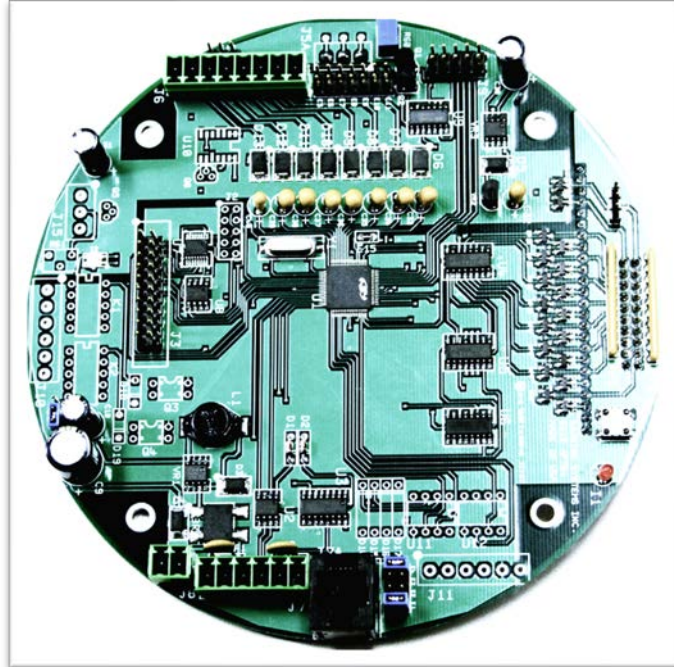




**2015**  
**Manual**

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## **All-Purpose Transmitter Board (APT3, APT3.5, APT3.6)**

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## Introduction

The APTB3 is the newest product in GSI's line of multi-purpose tank transmitter cards. It is backward compatible with the previous MACB and APTB products but utilizes enhanced microprocessor circuit board technology to provide a number of new features. It also provides all the functionality of the earlier GSI 1901 and 2001 transmitter cards and is mechanically and electrically compatible with those earlier products.

A header for a wireless UART device was added with version APTB3.5. It is available on all APTB3 models from version APTB3.5 and up. An off-the-shelf wireless UART device enables the user to use a smartphone app (Blue HHT) instead of a physical hand-held terminal to configure the board. The app is available from the Apple App Store for iPhone and iPad devices with iOS 13.0 or later.

Support for Capacitive Encoders was added with board version APTB3.6. APTB3 boards with this feature can utilize either legacy brush encoders or capacitive encoders. APTB3.6 boards must utilize firmware version 220406 or later when using capacitive encoder style A or firmware version 230607 or later when using capacitive encoder Style B.

Like its predecessors, the APTB3 utilizes plug-in Personality Modules (PMs) to provide electrical interfaces, power regulation, and surge protection to connect the APTB3 to a wide variety of communication networks. All PMs supported by the legacy MACB and APTB modules can also be utilized on the APTB3.

The basic APTB3 uses the same circuit board as its APTB2 predecessor, but has more memory, a more powerful microcontroller and a number of additional features. The APTB3 can be used as a direct replacement for any existing APTB2 applications. The APTB3.5 and later boards are physically different from the APTB2 and APTB3 boards because they have additional circuit components that were not on those earlier versions.

Some of the major APTB3 enhancements include:

- Live configuration and diagnostic capability utilizing a Hand-Held terminal or computer without disconnecting the board from the system
- Wireless configuration capability (APTB3.5 and up)
- Supports a wide variety of absolute level encoders utilizing either legacy brush and code disk encoders (APTB3 and up) or capacitive encoders (APTB3.6 and up)
- LED indicators for communication and operation status
- Expanded analog input capability, providing such capabilities as:
  - Support for averaging or multi-point RTD temperature inputs
  - Ability to measure product or water level from 4-20 mA instruments
  - Ability to measure parameters such as pressure, temperature, density, etc. from 4-20 mA instruments
- Ability to compute gross and net volumes if equipped with density input and configured with strapping tables and various tank and product parameters
- Optional configurable master or slave communication port with the ability to acquire data from secondary gauging devices and merge that data into the APTB3 calculations and data tables
- On-board sensor for monitoring ambient temperature within the transmitter housing – including low/high historical recording
- Broader range of protocol support including MODBUS-TCP
- Support for additional PMs that were not previously available with the earlier products including an Ethernet PM
- Non-volatile memory utilizing flash and EEPROM technology for program and configuration settings
- In-situ firmware upgrade capability when new features are released
- Capability of powering the board directly from an external power supply for special applications and for testing
- No DIP or Rotary switches
- Utilizes resettable fuses



# Theory of Operation

## General

The APTB3 is a 5" diameter circular circuit board with the same footprint and hole pattern as its predecessor MACB and APTB products. In general, plug-in Personality Modules (PMs) are used to provide electrical interface, power regulation, and surge suppression to connect the APTB3 to a variety of field networks. All protocol and data processing is performed on the main APTB3 as specified by individual application configuration settings. The configuration settings can be viewed and changed with a plug-in Hand-Held Terminal or with the GSI Config and GSI Test programs running on a laptop computer.

## Personality Modules

Personality Modules available for the APTB3 include the following:

- **RS485 PM** – Connects to a 2-wire RS485 data bus; requires 24VDC field power; supports MODBUS-RTU and a variety of ASCII protocols; the RS485 PM can optionally be powered from 48VDC field power
- **Ethernet PM** – Provides 10/100 BASE-TX copper connectivity via an RJ45 jack; requires 24VDC field power; supports MODBUS-TCP, MODBUS-RTU, and a variety of ASCII protocols; external copper-to-fiber optic converters are also available
- **Serial Fiber PM** – Provides high speed, fiber optic connectivity for serial data communication; requires 24VDC field power; supports MODBUS-RTU and a variety of ASCII protocols
- **Radio PM** – Provides wireless connectivity for serial data communication; requires 24VDC field power; supports MODBUS-RTU and a variety of ASCII protocols. It is available with either a point-to-point broadband radio or a mesh radio.
- **Mark-Space PM** – Connects to legacy Varec Mark-Space field busses; requires 48VDC field power; supports the Varec Mark-Space 56-bit and 40-bit protocols
- **TP600 PM** – Connects to legacy GPE Current Loop field busses; requires 48VAC field power; supports the various GPE 31422 and 31423 protocols
- **Tankway PM** – Connects to legacy L&J Tankway field busses; requires 48V to 60VDC field power; supports the L&J 2-byte Tankway protocol
- **Analog Output PM** – Provides two 4-20 mA analog outputs to transmit level and temperature to an analog-input device. Analog Output PMs may also be equipped with a serial communication interface to provide simultaneous digital and analog communication capability.

## Power Requirements

The APTB3 normally obtains +5VDC provided by voltage regulators on the attached PM device. Alternatively it can be powered directly from a +12V to +36VDC power supply (nominal +24VDC) by changing a jumper setting on the board. When powered directly from a power supply, the APTB3 requires approximately 100 mA at 24VDC (approximately 2.5 Watts), not including the power requirements of whatever PM is utilized with the APTB3.

## Operating Specifications

The APTB3 operating specifications are as follows:

Temperature Range	-25 °F to +160 °F
Relative Humidity	5% to 90%, non-condensing
Temperature Measurement Range	-82 °F to +388 °F (for Platinum RTDs)
Level Measurement Range	0 to 96 feet

Note: It is possible to configure and calibrate the APTB3 for an Extended Temperature range of -82 to +602°F. However, this requires different components, so boards must be ordered with this option – they cannot be changed from standard to high temperature range (or vice-versa) in the field.

## Major Circuitry

The major circuitry provisions of the APTB3 are described in this section. Some are optional features that may not be installed on all boards.

### Microprocessor

The APTB3 microprocessor is an 8051 derivative with 128K of flash memory and 8K RAM. This memory is supplemented by an external 256Kbit EEPROM. The microprocessor contains a 9-channel 12-bit ADC, on-chip voltage reference source, and two UARTs. It has 32 configurable, general-purpose I/O pins, including support for SPI and SMB data busses.

The microprocessor's flash memory can be updated via a JTAG programming device that connects to a computer's USB port. GSI firmware also permits firmware updates via direct serial communication to the APTB3 board.

One analog input is dedicated to an on-chip temperature sensor that monitors the ambient temperature of the APTB3. This sensor measures the die temperature of the microprocessor chip, and the APTB3 compensates for the self-heating characteristics of the chip so the ambient temperature of the board can be determined. This provides a good approximation (within +/-5 °F) of the temperature inside the transmitter housing. The high and low values measured by this sensor are stored in non-volatile memory for historical reference.

The APTB3 application program is stored in the on-chip flash memory of the microprocessor. All configuration parameters and downloadable user data are stored in the EEPROM.

The microprocessor includes both SPI and SMB interface capability. Both of these busses are routed to a dual in-line header so they can be utilized to provide additional expansion capability via external modules connected to that header.

### Analog Inputs

The APTB3 includes conditioning circuitry for 8 analog inputs that support either 4-20mA or 0-5VDC signal ranges. One of the analog inputs is dedicated for an RTD and the remaining 7 are routed to a connector for application use as required. One of these 7 may be used as for an optional second RTD input.

The analog conditioning circuitry also permits any or all of the 7 inputs to be used as digital input signals. Digital inputs may either be passive (dry contact) or active (maximum input voltage = 5VDC).

The 12-bit microprocessor ADC is over-sampled and filtered to provide pseudo 16-bit resolution. These algorithms plus the use of physical low-pass filters in the signal conditioning circuitry provide a high degree of stability for the analog inputs.

In general, the user is free to utilize the 7 available analog inputs for any purpose. Each input can be scaled and calibrated to generate any meaningful engineering unit representation that the user's application requires.

However, if it is desired to use some of the particular pre-defined APTB3 features, the user must only use the particular analog inputs that are allocated for those features. These are as follows:

- AIN1 (pin 1 of J6) – when an analog input is used for **Product Level** measurement in lieu of an actual level encoder
- AIN2 (pin 2 of J6) – when an analog input is used for **Product Temperature** measurement in lieu of an actual RTD input
- AIN3 (pin 3 of J6) – when a water bottom sensor is utilized to provide **BS&W** information to the APTB3 for advanced tank gauging calculations.

This input is also used when it is desired to utilize the "auxiliary analog input" feature of the GPE TP600 protocol. In that case, this input may be used for any purpose that the user & application require

- AIN4 (pin 4 of J6) – when a densitometer or other density measurement device is utilized to provide **Product Density** information to the APTB3 for advanced tank gauging calculations.

- AIN5 (pin 5 of J6) – when a pressure sensor is utilized to provide **Vapor Pressure** information to the APTB3 for advanced tank gauging calculations.
- AIN6 (pin 6 of J6) – when a bottom pressure sensor is utilized to provide to provide **Product Mass** measurement information to the APTB3 for advanced tank gauging calculations.
- AIN7 (pin 7 of J6) – if a second RTD input is to be connected to the APTB3, it will utilize AIN7. In that case, nothing may be connected to this pin. Note that this RTD must be a platinum device.

If a second RTD input is not required, then AIN7 is available for an analog input for any desired purpose.

The data value in engineering units of all analog inputs are available in the APTB3 MODBUS register map. If an APTB3 application does not require the use of AIN1-AIN6 for a pre-assigned purpose, the user may then use those inputs for whatever other purpose may be desired and read the results of those inputs via the Analog Input data registers in the MODBUS map.

### **Temperature Monitoring**

Temperature measurement is generally performed by connecting an RTD to the APTB3 board. The board utilizes a current transmitter chip with sensor excitation and linearization to produce a 4-20mA analog signal that is directly proportional to the RTD resistance. That 4-20mA signal is then measured and processed just like any other 4-20mA analog input.

This chip is configured (via gain and linearization resistors) to monitor RTD resistances from 75 to 175 ohms. This corresponds to a  $-82\text{ }^{\circ}\text{F}$  to  $+388\text{ }^{\circ}\text{F}$  range for Platinum RTDs or a  $-40\text{ }^{\circ}\text{F}$  to  $+440\text{ }^{\circ}\text{F}$  range for Copper RTDs. These ranges presume Platinum RTDs with 100 ohm resistance at  $32\text{ }^{\circ}\text{F}$  and alpha of .00385 and Copper RTDs with 100 ohm resistance at  $77\text{ }^{\circ}\text{F}$  and alpha of .00427.

The RTD resistance range of 75 to 175 ohms was chosen to achieve the highest possible temperature measurement resolution (approximately  $0.1\text{ }^{\circ}\text{F}$ ) while accommodating a temperature range that is suitable for most applications.

Alternatively, the APTB3 can be configured and calibrated for an RTD resistance range of 75 to 218 ohms which corresponds to a  $82\text{ }^{\circ}\text{F}$  to  $+602\text{ }^{\circ}\text{F}$  range for Platinum RTDs or a  $-40\text{ }^{\circ}\text{F}$  to  $+457\text{ }^{\circ}\text{F}$  range for Copper RTDs. The temperature measurement resolution of the APTB3 is reduced slightly to approximately  $0.15\text{ }^{\circ}\text{F}$  when this high-temperature range is selected.

The APTB3 can also be manufactured with alternate gain and linearization resistors to provide different ranges for special applications. Contact GSI for details if your application requires wider or different ranges of temperature measurement or different RTD types.

Two of these temperature sensing chips can be installed on the APTB3 and are normally used to monitor single 2-wire or 3-wire RTDs. The second RTD can be either a standard or high temperature range device, but it must be a platinum RTD. Alternatively, the board can communicate with an external temperature multiplexer to select an averaging or multi-point RTD inputs for either or both of the RTD input circuits.

In addition to RTD inputs, the APTB3 has the ability to measure temperatures from 4-20 mA instruments. Reference the previous Analog Input description for guidelines on using analog inputs for temperature measurement. It can also obtain temperature data from external serial communication devices.

Note: The APTB3 performs its temperature measurements based on Platinum RTD linearization. If copper RTDs are used, APTB3 performs a simple first-order algorithm to derive a corresponding temperature for a copper RTD. The maximum computation error is  $\pm 0.7\text{ }^{\circ}\text{F}$  in the range of 0 to  $+250\text{ }^{\circ}\text{F}$ . Copper RTDs should not be used outside this range.

### **Brush Encoder Inputs**

The APTB3 includes encoder-monitoring circuitry for both GSI and Varec mechanical encoders that utilize brushes and code disks. The direction of gauge rotation and the type of encoder (fractional, decimal, or metric) are configurable parameters.

