map

Input Registers						
Address	Description	Default	Unit	Min.	Max.	Resolution
30001	Discrete Inputs 1 - 16	0	NA	0	65535	1
30002	Discrete Inputs 17 - 32	0	NA	0	65535	1
30003	Discrete Inputs 33 - 48	0	NA	0	65535	1
30004	System / Cascade Setpoint	0	Degrees Celsius	0	130	0,5
30006	Cascade Total Power	0	%	100	800	1
30007	Cascade Current Power	0	%	0	800	1
30008	Outlet Setpoint 1	0	Degrees Celsius	0	130	0,5
30009	Outlet Temperature 1	0	Degrees Celsius	0	130	0,1
30010	Inlet Temperature 1	0	Degrees Celsius	-20	130	0,1
30011	Flue Temperature 1	0	Degrees Celsius	-20	130	0,1
30012	Firing Rate 1	0	%	0	100	0,1
30014	Unit 1 Status Code	0	NA	0	65535	1
30015	Unit 1 Blocking Code	0	NA	0	65535	1
30016	Unit 1 Lockout Code	0	NA	0	65535	1
30017	Outlet Setpoint 2	0	Degrees Celsius	0	130	0,5
30018	Outlet Temperature 2	0	Degrees Celsius	0	130	0,1
30019	Inlet Temperature 2	0	Degrees Celsius	-20	130	0,1
30020	Flue Temperature 2	0	Degrees Celsius	-20	130	0,1
30021	Firing Rate 2	0	%	0	100	0,1
30023	Unit 2 Status Code	0	NA	0	65535	1
30024	Unit 2 Blocking Code	0	NA	0	65535	1
30025	Unit 2 Lockout Code	0	NA	0	65535	1
Holding Registers						
40001	Configuration	0	NA	0	65535	1
40002	Coils	0	NA	0	65535	1
40003	0-10 Volt Input / Rate Command / Setpoint Command	0	%	0	100	1
40004	Tank Setpoint	0	Degrees Celsius	0	87,5	0,5
40005	Tank Temperature	0	Degrees Celsius	-20	130	0,1
40006	Outdoor Temperature	0	Degrees Celsius	-40	60	0,1
40007	System Supply Temperature	0	Degrees Celsius	-20	130	0,1

### Configuration Bits

Address 40001 contains configuration bits sent from the BAS to the boiler or water heater. These bits tell the appliance to use its own internal inputs, or inputs from the BAS. When a bit is set to 1, the appliance will ignore the corresponding value contained internally, and expect the BAS to write that value into the Holding Registers. The configuration bits are as follows:

Bit 0 (LSB): Unit Enable

Bit 1: Tank Thermostat

Bit 2: Rate Command / 10 - 10V Input / Setpoint Command

Bit 3: Tank Setpoint

Bit 4: System Supply Temperature

Bit 5: Outdoor Temperature

Bit 6: Tank Temperature

Bit 7: System Return Temperature

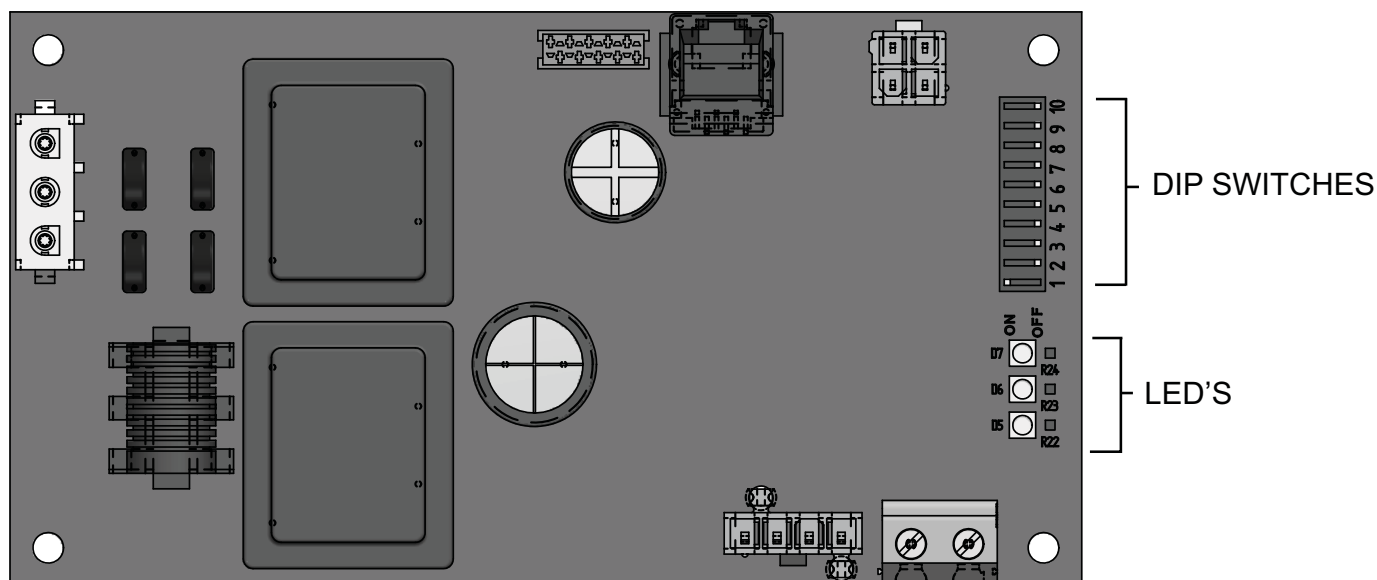
Bit 8 - 15: Not Used (Default = 0)



## 4 BACNET Configuration

The BACnet communication board is equipped with a set of ten dip switches that are used to set the board configuration (address and baud rate). The first eight are used to set the address of each board. The ninth and tenth are baud rate.

**Figure 4-1**\_Communication Board



### Addressing

The BACnet local addressing space is comprised of 256 different addresses.

- 255 is reserved for broadcast messages from a master device.
- 128 - 254 are free to use for slave devices only.
- 0 - 127 are free to use for master or slave devices.

Since the BACnet communication board is a BACnet master, address 127 is the highest address that can be used.

To set the BACnet local address, the dip switches can be set in either the 0 position or the 1 position. For switches set to the 1 position their value will be added together to determine the address.

Each switch set to the 1 position has the following value:

- Dip switch 1 = 1
- Dip switch 2 = 2
- Dip switch 3 = 4
- Dip switch 4 = 8
- Dip switch 5 = 16
- Dip switch 6 = 32
- Dip switch 7 = 64
- Dip switch 8 = 128

Any dip switch set to 0 has a value equal to 0.

*Example:*

To set the address of the BACnet board to 50, dip switches 2, 5, and 6 have to be set to the 1 position. The address is determined by adding the values of all the dip switches together.

Address = Value of Dip switch 1 + Value of Dip switch 2 + Value of Dip switch 3 + Value of Dip switch 4 + Value of Dip switch 5 + Value of Dip switch 6 + Value of Dip switch 7 + Value of Dip switch 8

In this example:

Address = 0 + 2 + 0 + 0 + 16 + 32 + 0 + 0 = 50

The BACnet Device Instance is calculated by adding the BACnet local address to 630000. Using the above example, the Device Instance will be:

Device Instance = 630000 + 50 = 630050

The base address (630000 in this example) is model dependant and can be changed by the integrator. It can be set to any value between 0 and 4194048. The resulting device instance will be this value + the local address, as before. Once the base address is changed, it can be reset back to the default base address (630000 in this example) using the following procedure:

1. Turn OFF power to the interface board.
2. Set Dip switches 1 - 8 to the 1 position.
3. Turn ON power to the interface board.
4. After a few seconds, turn OFF power to the interface board.
5. Set Dip switches 1 - 7 to the desired local address. Set Dip switch 8 to the 0 position.
6. Turn ON power to the interface board.

### Device Name

The default device name is "MTR-01 BACnet." This can be changed by the integrator as desired.