When configured for Brush Encoder operation, the APTB3 continuously reads the encoder positions and computes the corresponding product level multiple times each second. This level data is then stored in the internal RAM memory of the microprocessor for immediate transmission to a Host system when requested. The level data can be provided in a variety of engineering unit and numerical data formats.

In addition to encoder inputs, the APTB3 has the ability to measure either water level or product level (or both) from 4-20 mA instruments.

The maximum level value with brush encoders is 95-11-15 or 95.99.

### **Capacitive Encoder Inputs**

All APTB3 boards from version APTB3.6 and up include encoder-monitoring circuitry for both brush encoders and capacitive encoders. Like the legacy brush and code disk encoders, the capacitive encoders are absolute encoders, meaning that any level changes that occur while power is removed from the board or encoders will be tracked and updated when power is applied. The direction of gauge rotation is a configurable parameter. No mechanical calibration is required with capacitive encoders. Calibration is performed by simply entering the current hand-line value via a hand-held terminal or Blue HHT app.

When configured for Capacitive Encoder operation, the APTB3 continuously reads the encoder positions and computes the corresponding product level multiple times each second. This level data is then stored in the internal RAM memory of the microprocessor for immediate transmission to a Host system when requested. Level data from capacitive encoders is always calculated in thousandths of feet, but is available to Host interfaces in a variety of engineering unit and numerical data formats.

Two styles of capacitive encoders are available: Style A uses a 100:1 reduction gear assembly driven by a worm gear mounted on the drive shaft of the encoder; Style B uses a 96:1 reduction gear assembly driven by spline gears on the drive shaft.

The theoretical maximum level value with a Style A capacitive encoder is 99-11-15 (or 99.999 feet) while the maximum level with a Style B capacitive encoder is 95-11-15 (or 95.999 feet). For both styles, the maximum practical value is 96 feet for compatibility with brush encoder applications. Values from 96.001 to 99.999 feet should be considered error readings or an indication that the encoders are not properly calibrated.

### **Communication Ports**

The APTB3 contains two standard and one optional communication port. Port1 is routed to the Personality Module (PM) header and is used to provide Host Communication interfaces via the various plug-in PMs. This port can operate from 300 baud to 115200 baud.

Port2 provides an RS232 interface to the HHT/Laptop Computer connector (J7). This port normally operates only at 9600 baud, except that it can be switched to 115200 baud for downloading new firmware to the APTB3 microprocessor.

Port3 is an optional communication port that utilizes an SPI UART chip. It is configurable for either Master or Slave operation, depending on application requirements. An on-board RS232 or RS485 interface is available for Port3. This port is also routed to the PM header to accommodate Personality Modules that might require more than one communication port. This port can operate from 1200 to 115200 baud.

The APTB3 also supports bit-bang protocols such as Varec Mark-Space. In most cases, a Personality Module will only utilize either the standard Port1 or the custom bit-bang interface for Host Communication. However, APTB3 does have the ability to operate its standard Port1 simultaneously with bit-bang communication if an application requires this capability.

### **Switch Inputs**

The APTB3 can monitor 4 dry-contact switch inputs in addition to its ability to detect digital inputs via the analog input circuitry. Optical isolators in the switch detection circuitry provide isolation between the board and the field.

### **Relay Outputs**

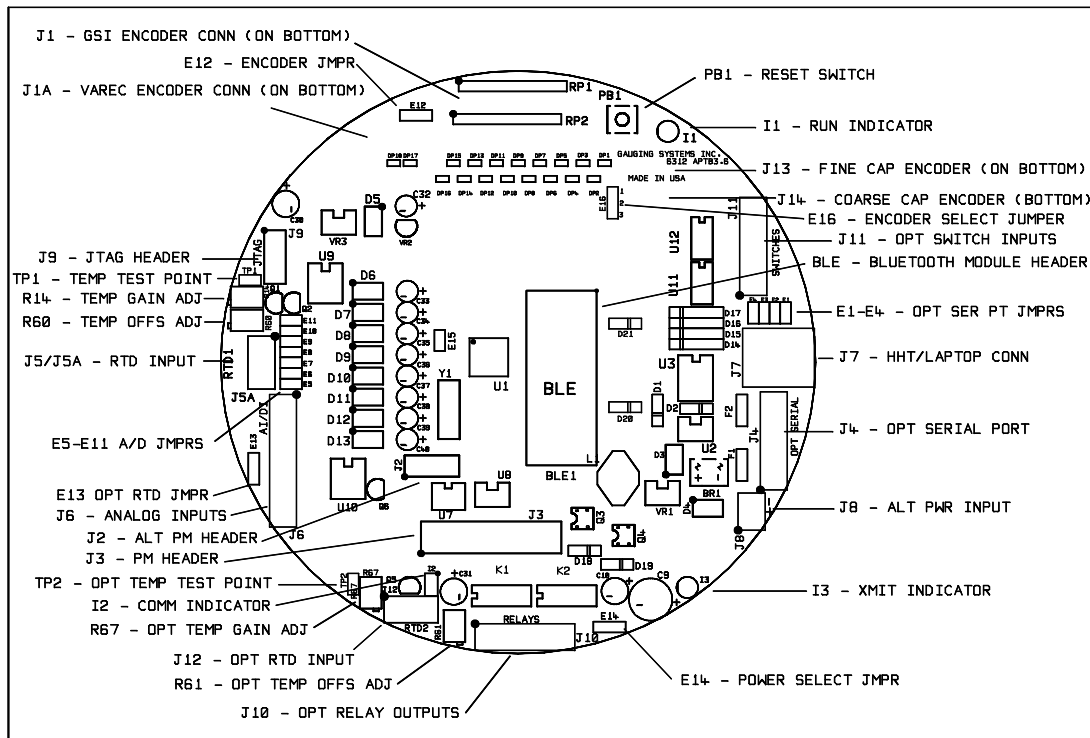
Relay Outputs are an optional APTB3 feature and are only available if the APTB3 is ordered with this feature – it is not a field-installable feature. This option equips the APTB3 with two form-C relay outputs. All 3 terminations (NO, NC, and C) from the relays are routed to the relay output connector. The relay contacts are rated at 1A @ 30VDC or 0.5A @ 120VAC.

The relays can be switched on or off via MODBUS write commands. They will normally be in their de-energized state when the board is reset or powered on. It is also possible to configure the relay outputs for automatic activation based on product level, product temperature, or ambient temperature.

# Physical Board Description

The APTB3 has a number of connectors, jumpers, and other physical features. These are shown in the figure below and described in this section.

**Figure 1 – Physical Board Layout**



## Indicators

The board has three LED indicators.

### I1 – Run Indicator

This indicator blinks at a once-per-second rate during normal operation to show that the board is powered up and running. If the LED is on steady or off, this is an indication that the board has no power or is defective.

This indicator will blink several times in rapid succession for about ½ second when the board is reset or when power is cycled. After this rapid blink sequence, it will start its normal once-per-second blink pattern.

### I2 – Communication Indicator

This indicator contains two LEDs, one on the TX line and one on the RX line of the built-in CPU communication port. These lights will blink whenever there is communication activity in and out of this communication port. This applies to all serial data protocols except those utilizing bit-bang communication techniques such as Mark-Space.

### I3 – Transmit Indicator

This indicator light will illuminate whenever the APTB3 is responding to a host poll. It shows the status of the Drive Enable line which is on during the entire time the APTB3 is transmitting to the host. The duration of its illumination depends on the baud rate and the message length of the transmission

## Reset Switch

PB1 is a momentary-pushbutton reset switch. Pressing this switch will halt the board operation and force it into a reset state. The board will restart when the switch is released.

## Temperature Adjustments

The board has four potentiometers for temperature adjustment. R60 (OFFSET) and R14 (GAIN) are the adjustment potentiometers for the standard RTD connected to J5 or J5A. R61 (OFFSET) and R67 (GAIN) are adjustment potentiometers for the optional RTD connected to J12. Optional potentiometers R61 and R67 are only installed on boards that are equipped with the optional second RTD feature.

Note: Before adjusting any of these potentiometers, ensure that the board has been properly calibrated and that its temperature measurement has been verified with appropriate test resistors as described in the calibration section of this manual.

## Temperature Adjustment Test Points

### *TP1 – Standard RTD Adjustment Test Point*

This test point provides a convenient way to monitor the R14 (GAIN) adjustments with a voltmeter.

### *TP2 – Optional RTD Adjustment Test Point*

This test point provides a convenient way to monitor the R67 (GAIN) adjustments with a voltmeter. This test point is only installed on boards that are equipped with the optional second RTD feature.

## Connectors & Terminal Strips

All connectors and terminal strips on the board are pluggable units to facilitate simple connection and disconnection for installation and replacement.

Note: All 2-piece, pluggable terminal strips are numbered from left to right when viewing the connector directly from the edge of the board nearest the connector.

### *J1 – GSI Encoder Header*

This is a 20-pin dual-in-line keyed header located on the bottom of the board for connection to a GSI encoder. It may also be used to connect Varec encoders to the board by using an encoder adapter connector.

### *J1A – Varec Encoder Header*

This is a 24-pin single-in-line header located on the bottom of the board for direct connection to a Varec encoder. This header is not keyed, so it is important to ensure that the encoder connector is properly plugged into the header. No damage will occur if the connector is reversed, but the board will not read the encoder properly if it is reversed. Pin 1 of J1A is on the side nearest the PB1 reset switch.

### *J2 – Alternate PM Header*

This is a 10-pin dual-in-line header for future applications. It is normally not installed unless it is required for a particular application. If it is installed, it may be located on the top or on the bottom of the board, depending on the application requirements.

### *J3 – Standard PM Header*

This is a 20-pin dual-in-line header for standard GSI PMs. Most PMs are equipped with mating 20-pin connectors, so it is only necessary to properly align the PM connector with this header and plug the two boards together.

Note: Some PM connectors have less than 20 pins. In these cases, care must be taken to ensure that the PM and APTB boards are properly aligned so the PM will be plugged into the correct pins on the J2 header. Use the 4 mounting holes on the PM board as the alignment guide for proper connection of these types of PMs.

#### **J4 – Optional Serial Port Connector**

This is a 6-pin pluggable terminal strip header located on the top of the board for an optional serial communication port. Pin 1 is on the side of the header nearest connector J8. The pin-out is as follows:

1	RS485 S+
2	RS485 S-
3	Ground
4	RS232 TX
5	RS232 RX
6	Fused +5VDC Output

This connector and its associated serial communication port are optional features that are not normally installed on the APTB3 unless required for particular applications.

#### **J5 – Standard RTD Header (bottom)**

This is a 3-pin Molex-type keyed push-on header located on the bottom of the board for connection of a 3-wire RTD. Pin 1 is on the side of the header farthest from the R60 potentiometer. The pin-out is as follows:

1	RTD Input A
2	RTD Input B
3	RTD Input C

If a two-wire RTD is used, it must be terminated on pins 1 and 2 and a jumper must be installed between pins 2 and 3.

#### **J5A – Standard RTD Header (top)**

This is a 3-pin pluggable terminal strip header located on the top of the board for connection of a 3-wire RTD. Pin 1 is on the side of the header nearest the R60 potentiometer. The pin-out is as follows:

1	RTD Input C
2	RTD Input B
3	RTD Input A

If a two-wire RTD is used, it must be terminated on pins 2 & 3 and a jumper must be installed between pins 1 & 2.

Note: An RTD (or calibration resistor) may be connected to either J5 or J5A, but only one of these connectors may be used at a time.

#### **J6 – Analog/Digital Input Header**

This is an 8-pin pluggable terminal strip header located on the top of the board for connection of Analog or Digital inputs. Pin 1 is on the side of the header nearest connector J5A. The pin-out is as follows:

1	Analog/Digital Input 1
2	Analog/Digital Input 2
3	Analog/Digital Input 3
4	Analog/Digital Input 4
5	Analog/Digital Input 5
6	Analog/Digital Input 6
7	Analog/Digital Input 7
8	Ground

Analog inputs may either be 4-20 mA or 0-5V. They must be powered externally and ground-referenced to pin 8.

Digital inputs may either be active or passive. Active inputs must provide a low-level voltage less than 1V and a high-level voltage of at least 2.5V, but no higher than 5V. Voltages between 1V and 2.5V will be indeterminate. Active digital inputs must be powered externally and ground-referenced to pin 8.

Passive inputs must be from open-collector or dry switch contacts connected to the input signal and ground-referenced to pin 8. Excitation voltage for passive inputs is provided on the board.



### **J7 – HHT/Laptop Header**

This is a 6-pin RJ12 modular jack located on the top of the board for serial communication with a Hand-Held terminal or laptop computer. Its pin-out is as follows:

- 1 RS232 TX
- 2 Unused
- 3 RS232 RX
- 4 Unused
- 5 Fused +5V
- 6 Ground

The pin-out arrangement of this connector is standard RJ12 Modular Jack arrangement with pins 1-6 numbered from left-to-right when viewing the end of the connector nearest the edge of the board.

### **J8 – Alternate Power Connector**

This is a 2-pin pluggable terminal strip header located on the top of the board for powering the board directly from a 24VDC power supply. Pin 1 is on the side of the header nearest the PM mounting hole. The pin-out is as follows:

- 1 +24VDC
- 2 Power Supply Ground

The board will operate from +12V to +36VDC; however, the recommended nominal input is +24VDC.

On-board protection allows the board to operate normally even if the power wiring is reversed on this connector; however, for consistency, the connector should be wired as shown here.

### **J9 – JTAG Programming Header**

This is a 10-pin dual in-line header located on the top of the board. Its only function is to provide a means for loading firmware updates into the CPU flash memory. Pin 1 is located on the side of the header nearest capacitor C30. The JTAG ribbon cable must be plugged into the header such that the red marker stripe is on the pin 1 side of the header.

### **J10 – Optional Relay Output Connector**

This is a 6-pin pluggable terminal strip header located on the top of the board to provide optional relay contact outputs. Pin 1 is on the side of the header nearest connector J12. The pin-out is as follows:

- 1 Relay 1 – Normally CLOSED (NC1)
- 2 Relay 1 – COMMON (C1)
- 3 Relay 1 – Normally OPEN (NO1)
- 4 Relay 2 – Normally CLOSED (NC2)
- 5 Relay 2 – COMMON (C2)
- 6 Relay 2 – Normally OPEN (NO2)

This is an optional feature, so the board will not have this header or the relay circuitry unless the board is manufactured with that option.

### **J11 – Optional Switch Input Connector**

This is a 6-pin pluggable terminal strip header located on the top of the board to provide optional switch contact inputs. Pin 1 is on the side of the header nearest connector J7A. The header and switches are only installed on boards that are manufactured with this option. The pin-out is as follows:

- 1 Switch Input 1
- 2 Switch Input 2
- 3 Switch Input 3
- 4 Switch Input 4
- 5 Ground
- 6 Ground

### **J12 – Optional RTD Header**

This is a 3-pin pluggable terminal strip header located on the top of the board for connection of a 3-wire RTD. Pin 1 is on the side of the header farthest from the R61 potentiometer. The pin-out is as follows:

- 1 RTD Input C
- 2 RTD Input B
- 3 RTD Input A

If a two-wire RTD is used, it must be terminated on pins 2 & 3 and a jumper must be installed between pins 1 & 2.

This is an optional feature, so this header and the RTD input circuitry will only be installed on the board if it is manufactured with that option

### **J13 – Fine Capacitive Encoder Header**

This is a 6-pin pluggable header located on the bottom of the board for connection of a capacitive encoder.

### **J14 – Coarse Capacitive Encoder Header**

This is a 6-pin pluggable header located on the bottom of the board for connection of a capacitive encoder.

Note: The fine and coarse capacitive encoders are identical and use identical cables to connect to the APTB3 board, so care must be taken to connect the correct encoder to header J13 or J14. No damage will occur if the encoders are not plugged into the correct headers; however, the level readings will not be correct.

### **Wireless Header (APT3.5 and above only)**

APT3.5 (and above) boards have a header for a wireless serial UART device located next to the CPU chip (U1). A compatible off-the-shelf wireless UART device must be plugged into this header in order to use this feature.

## **Jumpers**

The board has several sets of jumpers for various physical configurations as follows:

### **E1-E4 – Optional Serial Port Jumpers**

These 4 jumpers are located between connectors J7 and J11 and provide the following settings:

- E1 RS485 S+ Pullup on Optional Serial Port
- E2 RS485 S- Pulldown on Optional Serial Port
- E3 RS485 Termination for Optional Serial Port
- E4 Enables RS232 TX Output for Optional Serial Port

These jumpers are all associated with the Optional Serial Port and are normally not installed unless the board is manufactured with that option.

### **E5-E11 – Digit Input Configuration Jumpers**

These 7 jumpers are located behind connector J5A. These jumpers determine whether digital inputs connected to header J6 will be active or passive as follows:

- E5 Sets mode of Digital Input 1 on J6 Pin 1
- E6 Sets mode of Digital Input 2 on J6 Pin 2
- E7 Sets mode of Digital Input 3 on J6 Pin 3
- E8 Sets mode of Digital Input 4 on J6 Pin 4
- E9 Sets mode of Digital Input 5 on J6 Pin 5
- E10 Sets mode of Digital Input 6 on J6 Pin 6
- E11 Sets mode of Digital Input 7 on J6 Pin 7

If a digital input is active (field powered), the corresponding jumper should be omitted. If a digital input is passive (excitation voltage provided by the board), the corresponding jumper should be installed. A mix of active and passive digital inputs can be implemented since each input is individually configurable.

When J6 inputs are used for Analog Inputs, the corresponding jumpers must be omitted.

### ***E12 – Varec Encoder High-Bit Selection Jumper***

This is a 3-position jumper that selects which pin from the J1A Varec Encoder header will be read as the high-order 18<sup>th</sup> bit for high-range encoders. Pin 1 of the jumper header is nearest the edge of the board.

If a jumper is placed between pins 1 and 2, Pin 24 of the header will be selected for the high-bit 18. If a jumper is placed between pins 2 and 3, Pin 22 of the header will be selected for the high-bit 18. This jumper may be left open for normal range encoders.

### ***E13 – Analog Input 7 Selection Jumper***

This is a 3-position jumper that selects the appropriate configuration for Analog/Digital Input 7 on Pin 7 of connector J6. Pin 1 of the jumper header is nearest Pin 8 of J6.

For a normal Analog or Digital input signal on Pin 7 of J6, a jumper plug should be placed between pins 1 and 2.

If the board is equipped for an optional second RTD on connector J12, a jumper plug should be placed between pins 2 and 3. In this case, it will not be possible to use Pin 7 of J6 for an Analog or Digital input.

The appropriate jumper is normally soldered in place during manufacture in which case it is not necessary for the user to be concerned about this jumper. If the board is equipped with a jumper header, be sure that a jumper plug is installed in the appropriate position for your application.

### ***E14 – Power Selection Jumper***

This is a 3-position jumper that selects the power source for the board. Pin 1 is nearest capacitor C9.

Place a jumper plug between pins 1 and 2 if the board is powered directly from a power supply via J8. Place a jumper plug between pins 2 and 3 if the board is to be powered from a PM.

### ***E15 – Analog/Digital Ground Jumper***

This jumper provides a common connection point for the analog and digital grounds on the APTB3 board. This jumper is soldered in place during the manufacture of the board and must never be removed.

### ***E16 – Encoder Select Jumper***

This is a 3-position jumper that enables either a brush encoder or a capacitive encoder to be used with the APTB3. To use a capacitive encoder, a jumper must be placed between pins 1 and 2. To use a brush encoder, a jumper must be placed between pins 2 and 3.

## Hand-Held Terminal User's Guide

Connector J7 of the APTB3 is an RJ12 modular jack that supports either a GSI Hand-Held Terminal (HHT), as shown in Figure 2, or a computer serial comm port. In either case, communication with the APTB3 via this connector is always at 9600-N-8-1.

Either a GSI-DB9-CONFIG or a GSI-USB-CONFIG cable (depending on the type of serial port(s) available on the computer) must be used in order to connect a computer to J7. When using one of these cables, the APTB3 board will support the GSI Test and GSI Config programs. Refer to the GSI Config section of this manual for information on using the GSI Config program to configure an APTB3.

The APTB3 will automatically detect whether the external device plugged into the RJ12 connector is an HHT or a computer running GSI Config or GSI Test based on the data streams that it receives from the HHT or computer.

Note that there are two types of GSI HHT devices: an earlier model QTerm-J10 manufactured by QSI Corp (Beijer) and a newer model GSI-1585 manufactured by GSI. Both work the same, but there is a slight difference in the way the communication parameters of the HHT are changed. Also the GSI version uses a white on blue LCD display rather than the black on green display of the QTerm. The GSI version also displays a startup screen when powered up to show its firmware version.

It is also possible to use a virtual hand-held terminal on an iPhone or iPad device with the GSI BlueHHT app. The APTB3 must also have a wireless UART device to communicate with the app.

**Figures 2 & 3– GSI Hand-Held Terminal (HHT) and GSI BlueHHT App**



### Command Summary

The following table is a summary of all currently assigned HHT commands and the appropriate keys for initiating those commands. The commands are grouped into the following categories: Normal Operation, Configuration, Calibration, and Diagnostics.

KEY	SHIFT	FUNCTION	MODE
A-F	Y	Set Address	Configuration
A-F	N	English/Metric Toggle	Diagnostic
B-G	Y	Set Baud Rate	Configuration
B-G	N	Pause/Go or Raw/Valid Enc	Diagnostic
C-H	Y	Set Parity & Framing	Configuration
C-H	N	Cap Encoder Level Calibration	Calibration
D-I	Y	Set Protocol	Configuration
D-I	N	RX/TX Data Monitor Toggle	Diagnostic
E-J	Y	Encoder Configuration	Configuration
E-J	N	Set Analog Input Offset	Calibration
K-P	Y	Temperature Config	Configuration
K-P	N	Analog Input Calibration	Calibration
L-Q	Y	APT3 MODBUS Config	Configuration
L-Q	N	Analog I/O Configuration	Configuration
M-R	Y	MACB MODBUS Config	Configuration
M-R	N	Analog Output Calibration	Calibration
N-S	Y	Protocol Configurations	Configuration
N-S	N	Set Bus Drive Delay	Configuration
O-T	Y	Set Host Response Delay	Configuration
O-T	N	Set Host Timeout Delay	Configuration
U-X	Y	Temperature Calibration	Calibration
U-X	N	<b>DO NOT USE – RESERVED</b>	Firmware Reload
V-Y	Y	View Encoder Data	Diagnostic
V-Y	N	<b>DO NOT USE – RESERVED</b>	Firmware Reload
W-Z	Y	View Analog Inputs	Diagnostic
W-Z	N	Digital Output Configuration	Configuration
?-/	Y	Monitor Host Comm	Diagnostic
?-/	N	Unused at this time	
--+	Y	View Ambient Temps	Diagnostic
--+	N	Unused at this time	
(-#	Y	Level Offset Correction	Calibration
(-#	N	Show Startup Screen	Normal
)-*	Y	Temperature Offset Correction	Calibration
)-*	N	Show Config Screen	Normal
SP-ENT	N	Enter Command	Normal

A “Y” in the SHIFT column means that the Shift key must be pressed and released prior to pressing the indicated key. An “N” in the SHIFT column indicates that the Shift key must not be pressed before the indicated key. The HHT uses the cursor to indicate the shift mode: an underscore cursor means that shift is off while a block cursor indicates that shift is on. The BlueHHT app displays a “Shift On” or “Shift Off” message.

Note: some keys are used as "toggle" keys in conjunction with certain HHT commands to perform special actions within those commands. In such cases, the normal actions described for those keys in the above table do not apply, and some keys may have more than one such function. Refer to the HHT command description for more information on these special toggle functions.

These "toggle" keys include the following (without pressing the shift key):

A/F	Analog output enable with the “Set Protocol” command
A/F	English/metric data toggle for Normal Data Display
B/G	Go/pause toggle with the “Monitor Host Comm” command
B/G	Analog output disable with the “Set Protocol” command
B/G	Toggle between Raw and Valid capacitance encoder data with the “View Encoder Data” command
C/H	Low scale analog output with the “Set Protocol” command
D/I	Host/transmitter toggle with the “Monitor Host Comm” command
D/I	Mid-scale analog output with the “Set Protocol” command
E/J	Full scale analog output with the “Set Protocol” command

Note: the 4 arrow keys on the HHT keypad can also be used to perform some of the configuration functions as follows:

- Up Arrow – same function as Shift-A/F (Set Address)
- Down Arrow – same function as Shift-B/G (Set Baud Rate)
- Right Arrow – same function as Shift-C/H (Set Parity)
- Left Arrow – same function as Shift-D/I (Set Protocol)

## Terminal Setup

The HHT is powered from the RJ12 connector and should show a visible cursor on its screen as soon as it is connected to the APTB3 board. If this cursor does not appear, there is probably a problem with the board, the HHT, or its cable. The QTerm HHT will initially show a blank screen (except for the cursor) while the GSI-1585 HHT will show a startup display with the firmware version of the device.

If the cursor or startup screen does appear, press any key on the HHT to initiate communication with the APTB3 board. If the HHT is properly configured, a readable startup display will appear. After a few seconds, the standard HHT data display will appear and will be automatically updated every few seconds.

If a readable display does not appear, check the HHT to be sure that it has the proper baud rate. If the baud rate is correct, but no readable display appears, there is likely a problem with the APTB3 board, the HHT, or the HHT cable.

To check the baud rate, unplug the HHT momentarily, and then plug it back into the RJ12 connector while holding down any key. This will cause the HHT to startup in its configuration mode. This will allow you to change the Contrast and Baud Rate. The HHT settings will be retained in non-volatile memory, so it should not be necessary to adjust them again unless they have been changed to use the device in another application that requires different settings.

The exact procedure depends on which type of HHT you are using:

### **QTerm-J10 Configuration**

For the purpose of this HHT Setup mode, the ‘1’ Key is **UP**, the ‘2’ Key is **DOWN**, and the ‘3’ Key is **ENTER**.

When the HHT starts up in configuration mode, its firmware version number will appear briefly, followed by the word CONTRAST. You may use the **UP** or **DOWN** keys to adjust the contrast. When the contrast is satisfactory, press **ENTER**. You may then adjust the baud rate, if necessary, with the **UP** or **DOWN** keys. When the baud rate is at 9600, press **ENTER**. You may then adjust the HHT communication format, if necessary, with the **UP** or **DOWN** keys. When the format is at 8n1, press **ENTER**. The HHT will then switch to normal operating mode.

### **GSI-1585 Configuration**

The **F1-F4** keys are used to step the Baud Rate, Parity, Framing, and Contrast settings through their options. The **F5** key toggles the direction of the F1-F4 keys (Up or Down).

Cycle through the F1-F4 keys to change the various settings to the desired values, then press any key other than F1-F5 to save those settings and exit the configuration mode.

### **BlueHHT App Configuration**

The BlueHHT app does not require any configuration settings. All wireless UART devices used with APTB3 boards are preset to 9600 baud and must not be changed. The iOS Settings app can be used to change the keypad background color and the key click sound if you wish. The BlueHHT User Guide (included with the app) explains how to connect to a wireless UART device and verify that you are communicating with the proper APTB3 card.

### **Normal Operation**

When an HHT is plugged into the J7 header, it is usually necessary to press a key (any key) on the HHT keypad to inform the APTB3 that the HHT is connected. This is necessary because the APTB3 will time out its HHT updates after a period of time.

The HHT will present a Startup Message for a few seconds, and then switch to its normal data update screen. At this time, other keys can be pressed to activate the various modes of HHT operation.

### **HHT Startup Message**

The HHT startup message is similar to the following:

```
Gauging Systems Inc.  
APT3 XMTR 08.03.03  
ADDR=0123 PROT=GA  
SPD=4800 PAR=N8
```

The information after XMTR in the startup message is the APTB3 revision in YY.MM.DD format. The startup display also contains the following information:

ADDR	Device Address
PROT	Host Communication Protocol
	GA GSI ASCII
	MR MODBUS-RTU
	MT MODBUS-TCP
	MS Varec Mark-Space
	TP GPE TP600
	TW L&J Tankway
SPD	Baud Rate for Host Communication
PAR	Parity & Framing for Host Communication

This startup message will only appear for a few seconds and then will be replaced with the standard data display message. Press the “( #” key to see the Startup Message again. When the Startup Message is requested in this manner, it will remain on the screen until another key is pressed.

If Analog Outputs are enabled, the characters AO will appear after the host communication protocol (e.g. GA-AO).