## 4 BACnet Configuration

### Timing Specifications

The baud rate for the BACnet board is selectable with Dip switches #9 and #10.

Switch #9	Switch#10	Baud Rate
OFF	OFF	9600
ON	OFF	19200
OFF	ON	38400
ON	ON	76800

When the system temperature, tank temperature, and/or 0-10V BMS voltage is provided by the BAS to the boiler or water heater, it is critical that the values be updated every few seconds. If the appliance does not receive updated values within a timeout period (installer adjustable), the control will revert to using its own readings (if connected). The timeout is programmable by pressing the MAIN>>SETUP>>BMS buttons. The timeout is adjustable between 5 and 120 seconds. The default timeout is 10 seconds.

When the BAS is not providing any of these values, but is still controlling the boiler (such as providing an enable command), the BAS must refresh these commands at least every 4 minutes. If the commands are not refreshed, the boiler will revert to operating based on its own inputs.

### Communication Board Diagnostics

The Communication board is equipped with three LED's for visual diagnostics: Two yellow LED's and one green. One yellow LED (D5) is used to indicate transmission of data. The other yellow LED (D6) is used to indicate reception of data. The green LED (D7) is used to show internal faults.

#### Internal Faults:

Normal Operation = 1 second bright, 1 second dim

Controller Fault = Continuously on

No Burner Control Communication = 0.5 seconds on, 1.5 seconds off

No BACnet Communication = 1.5 seconds on, 0.5 seconds off.

## 5 BACnet Memory Map

### Primary Data Tables

Object Type	Data Type	Read / Write
Binary Input (BI)	Single Bit	Read Only
Binary Value (BV)	Single Bit	Read / Write
Analog Input (AI)	16-Bit Word	Read Only
Analog Value (AV)	16 Bit Word	Read / Write

### Memory Map

Object Name	Object Type	Object Instance	Units	Min	Max	Resolution
<b>Binary Values</b>						
Boiler Enable	BV	0	none	0	1	1
Tank Thermostat	BV	4	none	0	1	1
<b>Binary Inputs</b>						
Manual Reset High Limit 1	BI	0	none	0	1	1
Flow Switch 1	BI	1	none	0	1	1
Gas Pressure Switch 1	BI	2	none	0	1	1
Louver Proving Switch 1	BI	3	none	0	1	1
Flap Valve 1	BI	4	none	0	1	1
Blocked Drain Switch 1	BI	5	none	0	1	1
Auto Reset High Limit 1	BI	6	none	0	1	1
Flame 1	BI	7	none	0	1	1
Enable	BI	8	none	0	1	1
Tank Thermostat	BI	9	none	0	1	1
Manual Reset High Limit 2	BI	16	none	0	1	1
Flow Switch 2	BI	17	none	0	1	1
Gas Pressure Switch 2	BI	18	none	0	1	1
Louver Proving Switch 2	BI	19	none	0	1	1
Flap Valve 2	BI	20	none	0	1	1
Blocked Drain Switch 2	BI	21	none	0	1	1
Flame 2	BI	22	none	0	1	1
Run-time Contacts 1	BI	32	none	0	1	1
Alarm Contacts 1	BI	33	none	0	1	1
Boiler Pump 1	BI	34	none	0	1	1
DHW Pump 1	BI	35	none	0	1	1
Gas Valve 1	BI	37	none	0	1	1
System Pump	BI	38	none	0	1	1
Run-time Contacts 2	BI	40	none	0	1	1
Alarm Contacts 2	BI	41	none	0	1	1
Boiler Pump 2	BI	42	none	0	1	1
DHW Pump 2	BI	43	none	0	1	1
Gas Valve 2	BI	45	none	0	1	1
Fan 1 Power	BI	48	none	0	1	1
Fan 2 Power	BI	49	none	0	1	1

# 5 BACnet Memory Map

## Memory Map *(continued)*

Object Name	Object Type	Object Instance	Units	Min	Max	Resolution
<b>Analog Inputs</b>						
Binary Inputs 0 - 15	AI	0	none	0	65535	1
Binary Inputs 16 - 31	AI	1	none	0	65535	1
Binary Inputs 32 - 47	AI	2	none	0	65535	1
System / Cascade Setpoint	AI	3	Deg C	0	130	0.5
Cascade Total Power	AI	5	Percent	100	800	1
Cascade Current Power	AI	6	Percent	0	800	1
Outlet Setpoint 1	AI	7	Deg C	0	130	0.5
Outlet Temperature 1	AI	8	Deg C	0	130	0.1
Inlet Temperature 1	AI	9	Deg C	-20	130	0.1
Flue Temperature 1	AI	10	Deg C	-20	130	0.1
Firing Rate 1	AI	11	Percent	0	100	0.1
Unit 1 Status Code	AI	13	none	0	65535	1
Unit 1 Blocking Code	AI	14	none	0	65535	1
Unit 1 Lockout Code	AI	15	none	0	65535	1
Outlet Setpoint 2	AI	16	Deg C	0	130	0.5
Outlet Temperature 2	AI	17	Deg C	0	130	0.1
Inlet Temperature 2	AI	18	Deg C	-20	130	0.1
Flue Temperature 2	AI	19	Deg C	-20	130	0.1
Firing Rate 2	AI	20	Percent	0	100	0.1
Unit 2 Status Code	AI	22	none	0	65535	1
Unit 2 Blocking Code	AI	23	none	0	65535	1
Unit 2 Lockout Code	AI	24	none	0	65535	1
Binary Inputs 48 - 63	AI	25	none	0	65535	1
<b>Analog Values</b>						
Configuration	AV	0	none	0	65535	1
Binary Values	AV	1	none	0	65535	1
0-10 Volt Input / Rate Command / Setpoint Command	AV	2	Percent	0	100	1
Tank Setpoint	AV	3	Deg C	0	87,5	0.5
Tank Temperature	AV	4	Deg C	-20	130	0.1
Outdoor Temperature	AV	5	Deg C	-40	60	0.1
System Supply Temperature	AV	6	Deg C	-20	130	0.1

## 6 Wiring Requirements

Note that when the System Supply Temperature and/or the Tank Temperature are provided by the BAS, they need to be refreshed every few seconds. This is required in order to prevent unwanted fluctuations in these temperatures. If these values are not provided every few seconds (timeout is programmable), the boiler or water heater will revert to its own internal control. If neither of these temperatures is provided by the BAS, but any of the other control signals are being provided, the BAS will still need to refresh these inputs at least every 4 minutes.