### **APT3 Configuration Display**

The APTB3 Configuration Display is only shown when specifically requested. Press the “) \*” key to view this display which is similar to the following:

```
ENCDR=0123 TEMP=0123  
APT3=0123 LGCY=0123  
PROT=GA CONF=0123  
RSDLY=123 TIMR=123
```

The information in this message is as follows:

ENCDR        Encoder Configuration  
TEMP         Temperature Configuration  
PROT         Host Communication Protocol  
CONF         Configuration of the Host Communication Protocol  
RSDLY        Host Response Delay  
TIMR         Host Timeout Interval

Refer to the APTB3 Configuration section of this HHT User Guide for details on interpreting the data on this display.

If Analog Outputs are enabled, the characters AO will appear after the host communication protocol (e.g. GA-AO). If analog output calibration is in progress, the Analog Output indicator will appear as AL (low scale calibration), AH (high or full scale calibration, or AM (mid-scale range check).

### **Normal Data Display**

The Normal HHT Data Display is similar to the following:

```
                  Level          Temp  
                  xxx.xxx f tttttt Prd  
                  yyy-yy-yy aaaaaa Amb  
                  Stat:zzz Dig:dd ssss
```

The information in the data display is as follows on the following page.

xxx.xxx        Level in decimal format (feet or metric)  
f                Level is in feet (m = level is in meters)  
yyy-yy-yy      Level in FT-IN-16 format  
ttttt          Product temperature in °F or °C  
aaaaaa         Ambient temperature in °F  
zzz             APTB3 Status  
dd              State of the 7 analog/digital inputs  
ssss            State of the 4 APTB3 switch inputs

The APTB3 Status Indication may be one of the following:

ENC    Indicates an encoder error  
TMP    Indicates a temperature error  
OK     Indicates normal operation

The State of the 7 Analog/Digital inputs connected to J6 are shown in the low-order 7 data bits of the dd parameter, displayed as 2 hex characters (00 to 7F). Data bits (0-6) correspond to Analog/Digital inputs (1-7) respectively. If the value read by the APTB3 from these inputs is greater than 50% of the ADC range, the input will be considered to be "ON" and its corresponding bit will be set to "1". If the value for a given input is less than 50% of scale, its bit will be set to "0". This not only gives an ON/OFF status for Digital Inputs; it also gives a LO/HI range indication for inputs that are configured as Analog Inputs.

The states of the 4 optically-isolated switch inputs are shown in the ssss parameter. From left-to-right, these 4 characters represent the status of switch inputs 1-4 respectively. If the switch is OPEN, a number (1-4) will be displayed in the appropriate position to indicate that that switch is OPEN (which is considered to be the Alarm state). If the switch is CLOSED, an underscore character ( \_ ) will be displayed in the corresponding position for that switch to indicate that it is in the Normal state.

Fractional level data is always shown in FT-IN-16 format and ambient temperature is always shown in °F. However, it is possible to display the product level and temperature in either decimal feet and °F or in meters and °C. Press the A/F key on the HHT without pressing the shift key to toggle the product data between English and metric units.

When the level data is shown in English units, the level data will be followed by an "f" to indicate that the level is in decimal feet. When this is the case, the temperature data will be in °F.



When the level data is shown in metric units, the level data will be followed by an "m" to indicate that the level is in meters. When this is the case, the temperature data will be in °C.

An exclamation point (!) will appear in front of the decimal value for level when there is a level error. The level value will also be shown as 99.999 feet and 99-11-15 in this case. An exclamation point (!) will appear in front of the product temperature when there is a temperature error.

## Level Calibration

When brush encoders and code disks are used, level calibration must be performed manually as described in the GSI 2000 Transmitter Manual.

When capacitive encoders are used, level is calibrated with a hand held terminal or the Blue HHT app. Use the following procedure to calibrate capacitive encoders:

1. Obtain an accurate hand line reading of the product level in your tank.
2. Adjust the float gauge if necessary so the sight reading on the float gauge matches the hand line.
3. Press the **H** Key on the HHT to enter the Cap Encoder Calibration Mode
4. Enter the hand line reading in thousandths of feet or as ft-in-16 fractional data. Decimal entries must be between 0 and 99.999. Fractional entries must be between 0 and 95-11-15.

When your entry is complete, the APTB3 will auto-zero and align the capacitive encoders and store your hand-line entry as the current reference point in non-volatile memory. This process takes about 5 seconds and when it is complete, your new reference value will appear as the product level on the normal data display.

Note: The product level and the transmitter shaft position must not change while level calibration is in progress. If it does, the capacitive encoders may not be properly zeroed and aligned at the end of the process. If the level shown on the hand held terminal at the end of the 5 second alignment process is not correct, it will be necessary to repeat the above procedure.

Note: If your hand line was accurate, the level reading should exactly match the "zero reference" value for your tank when the float reaches the bottom of its travel. However, if the level reading is less than or greater than your "zero" reference when the float reaches the bottom (or if the level rolls over from 0 to 99.999 feet with a Style A encoder or from 0 to 95.999 with a Style B encoder) that is an indication that your hand line reading might not have been accurate when you last calibrated the encoders. In this case, take a new hand line at its current position and repeat the calibration procedure.

Note: The following rules apply when entering a hand line reading using this procedure:

1. Hand lines in even feet can be entered as a one or two digit whole number followed by the Enter key.
2. Decimal feet entries that are not whole feet must use a decimal point to separate feet and thousandths: such as 12.145
3. Fractional entries must use dashes to separate feet, inches, and sixteenths: such as 12-05-13
4. When entering decimal feet entries, the partial feet value may be 1, 2 or 3 digits in length: such as 12.140 or 12.12
5. When entering fractional levels, the inches and sixteenths values MUST be two digits each. Use leading zeros for values less than 10: such as 12-05-04
6. For hand lines under 1 foot, the entry may start with a decimal point or a dash. For example: 0.125, .125, 0-01-08, and -01-08 are all valid entries.
7. This HHT function will terminate automatically and process your entry after entering 6 characters in decimal mode or 8 characters in fractional mode. If your entry is less than that, you must tap the Enter key to terminate your entry.
8. The HHT function only performs limited error checking on your entry. If you enter an invalid value (such as inches greater than 11, etc.), the HHT function might calculate an incorrect value. Be sure to verify your entry after the encoders reset (which takes about 5 seconds). If the reading is incorrect, repeat this calibration process.

## Temperature Calibration

The HHT provides a simple means for calibrating the APTB3 temperature input. You will need a set of precision resistors to perform the calibration. The recommended (and simplest) method is to use the GSI 6315 Temperature Calibration Unit (TCU). NOTE: This calibration procedure only applies to the primary RTD input on connectors J5 or J5A.

The calibration procedure is as follows:

1. Disconnect the RTD input from connector J5 or J5A
2. Press the Shift Key on the HHT followed by the U key to enter the Temperature Calibration Mode
3. Connect the TCU to the APTB3 in place of the RTD and follow the prompts on the HHT to select the 75 ohm (ZERO) and 175 ohm (SPAN) calibration resistors of the TCU at the appropriate time. (Be sure to wait approximately 15 seconds after selecting the appropriate resistor value before pressing the "1" key to allow for adequate ADC settling time.) **Note:** if the APTB3 is configured for a high temperature range (-82 to +602°F), you will be prompted to use a 218 ohm SPAN resistor rather than a 175 ohm resistor.
4. After completing the procedure, the HHT will show the Zero and Span factors that it computed. These values should be approximately 8000 - 12000 for Zero and 45000 - 58000 for Scale.
5. If the Zero and Scale factors are in the correct general range, the temperature measurement circuit is operating properly and is now calibrated for Zero and Span.
6. Select the 100 ohm (OFFSET) calibration resistor of the TCU. The Data Display screen should show a temperature of 32F if the board is configured for a platinum RTD or 77°F if the board is configured for a copper RTD.
7. Adjust R60 if necessary, to obtain the exact correct readings with the 100 ohm resistor. This sets the Offset of the temperature measurement.
8. Select the 125 ohm (GAIN) calibration resistor of the TCU. The Data Display screen should show a temperature of 148°F if the board is configured for a platinum RTD or 195°F if the board is configured for a copper RTD.
9. Adjust R14 if necessary (if the board is equipped with R14), to obtain the exact correct reading with the 125 ohm resistor selection. This sets the Gain of the temperature measurement.
10. If either the Offset or Gain required more than a 5 degree adjustment with the 100 ohm and 125 ohm resistors, repeat Steps 2 through 9 to fine tune the Zero and Span settings and recheck the Offset and Gain settings.
11. The board is now calibrated. Remove the TCU and reconnect the RTD.

This procedure calibrates the board to ideal precision resistance inputs. Some minor Gain adjustment to R14 may be needed to balance the temperature measurement with the actual RTD. The procedure for making this Balancing adjustment is as follows:

1. Measure the RTD resistance with an ohmmeter at the connector that will be plugged into the APTB3 (this measurement must be made while the RTD is UNPLUGGED from the board).
2. Reference an RTD resistance table for the type of RTD that you are using (platinum or copper) and determine the proper temperature for the resistance that you measured in Step 1.
3. Connect the RTD to the APTB3 and observe the temperature reading on the HHT.
4. Adjust R14 if necessary, to obtain the correct temperature reading. This Balancing adjustment should not require more than a 5-degree adjustment. If the error is more than 5 degrees, repeat this Balancing procedure to ensure that your resistance measurements and RTD table lookup is correct.

## Analog Input Calibration

The HHT provides a simple means for calibrating the APTB3 analog inputs. You will need a precision voltage or current source to simulate the low and high range values of your analog inputs.

This following procedure must be repeated for every analog input (up to 7) that is terminated on connector J6:

1. Disconnect the analog input from connector J6 (Pins 1-7 for analog inputs 1-7 respectively).
2. Press the P Key on the HHT to enter the Analog Calibration Mode
3. When prompted, enter a number from 1-7 to specify which analog input is to be calibrated.
4. Follow the remaining prompts to connect a low scale analog value (e.g. 4 mA for a 4-20 mA signal or 0V for a 0-5 V signal) then a full scale analog value (e.g. 20 mA for a 4-20 mA signal or 5V for a 0-5V signal). Be sure to wait approximately 15 seconds after connecting the low or full scale analog input before pressing the "1" key to allow for adequate ADC settling time.
5. After completing the procedure, the HHT will show the Zero and Span factors that it computed. These values should be approximately 8000 - 12000 for Zero and 45000 - 58000 for Scale.
6. If the Zero and Scale factors are in the correct general range, the analog measurement circuit is operating properly and is now calibrated for Zero and Span.
7. Connect a mid-scale value to the analog input (e.g. 16 mA for a 4-20 mA signal or 2.5V for a 0-5V signal). The Data Display screen should show a value that is half-way between the low and high engineering units for the selected analog input.
8. If the mid-scale reading is not correct, an offset value can be entered to adjust for the error per the following procedure. Once that action is complete (if necessary), the analog channel is fully calibrated.

## Analog Input Calibration for a Secondary RTD

The calibration procedure for a secondary RTD connected to AIN7 is essentially as described above for 4-20 mA analog inputs; however, instead of connecting a low scale and full scale analog value as described in Step 4, use a precision 75 ohm resistor for low scale and a 175 ohm resistor (or a 218 ohm resistor for a high temperature range) for full scale.

Use a precision 100 ohm resistor in Step 7 instead of a mid-range analog input to verify if the temperature reading is correct. Adjust potentiometers R61 (offset) and R67 (gain) as needed to fine tune the temperature reading.

## Analog Input Offset

The HHT provides a simple means for entering an offset value for each analog input (maximum of 7) that is terminated on connector J6. The offset is automatically reset to 0 whenever an analog input is defined with the Q key or calibrated with the P key options.

If it is determined that an offset must be entered after performing an analog channel calibration, press the J key to enter the Analog Offset mode then proceed as follows:

1. When prompted, enter a number from 1-7 to specify the analog input for which an offset is to be entered.
2. Follow the next prompt to enter an offset value.

The following guidelines must be followed when entering the offset value:

- The offset must be an engineering unit value consistent in decimal format (e.g. -0.025 to specify a negative .025 feet adjustment if the analog input is calibrated for decimal feet)
- A maximum of 9 characters can be entered
- The first character may be a + or - character to indicate that the value is positive or negative. If no sign is entered, the number will be assumed to be positive.
- A period (.) may be entered in any of the 9 character positions to indicate the location of a decimal point. Note that a period is not required and no more than one period may be entered. If no period is entered, the number will be treated as a whole number.
- Other than the sign and period characters, all other characters must be numerical digits from 0 through 9.
- If your numbers require less than 9 characters, merely press the Space/Enter key after you have entered all necessary characters to advance the HHT to the next step.
- Entering any invalid character will cause the HHT to immediately exit the Analog Offset mode

## APT3 Configuration

Most standard APT3 operating parameters can be entered via the HHT; however, most optional APT3 features are not supported by the HHT and must be configured with the GSI Config software program. This section describes those standard APT3 features that can be configured via the HHT.

Most configuration commands require pressing the **Shift** Key followed by an **Alphabetic** Key to enter the desired APT3 Configuration Mode. (Note: you must press and release the **Shift** Key before pressing the **Alphabetic** Key.)

Note that all communication configurations discussed in this section (protocol, baud rate, etc.) only apply to the Host Communication port of the APT3 (Port 1). Port 3 configurations must be performed with GSI Config.

The following APT3 Configuration Modes are available:

Shift followed by:

A	Address
B	Baud Rate
C	Parity & Framing
D	Protocol
E	Encoder Configuration
K	Temperature Configuration
L	APT3 MODBUS Configuration
M	Legacy APTB/MACB MODBUS Configuration
N	Misc. Protocol Configurations
O	Host Response Delay
(	Level Offset
)	Temperature Offset

Commands not requiring the shift key:

Q	Analog Configuration
S	Bus Drive Delay
T	Host Timeout Interval
U	Digital Output Configuration

Whenever one of these configuration modes is selected, the current status of that feature will be displayed. The configuration mode may be exited without changes by pressing the Space/Enter key or any other key that is not valid for that mode. The valid keys that may be used to enter new information depends on the particular mode as described below.

As keys are pressed to enter new information, be sure to wait until the display echoes each key press before pressing the next key. Each mode allows from 1 to 4 characters to be entered – when the maximum number of characters is entered, the HHT will automatically exit that configuration mode and process the entry. In this case, it is not necessary to press the Enter key. However, if you enter less than the maximum allowed number of characters, you must press the Enter key to exit the current configuration mode and process your entry.

### **Shift - A – Address Configuration**

To change the Address of the board, enter a 1 to 4 digit number. Pressing the Space/Enter key after entering 1 to 3 digits will exit the Address mode and change the board address to the number that has been entered.

It is the user's responsibility to enter an address that is valid for the particular protocol mode that is being utilized. Examples of valid address ranges are:

MODBUS	1-247
GSI ASCII	0-999
Varec Mark-Space	0-999
GPE	0-99
L&J Tankway	0-127

Note: It is possible to enter an invalid address that is outside these ranges, but unpredictable results will likely occur, so be careful to enter a proper value!

Note: The APTB3 supports two special addresses for **test purposes only**. If an address of 254 is entered for MODBUS-RTU or MODBUS-TCP protocols, the board will respond to any valid MODBUS address (1-247). If an address of 1023 is entered for any other protocol, the board will respond to any valid address for that protocol. **These special addresses should only be used for testing purposes and ONLY when no other board is connected to the host communication BUS.**

### Shift - B – Baud Rate Configuration

To change the Baud Rate, enter a number from 0 to 9:

Value	Mark-Space	Other Protocols
0	HI SPD 20ms Dly	300 Baud
1	LO SPD 20ms Dly	600 Baud
2	HI SPD 30ms Dly	1200 Baud
3	LO SPD 30ms Dly	2400 Baud
4	HI SPD 40ms Dly	4800 Baud
5	LO SPD 40ms Dly	9600 Baud
6	HI SPD 50ms Dly	19200 Baud
7	LO SPD 50ms Dly	38400 Baud
8	HI SPD 60ms Dly	57600 Baud
9	LO SPD 60ms Dly	115200 Baud

### Shift - C – Parity & Framing Configuration

To change the Parity and Framing, enter a number from 0 to 8:

Value	Setting
0	NONE – 8
1	ODD – 8
2	ODD – 7
3	EVEN – 8
4	EVEN – 7
5	MARK – 8
6	MARK – 7
7	SPACE – 8
8	SPACE – 7

Note: Data bytes must be a total of 8 or 9 characters in length, so there is no provision for NONE-7. STOP bits are fixed at 1 for all protocols, baud rates, and parity/framing settings and cannot be changed.

### Shift - D – Protocol Configuration

This command is used to change the Host Communication Protocol and to enable or disable Analog Outputs.

When the current protocol/analog output configuration is shown, the existing protocol will be shown as a number from 0-5 which will be followed by the characters AO if analog outputs are also enabled.

To change the Host Communication Protocol, enter a number from 0 to 5:

Value	Setting
0	MODBUS-RTU (MR)
1	MODBUS-TCP (MT)
2	GSI ASCII (GA)
3	Mark-Space (MS)
4	GPE TP600 (TP)
5	Tankway (TW)

To enable Analog Outputs, press the **A/F** key. To disable Analog Outputs, press the **B/G** key. In either of these cases, a message indicating that Analog Outputs are being enabled or disabled will appear briefly before the function exits. If it is necessary to change the host communication protocol and enable or disable analog outputs, you must use this function twice: once to change the protocol and once to enable or disable analog outputs.

This function can also be used to set the Analog Output Calibration Mode. First enable Analog Outputs by pressing the **A/F** key as described above. Then use the **Shift-D** command again and press the **C/H** key to set the Analog Outputs to their low-scale value, the **D/I** key to set the Analog Outputs to their mid-scale value, or the **E/J** key to set the Analog Outputs to their full-scale value. When calibration is complete, be sure to use the **Shift-D** command again and press the **A/F** key once again to return the Analog Outputs to normal operation.

While in calibration mode, the Analog Output indicator on the protocol display will be **AL** for Analog Output Low-Scale, **AM** for Analog Output Mid-scale, or **AH** for Analog Output High-Scale.

The user must ensure that the Personality Module installed on the APTB3 provides the required electrical interface for the selected protocol or analog output capability. If the Personality Module is only equipped with analog outputs, the communication protocol can be any number from 0-5. However, if the Personality Module is only equipped with a communication interface (no analog outputs), the analog outputs should always be disabled.

Note: MODBUS-TCP protocol should only be selected when using an Ethernet Personality Module that is equipped with an XPORT-STD or XPORT-AR device. Select the MODBUS-RTU protocol if the Ethernet Personality Module is equipped with an XPORT-M device. For all Ethernet Personality Modules, the Baud Rate and Parity settings should be 115200-N8. This **must** match the configuration setting of the XPORT device on the Ethernet Personality Module which is typically set to 115200-N8.

### **Shift - E – Encoder Configuration**

To set the Encoder configuration, enter a 2-digit number. Both digits must be entered for the new value to be accepted. The 2 digits in the number (from left to right) have the following meaning:

<b>1<sup>st</sup> Digit</b>	<b>Encoder Data Format</b>
0	English Fractional (GSI or Varec)
1	English Decimal (GSI or Varec)
2	GSI Metric or Varec Metric <20m
3	Varec Metric >20m
4	Use AIN1 for Level rather than an encoder
5	Capacitive Encoders Style A (with worm gear on the drive shaft)
6	Capacitive Encoders Style B (with spline gears on the drive shaft)

<b>2<sup>nd</sup> Digit</b>	<b>Encoder Type</b>
0	GSI Encoder – Forward Reading (AIN1 = dec ft)
1	GSI Encoder – Reverse Reading (AIN1 = inches)
2	Varec Encoder – Forward Reading (AIN1 = 16ths)
3	Varec Encoder – Reverse Reading (AIN1 = meters)

The first digit can be either 0 or 1 when using a GSI English encoder because the same physical encoder is used for both fractional and decimal readings. When AIN1 is used for level measurement rather than an encoder, the second digit will specify the engineering units for interpreting the data read from AIN1.

Enter 50 for the first and second digits for Forward Reading Style A Capacitive Encoders or 51 for Reverse Reading Style A Capacitive Encoders. Enter 60 for the first and second digits for Forward Reading Style B Capacitive Encoders or 61 for Reverse Reading Style B Capacitive Encoders. Capacitive Encoders are always read as English Decimal (in thousandths of feet). The APTB3 automatically converts the native capacitive encoder readings to fractional and metric units.

Note: “Forward Reading” is defined as the float going down (level decreasing) when the encoder shaft rotates clockwise (as viewed from the front of visual readout on the float gauge). “Reverse Reading” is defined as the float going up (level increasing) when the encoder shaft rotates counter-clockwise (as viewed from the front of the visual readout on the float gauge). The GSI 2570 float gauge is a Forward Reading device.

### **Shift - K – Product Temperature Configuration**

To set the Temperature configuration, enter a 3-digit number. All 3 digits must be entered for the new value to be accepted. The 3 digits in the number (from left to right) have the following meaning:

<b>1<sup>st</sup> Digit</b>	<b>Temperature Range</b>
0	Standard – -82 to +388 °F
1	Extended - -82 to +602 °F
<b>2<sup>nd</sup> Digit</b>	<b>Temperature Source</b>
0	Platinum RTD – 100 ohm at 32°F
1	Copper RTD – 100 ohm at 77°F
2	Use AIN2 for temperature rather than an RTD
3	Use an MTG gauge for temperature
<b>3<sup>rd</sup> Digit</b>	<b>Temperature Enable</b>
0	RTD Connected to J5 or J5A (AIN2 = °F)
1	No Temperature (AIN2 = °C)

As indicated above, analog input AIN2 can be used for Product Temperature measurement rather than an RTD. In this case, the third digit will specify the engineering units for interpreting the data read from AIN2.

Product Temperature can also be determined by reading individual spot temperatures from an MTG gauge. In this case, the APTB3 will compute a volume-weighted average temperature from the wetted sensors. It is the user's responsibility to ensure that the APTB3 is properly configured to obtain data from an MTG gauge via the optional Port 3 communication port when the MTG setting is used for product temperature.

Note that the RTD configuration settings only apply to Product Temperature and the primary RTD connection at J5/J5A. These configuration settings do not apply to a secondary RTD connected to the AIN7 input via J12.

### **Shift - L – Standard APTB3 MODBUS Configuration**

To set the MODBUS Register Configurations for the Standard APTB3 Register Map (Starting at Register 0); enter a 4-digit number. All 4 digits must be entered for the new value to be accepted. The 4 digits in the number (from left to right) have the following meaning:

<b>1<sup>st</sup> Digit</b>	<b>Temperature Data Format</b>
0	Integer – No Scaling
1	Integer – 1/10 Scaling
2	Integer – 1/100 Scaling
3	Integer – 1/1000 Scaling
4	Floating Point – No Scaling
<b>2<sup>nd</sup> Digit</b>	<b>Temperature Units</b>
0	°F
1	°C
<b>3<sup>rd</sup> Digit</b>	<b>Level Data Format</b>
0	Long Integer – No Scaling
1	Long Integer – 1/10 Scaling
2	Long Integer – 1/100 Scaling
3	Long Integer – 1/1000 Scaling
4	Floating Point – No Scaling
<b>4<sup>th</sup> Digit</b>	<b>Level Data Format</b>
0	16ths
1	mm
2	feet
3	inches

### **Shift - M – Legacy APTB/MACB MODBUS Configuration**

The APTB3 simultaneously supports the Standard APTB3 MODBUS Register Map starting at MODBUS Register 0 and the Legacy APTB/MACB Register Map used by older GSI products starting at MODBUS Register 100. This Shift - M mode allows the format of those Legacy APTB/MACB MODBUS registers to be configured.

To set the MODBUS Register Configurations for the Legacy APTB/MACB Register Map (Starting at Register 100); enter a 4-digit number. All 4 digits must be entered for the new value to be accepted. The 4 digits in the number (from left to right) have the following meaning:

<b>1<sup>st</sup> Digit</b>	<b>Temperature Data Format</b>
0	Integer – No Scaling
1	Integer – x1.024 w/+100° offset
2	Integer – x1.024 w/-100° offset
<b>2<sup>nd</sup> Digit</b>	<b>Temperature Units</b>
0	°F
1	°C
<b>3<sup>rd</sup> Digit</b>	<b>No Assignment</b>
0	(only valid value)
<b>4<sup>th</sup> Digit</b>	<b>Level Units</b>
0	16ths
1	mm

### **Shift - N – Misc. Protocol Configurations**

Whenever it is necessary to use any communication protocol other than MODBUS, various Protocol Configuration parameters must be specified for that protocol with this **Shift-N** command.

It is only necessary to set a Protocol Configuration for MODBUS if you want to enable MODBUS Pass-Through capability. Note that MODBUS Pass-Through capability only applies if APTB3 Port 3 is used to communicate with a slave device (such as a GSI MTG gauge).

Enter a 4-digit number to set the protocol configuration. All 4 digits are required for the new value to be accepted. The 4 digits in the number (from left to right) have the following meaning depending on the particular protocol:

#### **Modbus-RTU or MODBUS-TCP Protocol**

<b>1<sup>st</sup> Digit</b>	<b>No Assignment</b>
0	Only valid value
<b>2<sup>nd</sup> Digit</b>	<b>No Assignment</b>
0	Only valid value
<b>3<sup>rd</sup> Digit</b>	<b>No Assignment</b>
0	Only valid value
<b>4<sup>th</sup> Digit</b>	<b>Pass-Through Control</b>
0	Pass-Through Mode Disabled
1	Use FC3 for Pass-Through
2	Use FC4 for Pass-Through

#### **GSI ASCII Protocol**

<b>1<sup>st</sup> Digit</b>	<b>Switch Status/Tenths of Temp Byte</b>
0	Combine Switch Status & Tenths of Temp
1	ASCII Switch Status – No Temp Tenths
2	ASCII Temp Tenths – No Switch Status



**2<sup>nd</sup> Digit      Temperature Adjustment**

0	No Adjustment
1	Add 100 Degrees
2	Subtract 100 Degrees
3	Add 200 Degrees
4	Subtract 200 Degrees
5	Add 300 Degrees
6	Subtract 300 Degrees

**3<sup>rd</sup> Digit      Temperature Units**

0	°F
1	°C
2	No Temperature

**4<sup>th</sup> Digit      Level Data Format**

0	English Fractional
1	English Decimal
2	Metric

**Varec Mark-Space Protocol**

**1<sup>st</sup> Digit      Temperature Sign/Hundreds Bits**

0	Varec 1800 Format
1	Varec 1900 Format

**2<sup>nd</sup> Digit      Temperature Adjustment**

0	No Adjustment
1	Add 100 Degrees
2	Subtract 100 Degrees
3	Add 200 Degrees
4	Subtract 200 Degrees
5	Add 300 Degrees
6	Subtract 300 Degrees

**3<sup>rd</sup> Digit      Temperature Units**

0	°F
1	°C
2	No Temperature (40-bit response)

**4<sup>th</sup> Digit      Level Data Format**

0	English Fractional Gray Code
1	English Decimal Gray Code
2	Varec Metric <20m Gray Code
3	Varec Metric >20m Gray Code

**GPE TP600 Protocol**

**1<sup>st</sup> Digit      No Assignment**

0	(only valid value)
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**2<sup>nd</sup> Digit      No Assignment**

0	(only valid value)
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**3<sup>rd</sup> Digit      Units**

0	English (Decimal Ft & °F)
1	Metric (Metric (Meters & °C))

**4<sup>th</sup> Digit      Protocol Variant**

0	Composite Level Data Format
1	Separate Coarse/Fine Level Format

### **L&J Tankway Protocol**

<b>1<sup>st</sup> Digit</b>	<b>Switch Indication</b>
0	Normal Switch Status Indication
1	Inverse Switch Status Indication
<b>2<sup>nd</sup> Digit</b>	<b>Temperature Indication</b>
0	Standard Temperature Sign Indication
1	Inverse Temperature Sign Indication
<b>3<sup>rd</sup> Digit</b>	<b>No Assignment</b>
0	(only valid value)
<b>4<sup>th</sup> Digit</b>	<b>Protocol Variant</b>
0	Legacy Tankway Gray Code Format
1	Tankway 32nds Format (truncated)
2	Tankway 32nds Format (rounded)

### ***Shift - O – Host Response Delay***

The Host Response Delay specifies the amount of time the APTB3 will wait before sending its reply to a Host poll. Normally this value should be 0 or as short as possible, but sometimes a slight delay is needed to give Host systems enough time to switch from poll mode to receive mode so characters do not get lost. Also, field wiring characteristics sometimes dictate the introduction of a slight delay in order to allow the lines to settle between data packets. This configuration mode allows such a delay to be introduced.

To change the Host Response Delay, enter a 1 to 3 digit number (000 to 999) to specify the desired number of mSec of delay time. Pressing the Space/Enter key after entering 1 or 2 digits will exit the Host Response Delay mode and change the delay time to the number that has been entered.