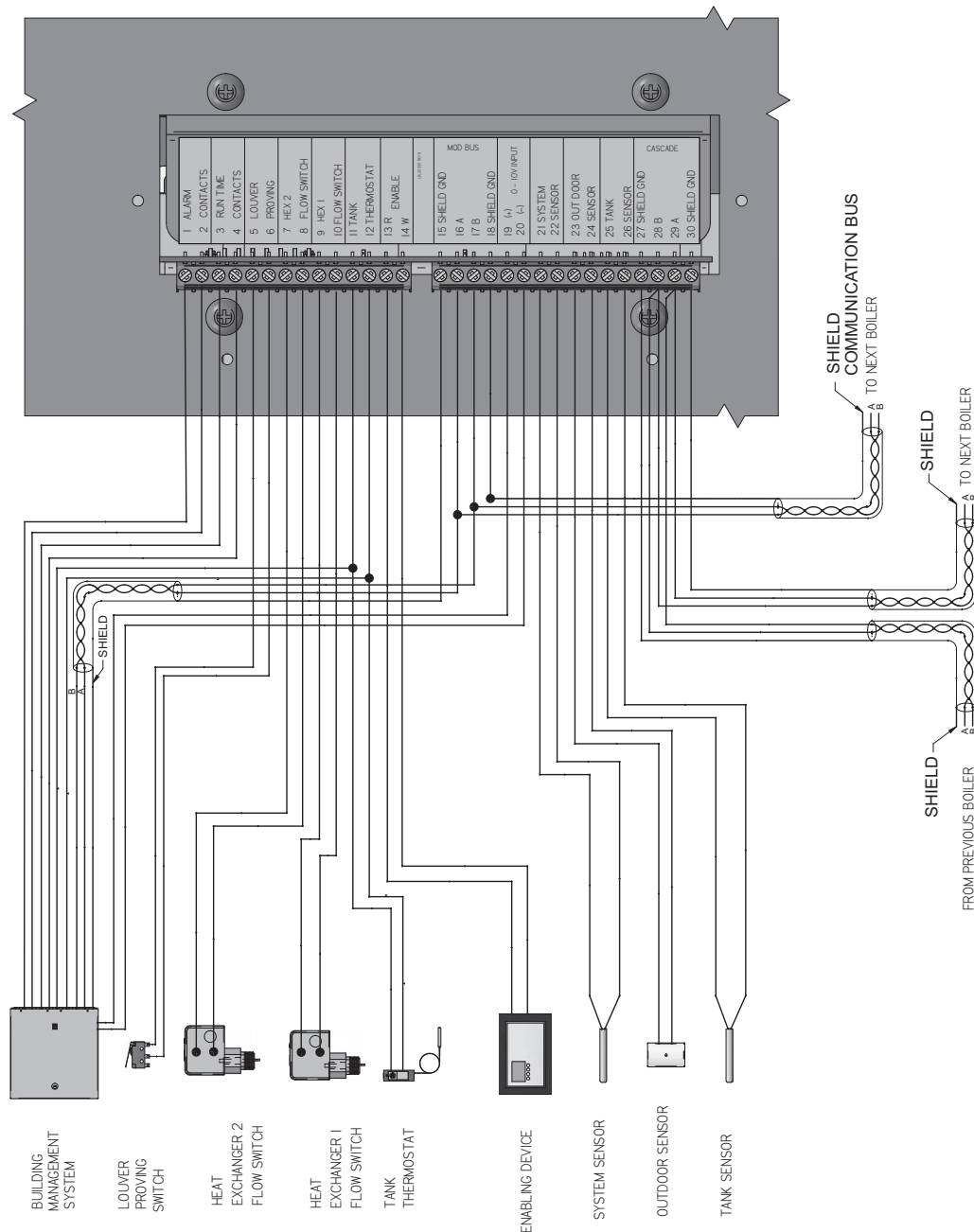
### Physical Wiring

#### RS-485 Communication Bus

- Maximum Length = 4000 feet
- Cable Specification = 24 AWG / A,B (twisted pair) and GND Shielded, with characteristic Impedance = 120 ohm
- Maximum Load = 32 units (32 nodes)

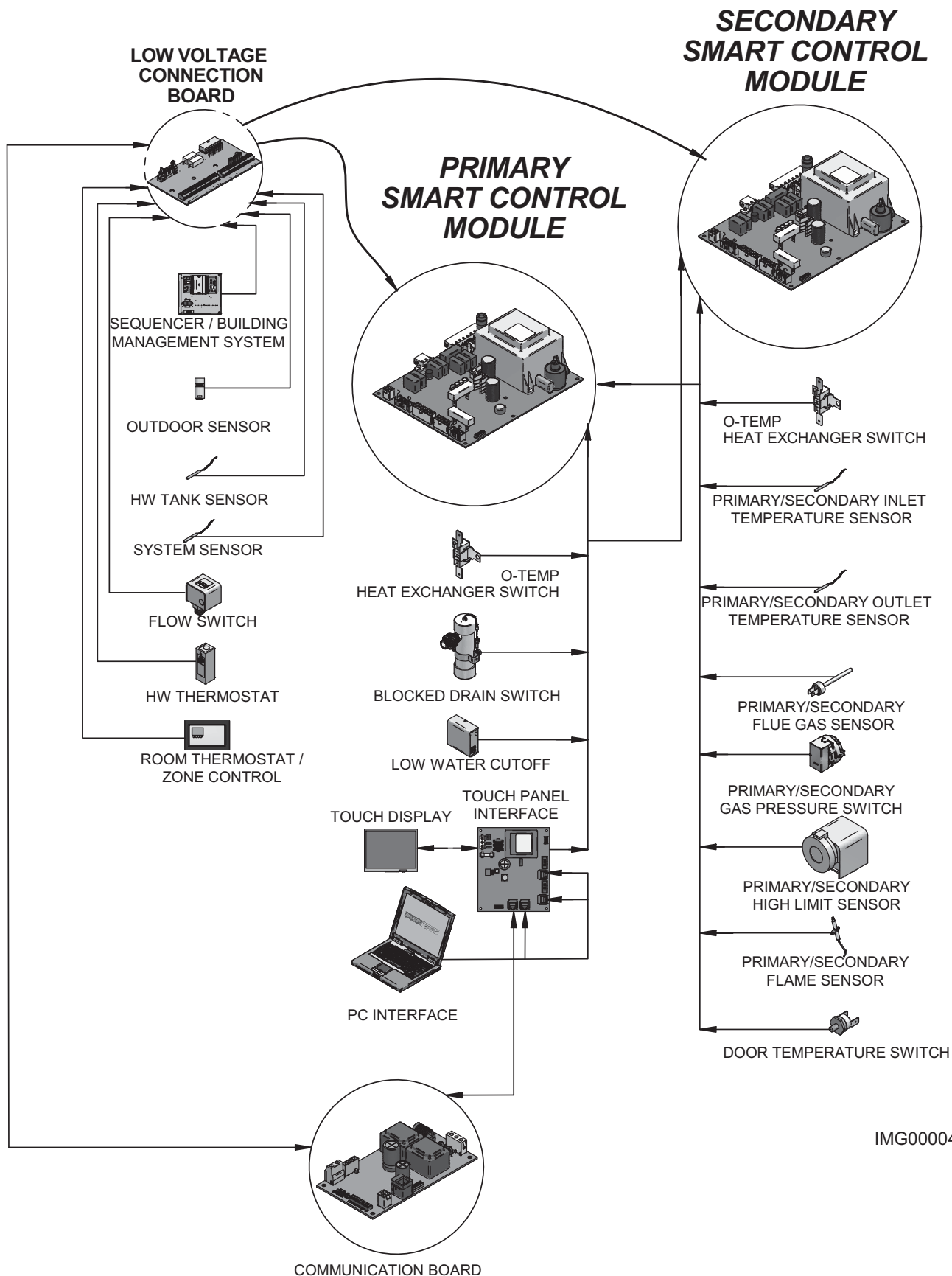
**NOTE:** Cable must be terminated with 120 ohm impedance matching resistor on each end.

**Figure 6-1**\_Terminal Strip Connections



## 6 Wiring Requirements

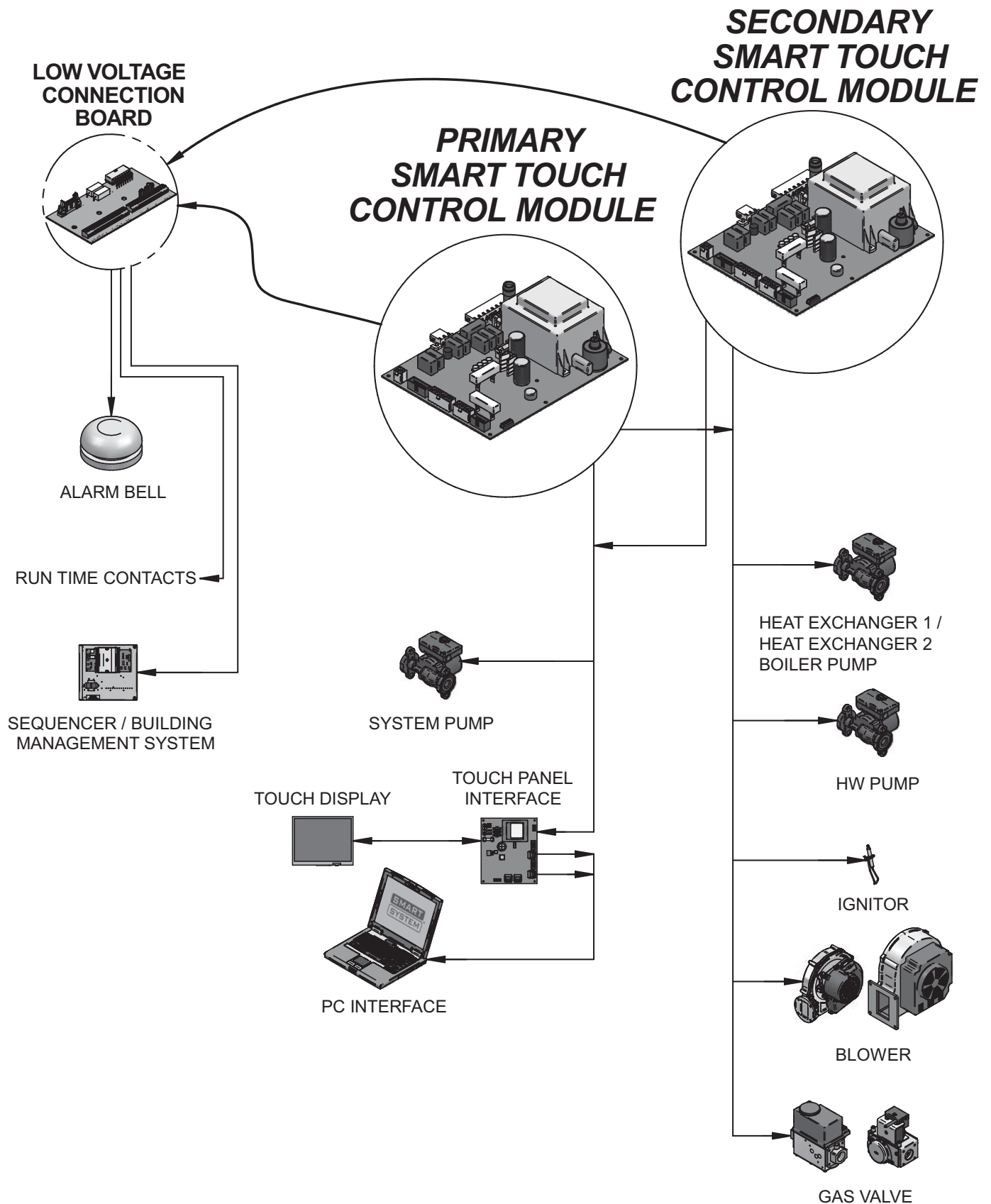
Figure 6-2\_Control Inputs



IMG00004

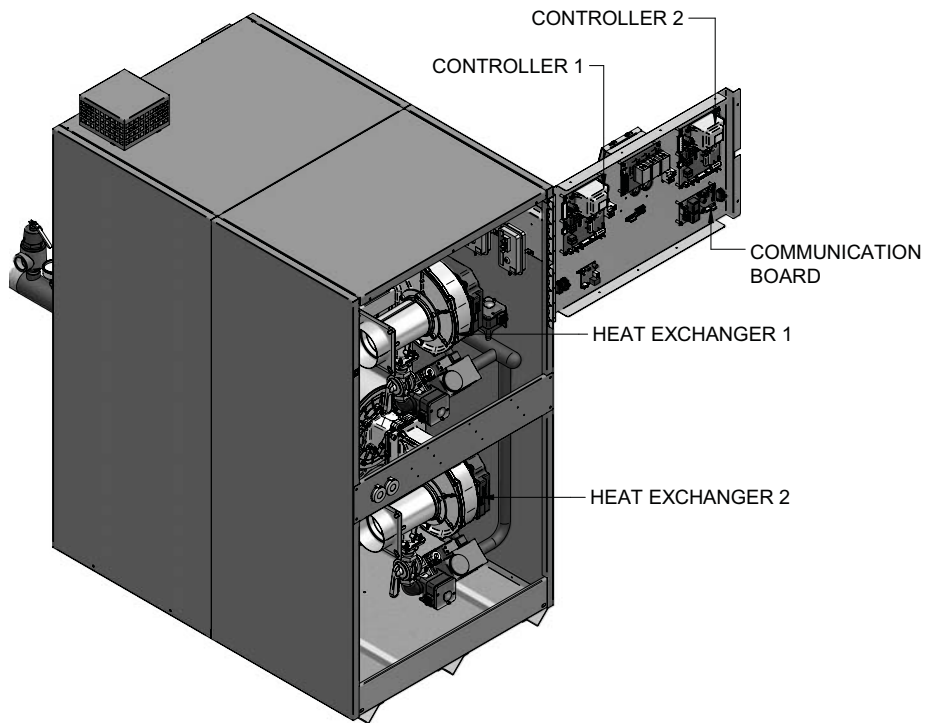
## 6 Wiring Requirements *(continued)*

**Figure 6-3**\_Control Outputs



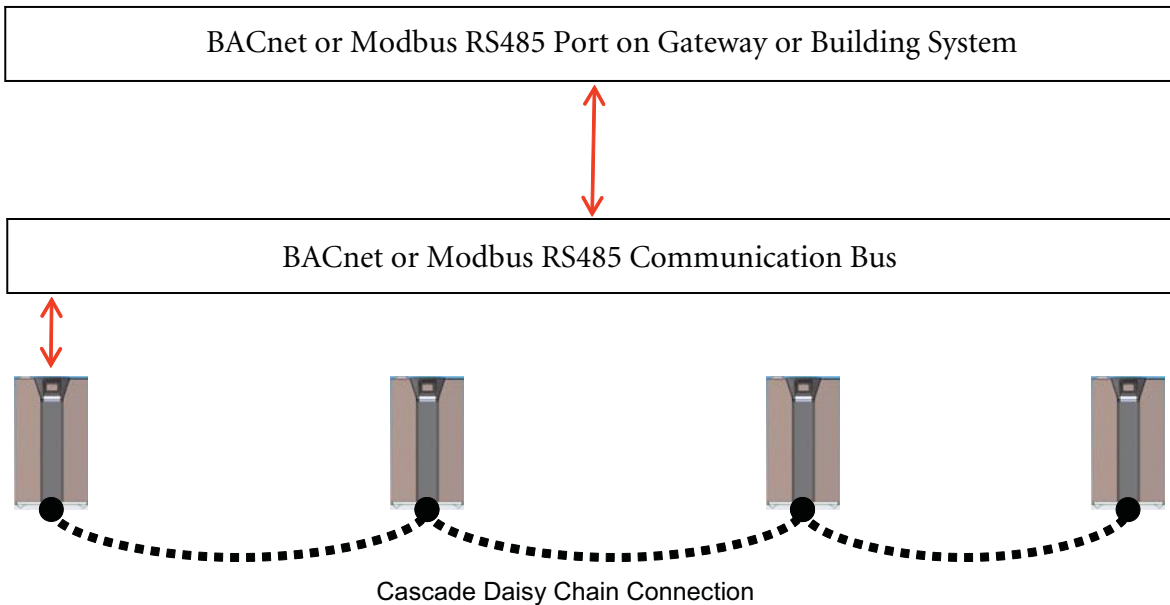
## 6 Wiring Requirements *(continued)*

**Figure 6-4**\_Control Location



### Typical System Wiring

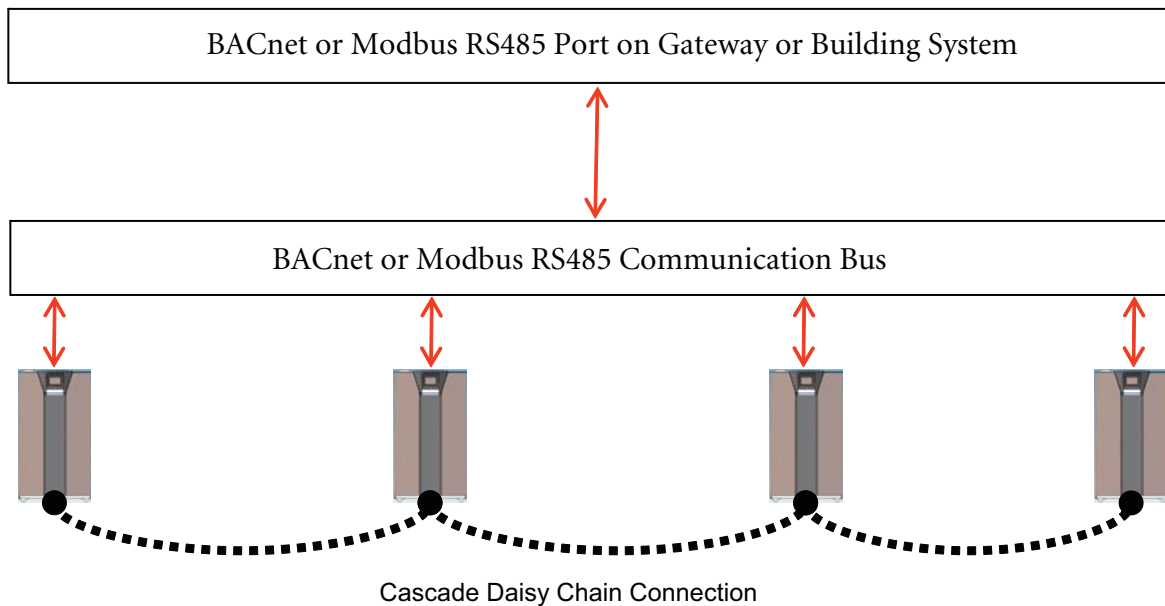
#### **Physical Configuration: Cascade without Individual Monitoring**



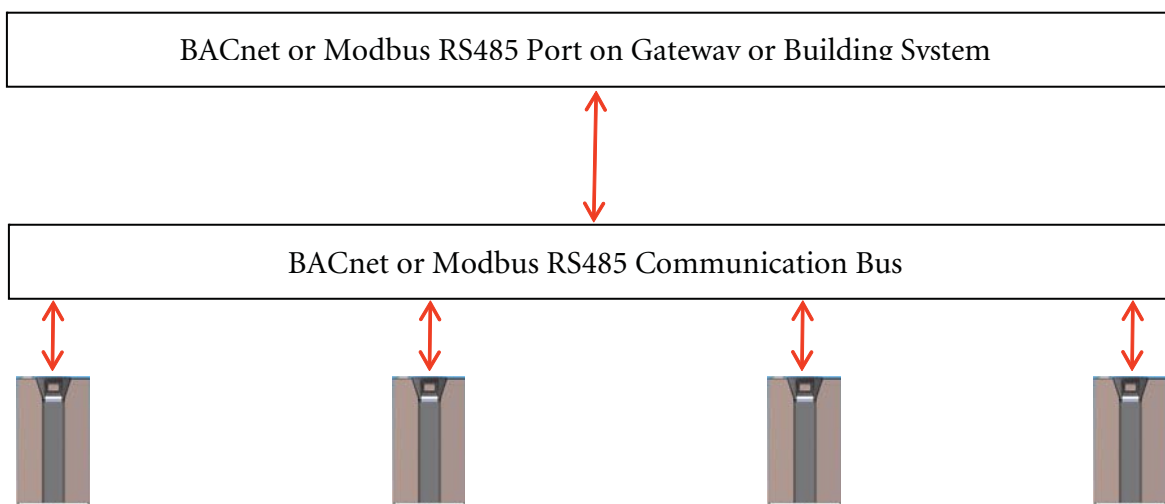


## 6 Wiring Requirements *(continued)*

### Physical Configuration: Cascade with individual Monitoring



### Physical Configuration: Direct Control

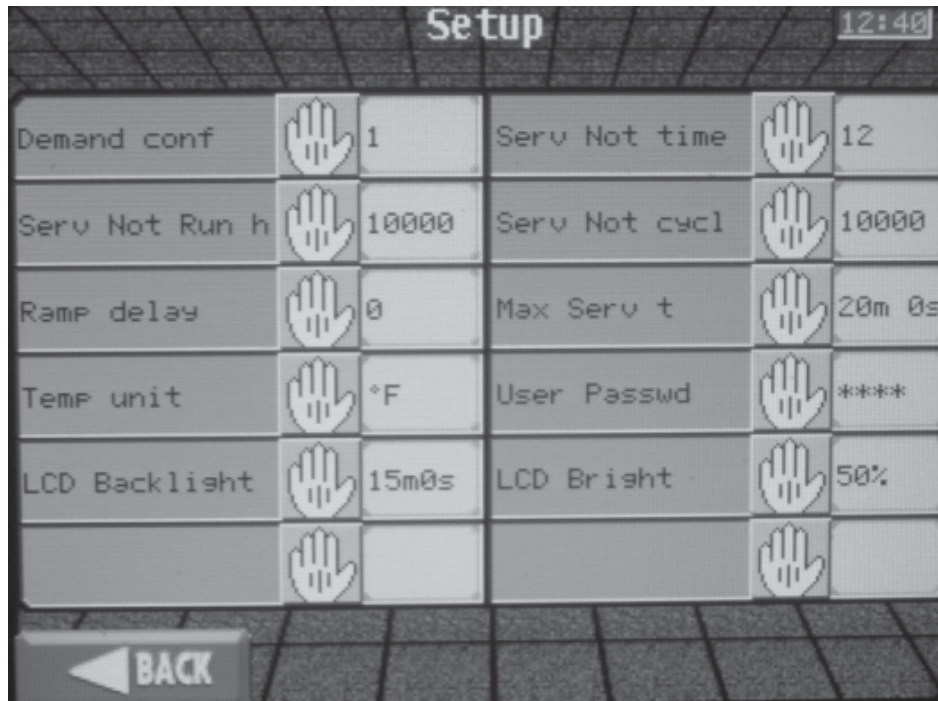


## 7 Unit Operation

### Unit Operation with Modbus or BACnet Communications

To control appliance through a Building Management System communicating through Modbus or BACnet, the appliance Demand Configuration must be set to a value of 4, 5, or 6. These configurations allow different control points for a variety of applications. The configuration can be set by selecting Main>>Setup>>Service/Setup>>Demand Config.

**Figure 7-1\_Setup Screen**



The appliance is equipped with a Modbus / BACnet communication timer. This timer is programmable from 0 - 120 seconds. The timer can be programmed from the Modbus / BACnet Setup Menu by selecting Main>>Setup>>BMS>>Modbus / BACnet Timeout. The purpose of the timer is to ensure proper temperature data is communicated to the boiler or water heater in a timely manner. Additionally, it will provide for fail safe operation should communication be lost. This timer will cause the unit to revert back to internal unit controls should the communication be interrupted longer than the timer. The timer is reset every time a Modbus / BACnet write command is received with updated temperatures or commands. Lochinvar recommends that this timer be set to the shortest value possible.

When controlling an appliance through a Building Automation System (BAS), it is very important to ensure that the correct configuration bits are sent to holding register 40001, and that the correct data and enable signals are sent to holding registers 40002 - 40007, per the demand configuration.

#### Demand Configuration 4

In this configuration the unit is controlled by setting the setpoints locally on the appliance and providing an enable signal through Modbus / BACnet communications.

All sensors and limiting devices should be hardwired to the terminal strip on the back of the unit excluding the thermostat enable and tank thermostat enable signal. These signals will be sent to the unit via Modbus or Bacnet.

The holding registers or analog values will need to be set as follows:

Object	Holding Registers	Definition	Bit Value (HEX)	Action
AV0	40001	Configuration	00 01	Set Configuration to read 40002
AV1	40002	Coils	00 01	Enables unit (00 00 disables unit)

**NOTE:** To ensure proper operation re-send the configuration bits to holding register 40001 prior to issuing a command.