Note that this Host Response Delay factor only applies to protocols that utilize the built-in CPU communication port. It does not apply to protocols that utilize bit-bang communication techniques such as Varec Mark-Space. Response delay times are specified as part of the communication speed settings for those types of protocols.

### ***Shift – ( – Level Offset Correction***

In general, level errors should always be corrected by calibrating the gauge or encoder. However, when brush encoders or analog input AIN1 are used to measure level, the APTB3 supports the ability to temporarily enter a level offset if it is not practical to immediately open the transmitter housing to perform a proper level calibration. Since it is just as easy to calibrate capacitive encoders as it is to enter a level offset value, the level offset factor is ignored for capacitive encoders and should be set to 0.

This feature allows the user to enter a level offset of up to +/- 1 inch. Entries are by whole 16ths of an inch from 0 to +/- 16. Use the HHT to enter Shift followed by a left parenthesis to enter the Level Correction Mode. The present level offset will be shown. Tap any key other than + or – or a numeric digit to exit without changing the offset. Enter a new offset amount from +/- 0 to 16 to change the offset. The + sign is optional for positive numbers. Any entry larger than 16 will be truncated to 16.

Note: The HHT will always display the corrected level, and the APTB3 will always transmit the corrected level to the host. If the encoder reading is 12-5-10 and the manual offset is +5, the HHT will display 12-5-15. Similarly if the manual offset is -5, the HHT will display 12-5-5.

Note: Be sure to set the level offset to 0 prior to starting a physical level calibration so the HHT will display the actual encoder reading during the calibration process. The APTB3 will automatically set the offset to 0 under some circumstances, such as when changing the encoder type; however, it has no way to automatically detect when a physical encoder adjustment is being made.

The APTB3 Device Status word includes a bit to indicate if a manual level offset has been entered; however, the legacy APTB Device Status word does not have that capability. If you want to be able to detect when a manual level offset has been entered, you must use the APTB3 register map starting at 0 rather than the legacy APTB register map starting at 100.

### **Shift – ) – Temperature Offset Correction**

In general, temperature errors should always be corrected by calibrating the transmitter's temperature sensing circuitry. However, the APTB3 supports the ability to temporarily enter a temperature offset if it is not practical to immediately open the transmitter housing to perform a proper temperature calibration. This feature allows the user to enter a temperature offset of up to +/- 5 degrees. Entries are by tenth of degree from 0 to +/- 5.0 (a decimal point must be used to enter fractional numbers).

Use the HHT to enter Shift followed by a right parenthesis to enter the Temperature Correction Mode. The present temperature offset will be shown. Tap any key other than plus (+) or minus (-) or period (.) or a numeric digit to exit without changing the offset. Enter a new offset amount from +/- 0 to 5.0 to change the offset. The + sign is optional for positive numbers. Any entry larger than 5.0 will be truncated to 5.0.

Note: The HHT will always display the corrected temperature, and the APTB3 will always transmit the corrected level to the host. If the RTD reading is 77.5 and the manual offset is +3.2, the HHT will display 80.7. Similarly if the manual offset is -3.2, the HHT will display 74.3.

Note: The APTB3 has no way of knowing when a physical adjustment is being made to the temperature potentiometers, so it is important to set the temperature offset to 0 prior to starting a physical temperature calibration so the HHT will display the actual temperature reading during the calibration process.

The APTB3 will automatically set the offset to 0 under certain circumstances such as when using the HHT to change the temperature source or perform a full temperature calibration; however, it cannot automatically clear the offset if a simple temperature potentiometers adjustment is made.

The APTB3 Device Status word includes a bit to indicate if a manual temperature offset has been entered; however, the classic APTB Device Status word does not have that capability. If you want to be able to detect when a manual temperature offset has been entered, you must use the APTB3 register map starting at 0 rather than the classic APTB register map starting at 100.

### **Q – Analog I/O Configuration**

The APTB3 supports up to 7 analog inputs (referenced as Analog Inputs 1-7) that may be used in a variety of ways. Typically these inputs are sourced from 4-20 mA or 0-5V analog transmitter devices. Regardless of the type of transmitter and the parameter it is measuring, the APTB3 must be properly configured to convert the analog signal into a useful engineering unit value.

The APTB3 also supports up to 2 analog outputs that may be used to transmit level and temperature data via 4-20 mA analog output signals.

To configure an analog input or output, press the Q key on the HHT and follow the prompts. The first prompt is for the desired analog input or output. Press any number key from 1-9 where the numbers 1-7 specify the analog input to be configured, the number 8 is used to configure an analog output for level, and the number 9 is used to configure an analog output for temperature. Press any other key to exit the Analog Configuration Mode at this point.

After selecting an analog input or output, you will be prompted to enter a low scale, then a full scale engineering unit value. For example, if your analog input is measuring levels from 0 to 40 feet (or if your analog output is transmitting levels from 0 to 40 feet), you would need to enter a value of 0 for the low scale value and 40 for the full scale value.

Note: when using AIN7 for a secondary RTD input, the low scale engineering units value must be set to -82 (°F) and the high scale value must be set to +388 (or +602 if the secondary RTD is configured for high temperature).

The following guidelines must be followed when entering the low scale and full scale values:

- A maximum of 9 characters can be entered
- The first character may be a + or – character to indicate that the value is positive or negative. If no sign is entered, the number will be assumed to be positive.
- A period (.) may be entered in any of the 9 character positions to indicate the location of a decimal point. Note that a period is not required and no more than one period may be entered. If no period is entered, the number will be treated as a whole number.
- Other than the sign and period characters, all other characters must be numerical digits from 0 through 9.
- If your numbers require less than 9 characters, merely press the Space/Enter key after you have entered all necessary characters to advance the HHT to the next step.
- Entering any invalid character will cause the HHT to immediately exit the Analog Configuration mode.
- The full scale value must be greater than the low scale value. This will be checked after both values have been entered. If the check passes, a Completed message will be displayed on the HHT. If the check fails, a FAILED message will be displayed on the HHT.

Note that the Analog Outputs will utilize the data formats and engineering units specified for level and temperature in the standard APTB3 MODBUS register configurations as described in the **SHIFT/L** configurations section. Therefore, the low and full scale settings for the analog outputs must be consistent with the **SHIFT/L** configuration settings.

For simplicity, it is recommended that the data formats for both level and temperature be set to **Floating Point – No Scaling** in the APTB3 MODBUS register settings and that the engineering units be set to whatever units are to be represented by the analog outputs. Then the low and full scale analog output values can be set directly to the desired transmission values. For example, if it is desired to represent a value of 0-40 feet by the 4-20 mA output signal, then set the level data format to **Floating Point – No Scaling** and the units to **feet** so the analog output configuration settings can be set directly to 0 and 40.

However, if the APTB3 is also transmitting MODBUS serial data to a host computer and if that host system requires a different APTB3 MODBUS register configuration with scaled integer data rather than floating point, it will be necessary to convert the desired analog output range into appropriate values that are consistent with the actual APTB3 MODBUS register settings.

For example, if level is configured for feet and a scaling of 1/1000 and a full scale value of 60.5 feet is desired, the proper value for a high scale value would be 60500 (corresponding to 60.500). Similarly, if temperature is set to °F with 1/10 scaling and a full scale value of 200 is desired, then the proper high scale value would be 2000.

The same rules apply for the low scale value if anything other than 0 is desired. If level scaling is set for 1/1000 and a low range of 10 feet is desired, the proper low scale value would be 10000. Similarly, if temperature scaling is set for 1/10 and a low range of 10 degrees is desired, the proper low scale value would be 100.

### **S – Bus Drive Enable Delay**

The Host Response Delay (Shift-O) described above specifies the amount of time the APTB3 will wait before sending its reply to a Host poll. The first step in this response process is to turn on the Bus Drive Enable which is followed by the actual data transmission. This Bus Drive Enable Delay value allows the user to specify some delay time between asserting the Bus Drive Enable and the start of data transmission. Normally this value should be 0 or as short as possible, but sometimes field wiring conditions may dictate a slight in order to allow the lines to settle after bus assertion.

To change the Bus Drive Enable Delay, enter a 1 to 3 digit number (000 to 999) to specify the desired number of mSec of delay time. Pressing the Space/Enter key after entering 1 or 2 digits will exit the Bus Drive Enable Delay mode and change the delay time to the number that has been entered.

Note that this Bus Drive Enable Delay factor only applies to protocols that utilize the built-in CPU communication port. It does not apply to protocols that utilize bit-bang communication techniques such as Varec Mark-Space.

Note that the total delay time between the last data bit received from a host poll and the first data bit transmitted by the APTB3 will be the sum of the Host Response Delay (Shift-O) and the Bus Drive Enable Delay (S).

## T – Host Timeout Interval

The Host Timeout Interval specifies the amount of time that the APTB3 will allow for receiving a complete poll message from the Host. This timing interval is important because the APTB3 receiver circuitry may sync on any partial or complete bit string on the data bus. If the APTB3 syncs on a bit near the end of the poll to another transmitter or on another transmitter's response, APTB3 must have some way of recognizing that it has only received a partial message prior to the Host sending out its next poll message so that the APTB3 receiving circuitry will be able to properly sync up on that next poll.

There is no set value for an ideal Host Timeout Interval. The following factors must be considered when determining the value to enter: **baud rate, poll message length, inter-character delay time, and host poll rate.** The value **must** be slightly longer than the total time required for the host to send a complete poll message, but **must** also be shorter than the time from the end of one transmitter's response until the start of the next Host poll message. **However, the value should never be less than 10 mSec.**

For an example, consider a Host utilizing MODBUS-RTU protocol at 9600 baud. The MODBUS-RTU poll message is 8 bytes in length, so the total Host poll time, assuming no inter-character delays, is approximately 8.3 mSec. For the sake of this example, we will assume that the Host poll rate (measured from the end of one transmitter's response to the start of the next poll message) is 50 mSec. For this example then, the Host Timeout Interval must be greater than 8.3 mSec and less than 50 mSec. As a general rule of thumb, the Host Timeout Interval should be set to the midpoint between these two extremes, or approximately 30 mSec in the case of this example.

If intermittent communications are experienced with one or more APTB3 boards, or if seemingly unrelated factors, such as the address setting, affect the communication reliability, it is very likely that this Host Timeout Interval requires adjustment. Sometimes it is possible to experiment with different values to determine a suitable setting; however, it is always best to analyze the actual nature of the communication on each individual system as described in the preceding paragraph to determine a suitable value that will guarantee reliable performance.

Contact GSI if you require assistance in evaluating your system's communication characteristics to determine the optimum setting for this parameter.

Note: This timing setting is also used for bit-bang protocols such as Varec Mark-Space; however, in the case of bit-bang protocols, the minimum value must be slightly longer than 1 bit time plus the nominal inter-bit delay time (if any). Again, the minimum value should not be less than 10 mSec.

Once an appropriate value is determined for your protocol, baud rate, and other communication considerations, enter a 1 to 3 digit number (000 to 999) to specify the desired number of mSec for the Host Timeout Interval. Pressing the Space/Enter key after entering 1 or 2 digits will exit the Host Timeout Interval mode and change the timeout to the number that has been entered.

## Z – Digital Output Configuration

The APTB3 supports up to 2 digital outputs (available as an option). Typically, two Form-C relays are installed when this option is selected. The digital outputs may always be turned on or off via MODBUS commands, but it is also possible to configure the APTB3 board to perform programmed control of the outputs.

To configure a digital output, press the Z key on the HHT and follow the prompts. The first prompt is for the desired digital output. Press a number key from 1-2 to specify the digital output to be configured. Press any other key to exit the Digital Output Configuration Mode at this point.

After selecting a digital output, you will be prompted to enter a mode, then the control polarity, then a low value, then a high value (both in engineering units). The mode specifies the data value that the APTB3 will use to perform its control. Valid entries are:

- 0 No control to be performed
- 1 Use Product Level for control
- 2 Use Product Temperature for control
- 3 Use Ambient Temperature for control

The control polarity defines how the APTB3 will use the low/high settings to actuate the digital outputs for the specified data value. Valid entries are:

- 0 Turn output ON when the data value is equal to or less than the low value and turn it OFF when the data value is equal to or greater than the high value
- 1 Turn output ON when the data value is equal to or greater than the high value and turn it OFF when the data value is equal to or less than the low value

The following guidelines must be followed when entering the low and high values for digital output control:

- Entries **MUST** be in the following units: decimal feet for level data and °F for temperature data, regardless of how the board is configured for protocol transmission
- A maximum of 9 characters can be entered
- The first character may be a + or – character to indicate that the value is positive or negative. If no sign is entered, the number will be assumed to be positive. **NOTE:** Level data **MUST** always be positive.
- A period (.) may be entered in any of the 9 character positions to indicate the location of a decimal point. Note that a period is not required and no more than one period may be entered. If no period is entered, the number will be treated as a whole number.
- Other than the sign and period characters, all other characters must be numerical digits from 0 through 9.
- If your numbers require less than 9 characters, merely press the Space/Enter key after you have entered all necessary characters to advance the HHT to the next step.
- Entering any invalid character will cause the HHT to immediately exit the Digital Output Configuration.
- The high value must be greater than the low value. This is checked after both values have been entered. If the check passes, a Completed message will be displayed, if not a FAILED message will be displayed.

## APT3 Diagnostics

Several APT3 diagnostics can be run on the HHT without interrupting its normal operation. Press the **Shift** key followed by and **Alphabetic** key to select the desired APT3 Diagnostic Mode. Note: you must press and release the **Shift** key, and then press the desired **Alphabetic** key. The following APT3 Diagnostic Modes are available:

Shift followed by:

- V View Encoder Data
- W View Analog Inputs
- ? Monitor Host Communication
- View Current and Min/Max Ambient Temperatures

Note: These diagnostic displays are intended primarily for the use of GSI's technicians. Interpretation and analysis of the information in these displays requires intimate technical knowledge of encoder design and construction, the CPU chip on the APT3, and the various protocols supported by the APT3. Such detail is beyond the scope of this manual.

### Shift - V – View Encoder Data

This feature presents a display similar to the following for brush/code disk encoders:

```
Raw Encoder Data
0 0 8 1 4
Dec Lev= 9.869 f
Frc Lev= 9-10-07
```

The first line of data shows the raw gray code data obtained from the encoder. The data consists of 18-bits of information presented in 5 hexadecimal digits. The converted value of the gray code data is shown in both Decimal Feet (or Meters) and Fractional (FT-IN-16) format. This display is automatically updated every few seconds.