## 7 Unit Operation *(continued)*

### Demand Configuration 5

In this configuration the unit is controlled by providing an enable signal and a rate command through Modbus communications. The rate command will be 0 - 100% of modulation.

All sensors and limiting devices should be hardwired to the terminal strip on the back of the unit excluding the thermostat enable and tank thermostat enable signal. These signals will be sent to the unit via Modbus.

The holding registers will need to be set as follows:

Object	Holding Registers	Definition	Bit Value (HEX)	Action
AV0	40001	Configuration	00 05	Set Configuration to read 40002 & 3
AV1	40002	Coils	00 01	Enables unit ( <i>00 00 disables unit</i> )
AV2	40003	Rate Command	00 ##	Sets Modulation % or Setpoint

**NOTE:** To ensure proper operation re-send the configuration bits to holding register 40001 prior to issuing a command.

For proper hexadecimal conversion of rate percentage, please refer to the Rate and Temperature Conversion section on page 17 of this manual.

### Demand Configuration 6

In this configuration the unit is controlled by setting the modulation setpoint from 0 - 100%.

Rate command will be 0 - 100% of the modulation range.

All sensors and limiting devices should be hardwired to the terminal strip on the back of the unit excluding the 0 - 10Vdc signal. This signal will be sent to the unit via Modbus.

The holding registers will need to be set as follows:

Object	Holding Registers	Definition	Bit Value (HEX)	Action
AV0	40001	Configuration	00 04	Set Configuration to read 40003
AV2	40003	Rate Command	00 00	Sets Modulation %

**NOTE:** To ensure proper operation re-send the configuration bits to holding register 40001 prior to issuing a command.

For proper hexadecimal conversion of rate percentage, please refer to the Rate and Temperature Conversion section on page 17 of this manual.

### Hot Water Generation

Hot water generation can be accomplished with one of two methods when an appliance is connected to a BAS system, DHW with direct control, and DHW with remote control.

#### DHW with direct control:

This is the typical installation with a hot water generator in close proximity to the boiler or water heater with the tank thermostat, or tank temperature sensor, wired to the terminal strip of the unit.

## 7 Unit Operation

### DHW with remote control:

This installation may or may not have the hot water generator in close proximity to the boiler or water heater. Its sensors and thermostat values are only available through the Modbus communication bus.

To ensure that the appliance can properly respond to a call for hot water generation the following holding registers must be set in addition to other commands:

Object	Holding Registers	Definition	Bit Value (HEX)	Action
AV0	40001	Configuration	00 45	Set Configuration to read 40002 & 3
AV1	40002	Coils	00 01	Enables unit ( <i>00 00 disables unit</i> )
AV3	40004	Rate Command	00 ##	Sets Modulation % or Setpoint
AV4	40005	Tank Temperature	0# ##	Passes tank temp from remote sensor

**NOTE:** To ensure proper operation re-send the configuration bits to holding register 40001 prior to issuing a command.

For proper hexadecimal conversion of rate percentage, please refer to the Rate and Temperature Conversion section on page 21 of this manual.

### Cascade

In order to operate the unit in Cascade with Modbus or BACnet communications, configure the leader appliance per the demand configurations in this manual. Connect the remaining appliances in the cascade through the normal cascade communications wiring. Cascade control can then be accomplished automatically through the leader boiler or water heater.

Please note that with Modbus / BACnet communication connected to only the leader appliance, total Cascade information can be seen through the communications link. If you wish to see all the individual temperatures of each unit in the Cascade, each unit will have to have a communication board. However, each unit can be monitored without the need to control each one individually.

### Monitoring Only

Any appliance can be equipped with the communication board and then be set up to operate with its own internal controls. If necessary, Modbus / BACnet can be configured as a monitoring device by selecting demand configurations 1 - 3, and polling the communication board for the read only variables.

## 7 Unit Operation *(continued)*

### Rate and Temperature Conversions:

#### Rate

When issuing a rate command the rate can be communicated as percent modulation or a desired setpoint, depending on the setting of the BMS Type in the BMS Setup Menu.

The proper data format for the modulation percentage is the direct conversion to hexadecimal. This conversion can be accomplished through online number based converters or some scientific calculators.

*For Example:*

Rate %	HEX
0	00
20	14
45	2D
60	3C
80	50
95	5F
100	64

To send a desired setpoint, the hexadecimal value must be determined through linear interpolation of programmable parameters on the BMS Setup Menu:

- BMS temperature set-point at low analog input
- BMS temperature set-point at high analog input

These variables set the temperature values corresponding to the minimum and maximum voltage settings of the 0-10 volt signal. The defaults are as follows:

PARAMETER	DEFAULT VALUES		DEFAULT
	Deg C	Deg F	Voltages
BMS temperature setpoint at low analog input	21	69.8	2
BMS temperature setpoint at high analog input	82	179.6	10

*For Example:*

Send a setpoint of 110°F.

The formula to use for the interpolation is:

Rate Command =

$$\frac{(\text{Desired Setpoint} - \text{BMS Temp at Low Analog Input}) (\text{High Voltage} - \text{Low Voltage})}{\text{BMS Temp at High Analog Input} - \text{BMS Temp at Low Analog Input}}$$

From the default values:

Desired Setpoint = 110

BMS Temp at Low Analog Input = 68

BMS Temp at High Analog = 158

High Voltage = 10

Low Voltage = 2

$$[(110 - 68)(10 - 2) / (158 - 68)] + 2 = 4.92 \text{ Volts}$$

$$(4.92 / 10) \times 100 = 49.2$$

$$49 = 31 \text{ Hexadecimal}$$

A value of [00][31] in hexadecimal would be written to Holding register 40003 to issue a command for a 110°F setpoint.

#### Temperature

The unit passes temperature data in degrees Celsius. Also, to accommodate decimal places the decimal value must be divided by 10.

Here are the conversions to and from Celsius:

$$T_c = (5/9) * (T_f - 32) \quad T_f = (9/5) * T_c + 32$$

*Example:*

Outdoor temperature from remote sensor on BAS System = 80°F

$$80^\circ\text{F} = 26.7^\circ\text{C}$$

Data that needs to be transmitted is  $26.7 * 10 = 267$

Decimal	Binary	HEX
267	100001011	10B

Outlet temperature from unit sensor = 155°F

$$155^\circ\text{F} = 68.3^\circ\text{C}$$

Data transmitted from unit in HEX = 2AB = 683

$$683 \div 10 = 68.3 (^\circ\text{C})$$

Decimal	Binary	HEX
683	1010101011	2AB

## 8 Troubleshooting

Should you encounter problems communicating over Modbus, the following items should be checked in this order:

1. Physical Layer
2. Communications Configuration and Port Settings
3. Modbus Error Codes
4. Unit Status / Blocking / Lockout Codes

### Physical Layer

1. Check that all components have power (Boiler, Gateway, BAS Master)
2. Check all wire lengths. Are any drops too long?
3. Check proper shield grounding
4. Check A, B terminal connections
5. Check for Terminating Resistors (120 ohms)
6. Check for broken wires

### Communications

1. Check Dip Switch Configuration of MTR-01 Board
2. Check Baud Rate (9600, 19200)
3. Check Parity
4. Check Slave ID
5. Check Port Setting on Master, Gateway, and Computers

### Modbus Error Codes

1. Check Modbus communication for error codes (see page 6 for Modbus Exception Codes)
2. Check Modbus PDU
3. Check Slave ID
4. Check Modbus Command
5. Check Configuration bits for Holding Register 40001
6. Check Commands and data for Holding Registers 40002 - 40007

### Unit Status Codes

See Codes in this section

### Unit Status

The unit displays a state code on the Building Screen to help aid in troubleshooting. The unit state indicates what the appliance is actually doing. This state should be compared to the command issued and what is expected. If the boiler or water heater state does not agree with the command issued, check communication and configuration.