The Fractional level will always be in FT-IN-16 format, but the decimal value will be followed by an "f" if the HHT data mode is set for decimal feet or an "m" if the HHT data mode is set for meters. This is determined by the current A/F toggle setting in the normal data display mode. If it is desired to change the data mode, return to the normal data display and toggle the data display mode, then enter the View Encoder Data feature once again.

This feature presents a display similar to the following for capacitive encoders:

```
Raw Encoder Data
f: 2 0774 1908 Val
c: 2 01fa. 506 cksm
Lev= 3.116 f d= xxx
```

The first line of data shows the position data from the fine (inches) encoder and the second line of data shows the position data from the coarse (feet) encoder as noted by f: or c:

The f: or c: indicator is then followed by a single digit number from 0 to 3, then a 4-digit hex number, then a decimal integer value from 0 to 16383.

The encoders are 14-bit devices that also transmit a 2-bit checksum to validate its position data (for a total of 16 bits of data). The single digit number after f: or c: is the checksum for the data which is then shown in two forms: hex (4 digits – 0000 to 3FFF) and decimal (0 to 16383).

The APT3 always validates the checksum of the data that it receives from the encoders and will not process the readings if the checksum is invalid. The data displayed can be toggled from "Valid Checksum" to "Raw Data" by pressing the **B/G** key on the hand held terminal. Valid Checksum data will only show data that passes the checksum test. Raw Data will show the actual data value from the encoders, which could contain a checksum error.

The last line of the display shows the level in Decimal Feet and the synchronization between the two encoders, expressed as a delta (d) value between 0 and 500. Ideally, this number should be as close to 0 as possible.

### **Shift - W – View Analog Inputs**

This feature supports three displays as follows:

```
RAW ANALOG DATA
1=0174 2=0000 3=0000
4=0000 5=0000 6=0000
7=0000 8=0000 9=05a7

FILT ANALOG DATA
1=174c 2=0000 3=0000
4=0000 5=0000 6=0000
7=0000 8=0000 9=5a74

J6 INPUTS  A1= -32.1
A2=1000.0  A3= 215.5
A4=N       A5= N
A6=N       A7= N
```

The first display shows the raw 12-bit data from the 9 analog inputs supported by the CPU chip on the APTB3 board. Value 1 corresponds to the RTD input connected to J5 or J5A. Values 2-8 correspond to the analog/digital inputs connected to pins 1-7 of J6 respectively. Value 9 is the raw analog reading of the on-board ambient temperature sensor.

The second display shows the pseudo 16-bit filtered value of the 9 analog inputs.

The third display shows the engineering unit conversion of the 7 analog inputs connected to pins 1-7 of J6 respectively. These values will be shown with a maximum of 6 characters, including a decimal point, one tenths digit, and a sign character if the value is negative. This display may show an “N” for unconfigured analog inputs.

The Engineering Units display only shows data for the 7 analog inputs terminated on J6. The engineering units values of remaining two analog inputs (RTD input and ambient temperature sensor) are shown on the normal data display screen.

It is up to the user to know the relevant engineering units for each of the 7 data values connected to J6. Unless A1 is configured for level or A2 is configured for temperature, the APTB3 board does not know which engineering units to attribute to these inputs.

If it is desired to know the values of the seven analog inputs on J6 that are presented on the Engineering Units display, the user must use a MODBUS host program to poll data from the appropriate APTB3 data registers as described in the MODBUS protocol section of this manual. The user may poll MODBUS registers using either the HHT port or the primary APTB3 communication port (if it is properly configured for MODBUS communication).

The Raw Analog Data display will be shown when the Shift – W keys are first pressed. Continue to press the Shift – W keys to cycle the display through the 3 displays.

### **Shift - ? – Monitor Host Communication**

This feature provides a means of monitoring communication between APBT2 and the Host system to verify that the Host is actually polling the APTB3 and that APTB3 recognizes and is responding to the Host. As data is received from or transmitted to a Host system, it will be displayed on the screen in a scrolling mode. This feature does not interfere with the normal APTB3 communication.

Data can be displayed in either Hex or ASCII formats. The default mode when the feature is first requested is to display data received from the Host in Hex. In this mode, each character received from the Host is displayed as two Hex-ASCII digits with a space separating them from the next two Hex-ASCII digits.

When data is displayed in ASCII format, each character is sent directly to the HHT in its raw ASCII form. This mode is generally only useful for protocols that are strictly ASCII-based.

Pressing the Shift – ? keys will cycle the display between HEX and ASCII formats.

Press the I key to switch between displaying data that is received from the Host or data that is transmitted to the Host. Pressing the I key does not affect the current setting of the Hex or ASCII display mode.



The data to or from the Host streams onto the HHT screen as it is transmitted or received by the APTB3. For high-speed communication, it can be quite difficult to read the data in this manner. Pressing the G key provides a Go/Pause feature. Press it once to pause the streaming. Press it again to restart the streaming.

Note: This feature is not intended for detailed protocol analysis such as that provided by actual data line monitor devices. It attempts to simultaneously capture and display the data streams from the Host; however, physical limitations of the HHT refresh may result in some characters being missed.

Also, when displaying the data received from the Host, the HHT will actually display all data that it sees on the data bus. This will include replies by other devices on the bus as well as polls from the Host.

Therefore, this feature is only intended to provide a general indication that the APTB3's receiver and transmitter circuitry is working.

### **Shift - - - View Ambient Temperatures**

In addition to monitoring its current ambient temperature, the APTB3 also retains historical low and high ambient temperature readings in its non-volatile memory. This feature presents a display like the following to view this information.

```
Ambient Temperature  
Current = 123.4  
Min Low = 123.4  
Max Hi  = 123.4
```

Although an HHT cannot show when the historical low and high values occurred, this display does allow the user to determine if the temperatures inside the transmitter housing ever exceed the specified ratings of -25°F to +160°F.

It is not possible to reset the historical low and high values with the HHT. These values may only be reset at the GSI factory.

Note: Ambient temperature is always displayed in °F, both in the normal data display and in this feature. The ability to toggle data formats between English and metric units only applies to product level and temperature.

## APT3 Analog Outputs

This section describes the operation and calibration of the Analog Output option for the APT3:

### Analog Output Specification

The APT3 supports up to two 4-20 mA analog outputs for transmitting level and temperature information to devices equipped with analog input capability. An appropriate Personality Module equipped with analog outputs must be utilized in order to implement the Analog Output Option.

The APT3 can simultaneously transmit level and temperature data to a host computer via any of its host communication protocols while also driving the two analog outputs. An appropriate Personality Module equipped with both analog outputs and the desired host communication interface circuitry must be utilized to implement this simultaneous communication capability.

When Analog Outputs are utilized, channel 1 will always be utilized to transmit level and channel 2 will always be utilized to transmit temperature. The engineering units and format of the transmitted over these two analog output channels will be as specified in the **APT3 MODBUS Configuration**. The high and low range of the 4-20 mA outputs will be as specified in the **Analog Configuration** settings.

For simplest configuration, it is recommended that both the level and temperature data formats be set to **Floating Point – No Scaling** in the APT3 MODBUS Configuration and that the units for both level and temperature are set to whatever units the analog outputs will represent. Then the low and high scale values for the Analog Output Configuration can be set directly in the desired units.

For example, if it is desired to transmit a range of 0-40 feet for level, simply set the data format for level to Floating Point – No Scaling and the units to Feet. Then you can simply set 0 as the low scale value and 40 as the full scale value for the analog output configurations.

However, if the APT3 is also used to provide MODBUS communication to a host computer and the host requires the APT3 MODBUS Configuration to be configured differently, it will be necessary to set the low and full scale values for the analog output configuration in a compatible manner.

For example, suppose the host system requires that level be configured for units of inches and scaling of 1/10. For a 40-foot tank, this level range would be represented by the numbers 0 to 4800 (0-480.0 inches) in the MODBUS registers. It would then be necessary to use these same numbers (0 and 4800) as the low scale and full scale analog output configuration values to transmit the same 0-480 inches (or 0-40 feet) range with the 4-20 mA analog output signal.

### Analog Output Calibration

The HHT provides a simple means for calibrating the APT3 analog outputs. You will need to connect a mA meter to the analog outputs to measure the output current from the analog outputs while performing this procedure.

Be sure that you have enabled analog outputs and set appropriate configuration parameters via the SHIFT/D and Q commands before attempting to perform this Analog Output Calibration procedure.

This calibration procedure will drive both analog outputs to their low, mid, or full scale values simultaneously, so you simply need to move the mA meter from one output to the other to measure the output signal and determine the appropriate calibration factors for each channel as described below.

The calibration procedure is as follows:

1. Use the **SHIFT/D** command to select the low-scale analog output calibration mode.
2. Measure and note the analog output on the two analog output channels. At the low scale setting, both outputs should measure 4.0 mA. If they are both close enough, then skip to step 9 otherwise proceed with step 3.
3. Determine the error factor for each channel by dividing its output value by 4.0 (for example, if the output is 5.0 mA, the error factor will be 1.25 and if the output is 3.0 mA, the error factor will be 0.75)
4. Press the **R Key** on the HHT to enter the Analog Calibration Mode

5. When prompted, enter a number from 1-2 to specify which analog output is to be calibrated.
6. After selecting the analog output channel, enter an L at the next prompt to enter a low scale value.
7. The current low scale setting for that channel will be displayed as a whole number, generally between 8000-12000. Divide this number by the error factor of that channel and round the result off to the nearest whole number to determine a new low scale value. For example, if the current low scale value is 9500 and the error factor is 1.25, the new value should be 7600. Enter that number and press the ENTER key.
8. Repeat steps 5-7 for the other analog output channel if needed.
9. Use the **SHIFT/D** command to select the full-scale analog output calibration mode.
10. Measure and note the analog output on the two analog output channels. At the full scale setting, both outputs should measure 20.0 mA. If they are both close enough, then skip to step x otherwise proceed with step 11.
11. Determine the error factor for each channel by dividing its output value by 20.0 (for example, if the output is 22.0 mA, the error factor will be 1.1 and if the output is 19.0 mA, the error factor will be 0.95)
12. Press the **R Key** on the HHT to enter the Analog Calibration Mode
13. When prompted, enter a number from 1-2 to specify which analog output is to be calibrated.
14. After selecting the analog output channel, enter an H at the next prompt to enter a full-scale span value.
15. The current full-scale span setting for that channel will be displayed as a positive floating point number, generally between 0.9 and 1.2. Divide this number by the error factor of that channel and round the result off to a floating point number with 1 or 2 fractional digits. For example, if the current full-scale span value is 1.2 and the error factor is 1.1, the new span value should be 1.09. Enter that number and press the ENTER key.
16. Repeat steps 12-15 for the other analog output channel if needed.
17. Use the **SHIFT/D** command to select the mid-scale analog output calibration mode.
18. Measure and note the analog output on the two analog output channels. At the mid-scale setting, both outputs should measure 12.0 mA. There is no calibration adjustment for the mid-scale reading; this is merely a check to determine if the calibration procedure has been successful. If either analog output is off by an unacceptable amount, repeat this procedure.
19. If the mid-scale setting is close enough to 12.0 mA for both channels, it is still recommended to use the **SHIFT/D** command to select the low-scale and full-scale values to recheck the analog outputs at the 4.0 and 20.0 mA targets. If both outputs are at acceptable values for all 3 check points, then the calibration is complete. If any of these 3 targets are off by an unacceptable amount, it is necessary to repeat this entire procedure to fine tune the calibration a little further.

Note that the analog output calibration is an iterative procedure and if the error is significant, the calibration procedure may have to be repeated several times to reduce the errors at both the low and high end to acceptable values.

Note: The first time this calibration procedure is used, the current low scale and full scale settings in Steps 7 and 15 might be shown as NAN rather than an actual number. That simply means that no entry has yet been made.

# APT3 Protocol Specifications

This section contains information on the various protocols supported by the APT3. All native GSI protocols and MODBUS Register Maps are described in full detail.

The APT3 supports many other protocols in addition to the native GSI protocols thereby enabling the APT3 to coexist with legacy devices from those manufacturers and to communicate with their host systems. Detailed descriptions of those legacy protocols are not included in this manual. For such information, reference the protocol documents from those manufacturers.

## APT3 MODBUS

The standard APT3 MODBUS Register Map consists of 74 registers starting with Register 0. The first 32 registers (0-31) are always available from any APT3 board; however, the remaining registers will only have valid data if the relevant options are enabled to populate those registers. The following table shows the contents of these registers:

STANDARD APT3 DATA			
Data	MODBUS Register		Data Type
	(Decimal)	(Hex)	
Product Level	0	0000	FLOAT OR LONG
Product Temperature	2	0002	FLOAT OR LONG
Cap Encoder Status	4	0005	UNS INTEGER
Coil Counter	5	0005	UNS INTEGER
Device Address	6	0006	UNS INTEGER
Device Status (APT3)	7	0007	UNS INTEGER
Device Status (CIM)	8	0008	UNS INTEGER
Switch Status	9	0009	UNS INTEGER
Analog0 Data	10	000A	FLOAT
Analog1 Data	12	000C	FLOAT
Analog2 Data	14	000E	FLOAT
Analog3 Data	16	0010	FLOAT
Analog4 Data	18	0012	FLOAT
Analog5 Data	20	0014	FLOAT
Analog6 Data	22	0016	FLOAT
Analog7 Data	24	0018	FLOAT
Ambient Temperature	26	001A	FLOAT
Lowest Ambient Temp	28	001C	FLOAT
Highest Ambient Temp	30	001E	FLOAT
MP Temperature Status	32	0020	UNS INTEGER
MP Coil Counter	33	0020	UNS INTEGER
AVG Wetted Temp	34	0022	FLOAT OR LONG
MP Temperature 1 (Bot)	36	0024	FLOAT OR LONG
MP Temperature 2	38	0026	FLOAT OR LONG
MP Temperature 3	40	0028	FLOAT OR LONG
MP Temperature 4	42	002A	FLOAT OR LONG
MP Temperature 5	44	002c	FLOAT OR LONG
MP Temperature 6	46	002E	FLOAT OR LONG
MP Temperature 7	48	0030	FLOAT OR LONG
MP Temperature 8	50	0032	FLOAT OR LONG
MP Temperature 9	52	0034	FLOAT OR LONG
MP Temperature 10	54	0036	FLOAT OR LONG
MP Temperature 11	56	0038	FLOAT OR LONG
MP Temperature 12	58	003A	FLOAT OR LONG

MP Temperature 13	60	003C	FLOAT OR LONG
MP Temperature 14	62	003E	FLOAT OR LONG
MP Temperature 15(Top)	64	0040	FLOAT OR LONG
Total Obs Vol (TOV)	66	0042	FLOAT OR LONG
Gross Std Vol (GSV)	68	0044	FLOAT OR LONG
Product Mass	70	0046	FLOAT OR LONG
Spare	72	0048	UNS INTEGER
Cap Encoder Delta	73	0049	UNS INTEGER

These registers may be read using either MODBUS Function Code 3 or Function Code 4. A MODBUS query may start with any register in this set and may pull any number of registers up to the last. Any attempts to read past the last register will result in an Exception Code error response from the APTB3.