### Status Codes (Input Registers 30014 and 30023 / Analog Inputs AI13, AI22)

- 2 = Heat Demand blocked due to high absolute outlet temperature
- 3 = Heat Demand blocked due to high absolute flue temperature
- 4 = Heat Demand blocked due to high absolute Delta T (Outlet - Inlet)
- 8 = Heat Demand blocked due to Low 24 VAC
- 9 = Outdoor shutdown
- 10 = Block due to switch OFF boiler or water heater (ON/OFF of Display)
- 12 = Block due to no correct communication Cascade
- 16 = Service function
- 19 = DHW function Storage Tank
- 21 = SH function Heat demand from Room Thermostat
- 22 = SH function Heat demand from Boiler Management System
- 23 = SH function Heat demand from Cascade
- 30 = Heat demand activated by Freeze Protection
- 32 = DHW Pump Delay
- 33 = SH Pump Delay
- 34 = No heat function (after pump delay)
- 40 = Lockout
- 32764 = Busy with updating status
- 32765 = DHW blocked due to no present tank sensor
- 32766 = Burner control(s) manually shut down
- 32767 = Code not present

### Blocking Codes (Input Registers 30015 and 30024 / Analog Inputs AI14, AI23)

- 0 = No blocking \_> is divided into sub blockings
- 1 = SH blocking
- 2 = Blocking Due to Low 24 VAC Supply
- 3 = Blocking due to General block
- 4 = Blocking MRHL is open
- 5 = Blocking due to Switched OFF boiler or water heater (Display ENTER switch)
- 6 = Blocking due to wrong communication of Cascade
- 7 = Blocking due to High Delta
- 8 = Blocking due to High Flue Temperature
- 9 = Blocking due to High Outlet Temperature
- 10 = Service blocking
- 12 = DHW blocking high outlet temperature (DHW configured as storage tank)
- 13 = Blocking anti-cycling time
- 14 = Storage Tank demand Blocked due to Fan problems
- 15 = No system sensor connected and leader control present
- 16 = Limit fan speed due to high outlet temperature
- 17 = Fan min decreased due to low flame current
- 18 = Limit max fan speed due to high Delta T
- 19 = Limit max fan speed due to high flue temp
- 32767 = Code not present



## 8 Troubleshooting *(continued)*

### Lockout Codes (Input Registers 30016 and 30025 / Analog Inputs AI15, AI24)

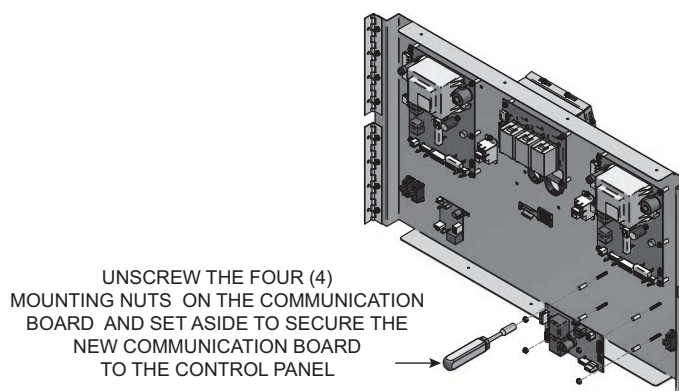
#### NOTICE

The lockout codes (Input Registers 30016 and 30025) are constantly changing during operation and should not be used for lockout notification until the corresponding status code (Input Registers 30014 and 30023 respectively) indicates a code of 40.

- 161 = EEPROM code Parameters not Re-Programmed by Lochinvar
- 164 = EEPROM code No Reset Allowed (> 15 minutes)
- 166 = EEPROM code Auto Reset High Limit/HEX O-Temp Sw/Burner Door Temperature Reset
- 167 = EEPROM code Blocked Drain
- 168 = EEPROM code Louver Proving
- 169 = EEPROM code Gas Pressure Sw
- 170 = EEPROM code Flow Switch
- 177 = Sensor 3 short (Flue Sensor)
- 178 = Sensor 3 open (Flue Sensor)
- 179 = Sensor 2 short (Inlet Sensor)
- 180 = Sensor 2 open (Inlet Sensor)
- 192 = Sensor 1 short (Outlet Sensor)
- 193 = Sensor 1 open (Outlet Sensor)
- 204 = CRC EEPROM failed
- 205 = EEPROM programmed (display shows "PP")
- 206 = EEPROM error in programming
- 207 = Write error EEPROM
- 229 = EEPROM code Watch Dog
- 230 = EEPROM code fan low (should be high)
- 231 = EEPROM code fan high (should be low)
- 232 = EEPROM code no flame when running
- 233 = EEPROM code no flame after ignition
- 234 = EEPROM code simultaneous output APS and Fan
- 235 = EEPROM code APS active not Closed
- 236 = EEPROM code APS active not Open
- 237 = EEPROM code flame out of sequence
- 239 = EEPROM code when gas valve relay test fails
- 240 = EEPROM code MRHL
- 32767 = Code not present

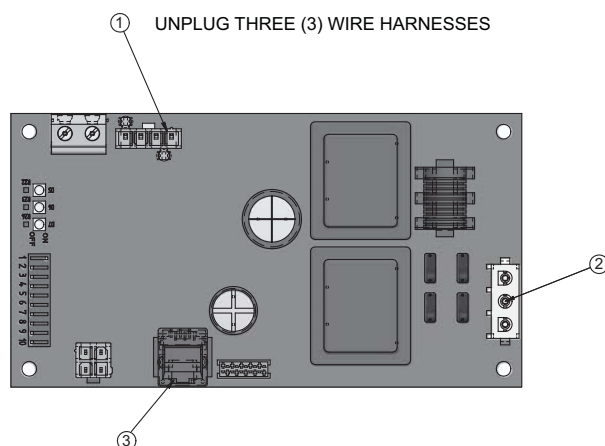
1. Turn OFF the main electrical power to the appliance.
2. Turn OFF the main manual gas shutoff to the appliance.
3. Unplug the three (3) wire harnesses on the communication board (see FIG. 6-1).
4. Unscrew the four (4) mounting nuts on the communication board and set aside. Remove the communication board (see FIG. 6-2).
5. Replace / install the new board.
6. Replace the four (4) mounting nuts removed in Step 4.
7. Reconnect all three (3) wire harnesses unplugged in Step 3.
8. Turn on the main electrical power and the main manual gas shutoff to the appliance.
9. Configure the communication board and unit controls per this manual and resume operation.

**Figure 8-2**\_Control Panel Communication Board



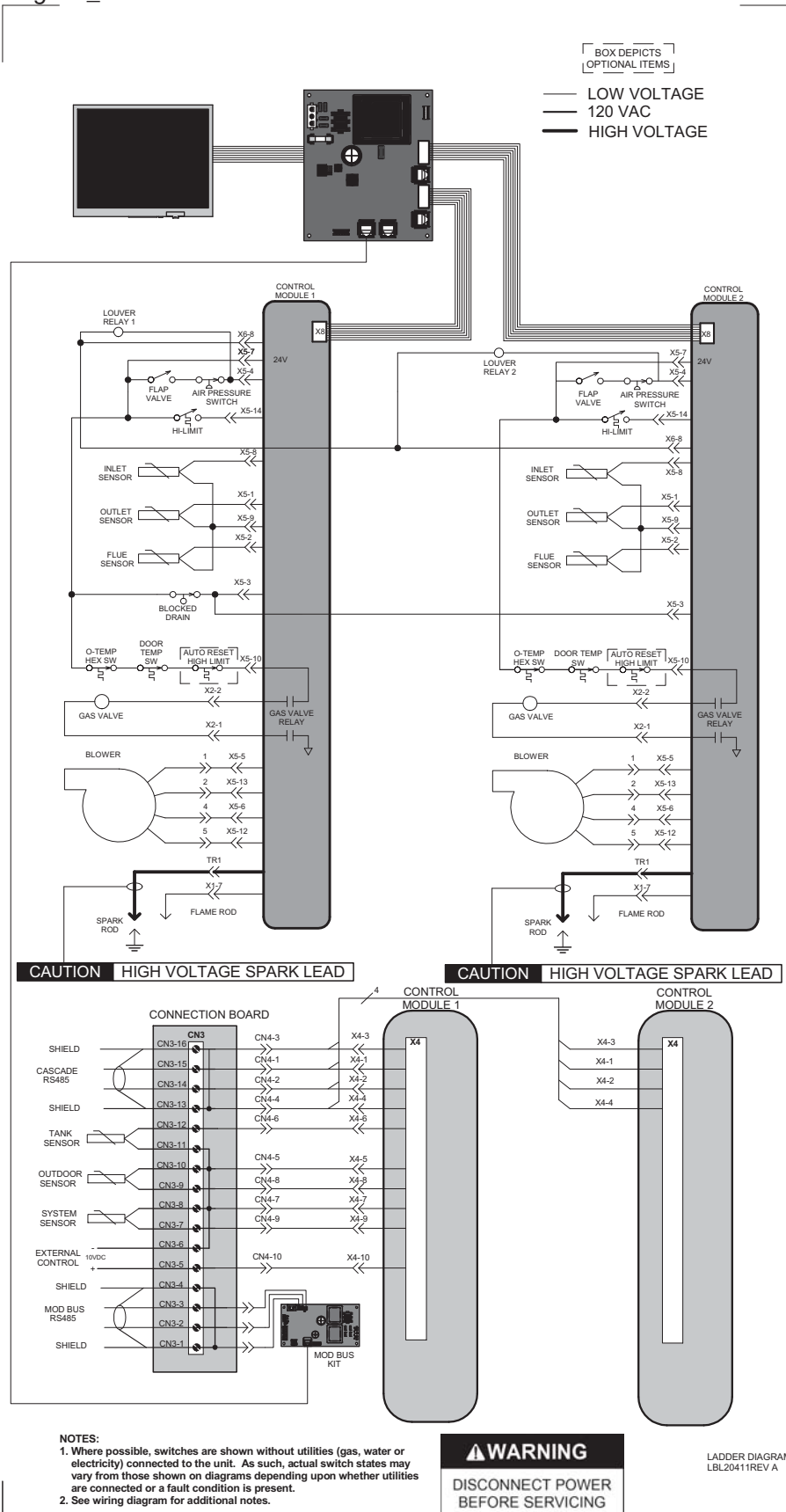
### Installation / Replacement Procedure

**Figure 8-1**\_Communication Board



# 9 Diagrams

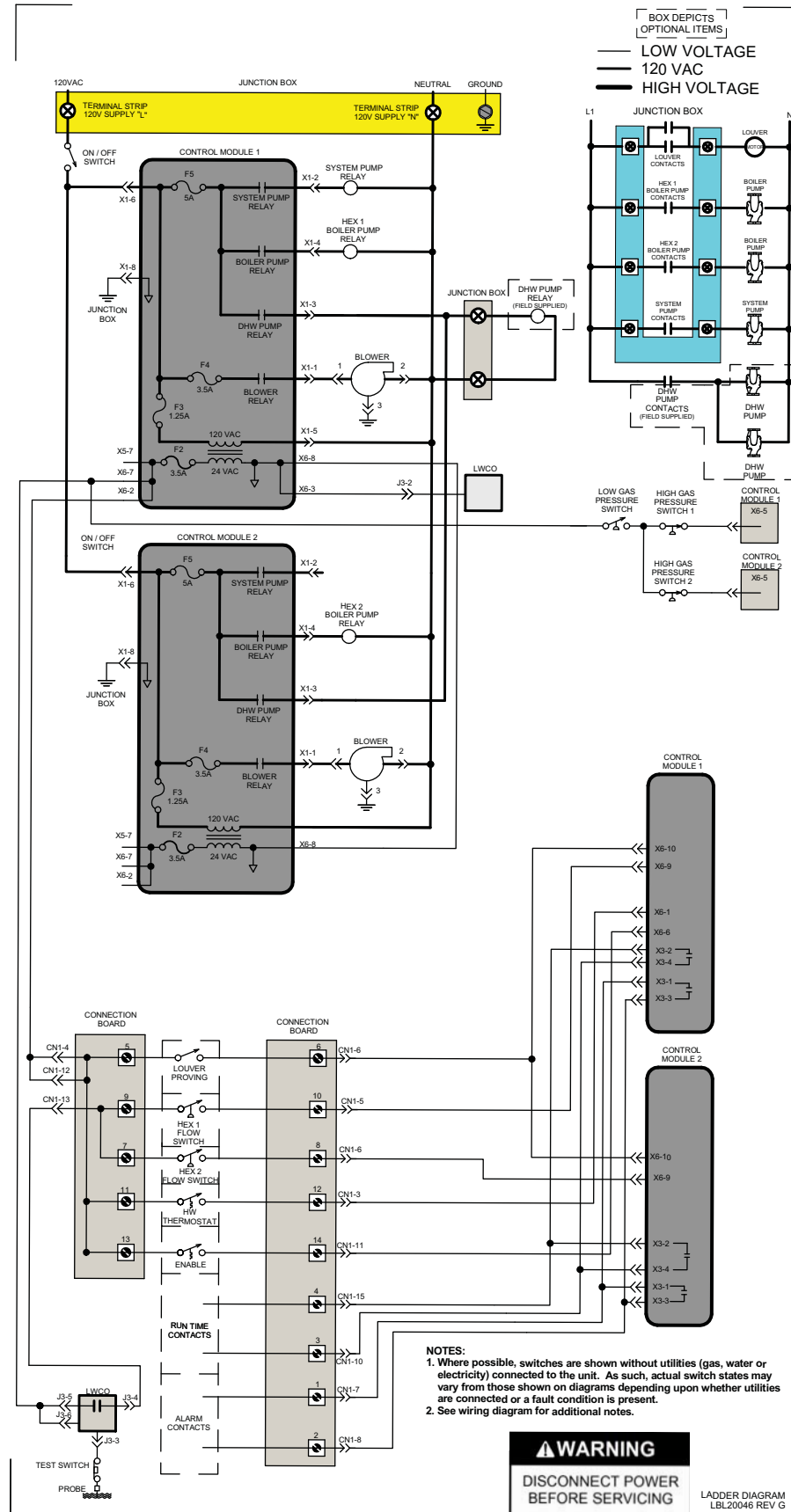
**Figure 9-1 Ladder Diagram\_Part 1**



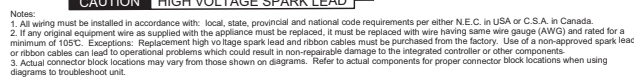


## 9 Diagrams (continued)

Figure 9-2 Ladder Diagram\_Part 2



**Figure 9-3** *Wiring Diagram*



---

# Notes

---

**Revision Notes:** Revision A (ECO #C04560) initial release.

Revision B (ECO C07191) reflects the correction of the information in the Parity section on page 4.

Revision C (ECO C07283) reflects the update of the Ladder and Wiring Diagrams on pages 21 and 22.

Revision D (ECO C08689) reflects changes made to LBL20046 Rev F.

Revision E (ECO C10327) reflects the addition of AWX2 Models and update of manual cover.

Revision F (ECO C10594) reflects the update of ladder and wiring diagrams on pages 21 and 22.

Revision G (ECO C11616) reflects the addition of the lockout code notice on page 19 (R05772).

Revision H (ECO C13224) reflects resolution changes to 30012 and 30021 from 1 to 0,1 (R06251) on page 8).

Revision I (ECO C13647) reflects the inclusion of AQUAS models.

Revision J (ECO C15251) reflects the addition of the burner door temperature switch (R6322).

Revision K (PCP# 3000002377 / CN# 500002607) reflects the addition of BACnet information and images, edits made to wording of Timing Specifications on pages 4 and 10, and edits made to Memory Map tables on pages 7 and 11.

Revision L (PCP# 3000008406 / CN# 500008361) reflects an update to the addressing information of BACnet configuration on page 9.