Floating Point data is stored in standard IEEE-754 32-bit format. Each Long Integer or Floating Point value occupies two consecutive MODBUS registers as indicated in the above table.

The data in this register is as follows:

**Product Level** – The engineering units for level and the data format is determined by the APTB3 MODBUS configuration settings.

**Product Temperature** – The engineering units for temperature and the data format is determined by the APTB3 MODBUS configuration settings.

**Cap Encoder Status** – This register contains a 16-bit status code with the following information (shown as 4 hex digits) when capacitive encoders are used. It has no meaning when brush encoders or analog input AIN1 are used to measure level.

- 0000 Normal Operations
- 0001 No Communication to the Fine Encoder
- 0002 No Communication to the Coarse Encoder
- 0004 Fine Encoder Checksum Error
- 0008 Coarse Encoder Checksum Error
- 0010 Encoder Synchronization Error

An Encoder Synchronization Error occurs when the delta between the two encoders exceeds the allowable amount.

**Coil Counter** – A register that is incremented by the APTB3 whenever the Product Level register is updated. It can be used to monitor the run status (operational health) of the board.

**Spares** – Reserved for future use.

**Device Status (CIM)** – This register contains a 16-bit status code with the following information (shown as 4 hex digits):

- 0000 Normal – Good Level and Temperature
- 0001 Invalid Level Data
- 0002 Bad Temperature Data
- 0100 Bad Multi-Temperature Condition
- 4000 No Temperature Option

Note that it is possible to have a combination of some of these conditions. In that case the register will contain a value representing the hexadecimal sum of those errors. For example, a hexadecimal value of 4001 indicates an Invalid Level error on a transmitter with No Temperature Option.

A Bad Multi-Temperature Condition indicates that one or more faults have been detected while attempting to read a multi-temperature device or process multi-point temperature data. Refer to the MT Status word in the Multi-Temperature data to determine the exact nature of the Multi-Temperature error.

If a Bad Multi-Temperature condition exists AND if the APTB3 is also configured to obtain Product Temperature from a multi-temperature device, then the Temperature Over Range and the Temperature Under Range bits will also be set in the device status word.

This Device Status word is configured for compatibility with CIM Simple Register Types.

**Device Status (APTB3)** – This register contains a 16-bit status code with the same information as the Device Status (CIM) register, except with the following additional bits:

1000	User Has Entered a Level Offset
2000	User Has Entered a Temperature Offset

By monitoring these additional bits in this second Device Status register, it is possible to know that the level or temperature reading includes a manually-entered offset.

**Digital/Switch Status** – This register contains the current ON/OFF status of the optional 4 switch inputs in the lower 4-bits of the register. A bit value of 1 indicates that the switch is OPEN and a 0 indicates that the switch is CLOSED. The data will appear as follows (in hexadecimal notation):

0000	All 4 switches normally CLOSED
0001	Switch #1 is OPEN
0002	Switch #2 is OPEN
0004	Switch #3 is OPEN
0008	Switch #4 is OPEN

If multiple switches are open, this will be indicated by a hex value that represents the sum of the data value for each individual switch. For example, a value of 000F indicates that all 4 switches are open.

The high byte of this register contains the state of the Analog/Digital Inputs connected to J6. If an input exceeds 50% of scale, its corresponding bit will be set to 1; otherwise its bit will be set to 0.

Analog/Digital Input 1 is stored in Bit 0 of the high byte. Input 7 is in Bit 6. Bit 7 (most significant bit) is unused and will always be 0.

**ANALOG0 DATA through ANALOG7 DATA** - These registers contains the engineering unit values of the 8 analog/digital inputs.

Analog0 DATA is the RTD input connected to J5 or J5A. The value in this register will normally be the same as the value in the Temperature register. However, if the board is configured to measure its primary temperature from some source other than the RTD input at J5/J5A, this register will still show the data measured from the J5/J5A RTD source in which case, the value in this register may be different from the value in the Temperature register.

The registers for Analog1 DATA through Analog7 DATA contain the data from the analog/digital inputs connected to pins 1-7 of J6.

**Ambient Temperature** - This register contains the data from the on-board temperature sensor. The value in this register will always be in floating point format. The units will either be °F or °C, to match the units that were specified for product temperature in the APTB3 MODBUS configuration settings.

Note: This feature is only intended to provide an approximate indication of the ambient temperature within the transmitter enclosure. The overall accuracy of the sensor is +/- 5 °F.

**Lowest Ambient Temp** – This register contains the lowest value that was ever read for Ambient Temperature which provides a means of determining if the ambient temperature inside the transmitter housing ever exceeded the operating specifications of the APTB3 (-40 °F).

**Highest Ambient Temp** – This register contains the highest value that was ever read for Ambient Temperature which provides a means of determining if the ambient temperature inside the transmitter housing ever exceeded the operating specifications of the APTB3 (+160 °F).

Note: If it is desired to know when Min Low and Max High ambient temperatures occur, the Host system should timestamp and record the values from these two registers in a historical database.

**Multipoint Temperature Status** – This register contains the operational status of Multipoint Temperature

**Multipoint Coil Counter** – This register is incremented each time a multi-temperature scan is made and the multipoint data is updated.

**Average Wetted Temperature** – This register contains the volume-weighted average temperature of the temperature sensors that are covered by liquid when a multipoint temperature option is used. The value in this register will always be in floating point format. The units will either be °F or °C, to match the units that were specified for product temperature in the APTB3 MODBUS configuration settings. The value in this register may also appear in the Product Temperature register if Avg Wetted Temp is selected as the source for Product Temperature.

**Multipoint Temperature 1-15** – These are the individual temperature readings in °F or °C from the individual temperature sensors whenever the multipoint temperature option is used. MP Temp 1 is always the bottom sensor. MP Temp 15 is the topmost sensor if the maximum 15 sensors are used. The actual top sensor may be less than 15, depending on the total number of sensors actually in use. The data in any unused sensor registers will be meaningless.

**Total Observed Volume (TOV)** – This register contains TOV data if the APTB3 is configured for measuring Volume.

**Gross Observed Volume (GOV)** – This register contains GOV data if the APTB3 is configured for measuring Volume.

**Gross Standard Volume (GSV)** – This register contains GSV data if the APTB3 is configured for measuring Volume.

**Product Mass** – This register contains Product Mass data if the APTB3 is configured for measuring Mass.

It is possible to configure the APTB3 for such parameters as Water Bottom, Vapor Pressure, Liquid Pressure, Density, etc. These parameters require the use of sensors for those particular purposes with 4-20 mA analog outputs so they can be connected to the available Analog Inputs. Once assigned to a particular analog input channel, follow instructions given in this manual to configure and calibrate the input to provide the desired engineering unit data in the Analog Input registers described above.

**Cap Encoder Delta** – This register contains the most recent Cap Encoder Delta value. The contents of this register are updated every time the capacitive encoders are read, which is several times per second. Therefore, a host system is only able to periodically read a single snapshot of these values, but it can help to show the general magnitude of the delta values.

The delta value will be a number from 0 to 500 and ideally should be as small as possible. The maximum allowable amount is a configurable parameter. If the capacitive encoder processing logic detects 10 or more consecutive readings that exceed the allowable amount, the appropriate bit will be set in the Cap Encoder Status register.

Ideally, the fractional foot value of the fine and coarse encoders should be identical (within their precision). For example, when the fine encoder is at the half-foot position, its fractional reading is 0.500 feet. Similarly the coarse encoder should also read X.500 (where X is the whole number of feet) at that point. However, the coarse encoder only increments once for every 100 steps of the fine encoder, so there will usually be some difference in the fractional feet reading of the two encoders at any given position of the fine encoder. The difference between the two fractional feet values of the two encoders is multiplied by 1000 so it can be expressed as a whole number from 0 to 500. The maximum permissible value is a configurable parameter through GSI Config.

## VAREC 2900 MODBUS

The APTB3 is able to emulate portions of the MODBUS Register Maps in the Varec 2900, 2910, 2920, and 4000 transmitters as described in this section. The objective of this emulation is to provide the data requested by Varec 8303 Communicate devices for these transmitters (Level & Temperature & Calibration Level via Function Code 65 and Alarm & Tank Status via Function Code 4). The following tables shows the registers provided by the APTB3 to support that emulation. Except as noted below, these registers are in addition to those described above for the GSI MODBUS.

<b>VAREC 2900 DATA (FC65)</b>			
<b>Data</b>	<b>MODBUS Register</b>		<b>Data Type</b>
	<b>(Decimal)</b>	<b>(Hex)</b>	
Product Level	0	0000	FLOAT
Product Temperature	1	0001	FLOAT
Reserved	2	0002	FLOAT
Reserved	3	0003	FLOAT
Reserved	4	0004	FLOAT
Reserved	5	0005	FLOAT
Reserved	6	0006	FLOAT
Reserved	7	0007	FLOAT
Reserved	8	0008	FLOAT
Reserved	9	0009	FLOAT
Reserved	10	000A	FLOAT
Reserved	11	000B	FLOAT
Reserved	12	000C	FLOAT
Reserved	13	000D	FLOAT
Reserved	14	0006	FLOAT
Reserved	15	0007	FLOAT
Reserved	16	0008	FLOAT
Reserved	17	0009	FLOAT
Reserved	18	000A	FLOAT
Reserved	19	000B	FLOAT
Reserved	20	000C	FLOAT
Calibration Level	21	000D	FLOAT

<b>VAREC 2900 DATA (FC4)</b>			
<b>Data</b>	<b>MODBUS Register</b>		<b>Data Type</b>
	<b>(Decimal)</b>	<b>(Hex)</b>	
Alarm Status	5	0005	UNS INTEGER
Tank Status	6	0006	UNS INTEGER

Function Code 65 (FC65) is a User Defined MODBUS function. Varec uses FC65 to transmit floating point data as a single 32-bit register value rather than two 16-bit registers. The data is the same in either case but the message format is slightly different. Varec uses FC65 registers from 0 to 2; however, only registers 0, 1, and 21 are emulated by the APTB3. Registers 2-20 will always return a value of 0.

Registers 0 through 21 exist in both the APTB3 MODBUS register map and in the Varec 2900 FC4 register map. In general, when data is requested from registers 0-73 via FC3 or FC4, data will be returned in accordance with the description on the APTB3 MODBUS section. The following exceptions apply for Varec 2900 emulation:

1. If FC65 is used rather than FC3 or FC4 for registers 0-21, the APTB3 will return data in accordance with the Varec FC65 register map shown here.
2. If FC4 is used to poll Registers 5 and 6, the APTB3 will return data in accordance with the Varec 2900 FC4 register map shown above.



NOTE: The polling device must issue FC4 for two 16-bit registers of data starting at register 5 to acquire this specific data. If FC3 is used, data will be returned in accordance with the APTB3 MODBUS register map. Similarly if any other starting register is specified or if any other number of registers are requested via FC4, the APTB3 will return data in accordance with the APTB3 MODBUS register map.

NOTE: The 2900 MODBUS Registers are available at all times, so no special configuration settings are needed to enable the Varec 2900 MODBUS support; however the following rules must be observed to ensure that data is stored in those registers in a manner that is consistent with 2900 operation:

1. Data formats for Level and Temperature MUST be set to Floating Point. No data will be stored in the 2900 MODBUS FC65 registers if Integer or Long Integer data formats are used.
2. Any of the available units (Feet, Inches, 16ths, or Millimeters) may be used. However, if Millimeters is selected, the APTB3 will actually store level data into the 2900 MODBUS FC65 register map in METERS rather than Millimeters (Millimeters will still be stored in the APTB3 Register Map).
3. The APTB3 does not support remote calibration or writing to any data registers, so Function Codes 16 and 66 are not supported. Since remote calibration is not supported, the APTB3 merely returns the current level in the Calibration Level register.
4. The APTB3 does not support software alarm setpoints, so the Alarm Status register will always be 0.
5. The Tank Status register only uses two bits: Bit 0 indicates a Bad Level and Bit 1 indicates a Bad Temperature.
6. The Reserved FC65 Registers (2-20) will always return a floating point ZERO value.

## Legacy APTB/MACB MODBUS

The legacy APTB/MACB MODBUS Register Map consists of 6 registers starting with Register 100. The following table shows the contents of these registers:

LEGACY APTB DATA			
Data	MODBUS Register		Data Type
	(Decimal)	(Hex)	
Level	100	0064	UNS INTEGER
Temperature	101	0065	INTEGER
Device Status	102	0066	UNS INTEGER
Switch Status	103	0067	UNS INTEGER
Spare	104	0068	INTEGER
Spare	105	0069	INTEGER

These registers may be read using either MODBUS Function Code 3 or Function Code 4. A MODBUS query may start with any register from 100 to 105 and may request any number of registers up to register 105. Any attempts to read past register 105 will result in an Exception Code error response from the APTB3.

The data in this register map is as follows:

**Level** – The engineering units for level and the data format is determined by the Legacy APTB/MACB MODBUS configuration settings.

**Temperature**– The engineering units for temperature and the data format is determined by the Legacy APTB/MACB MODBUS configuration settings. Temperature will be presented in tenths of degree as a 10x scaled integer in this register (e.g. 1045 = 104.5 degrees).

**Device Status** – This register contains a 16-bit status code with the following information (shown as 4 hex digits):

0000	Normal – Good Level and Temperature
0004	Invalid Level Data
0008	No Temperature Option
0020	Temperature Over Range
0040	Temperature Under Range
0080	Bad Data
0100	Bad Multi-Temperature Condition

Note that it is possible to have a combination of some of these conditions. In that case the register will contain a value representing the hexadecimal sum of those errors. For example, a hexadecimal value of 000C indicates an Invalid Level error on a transmitter with No Temperature Option.

A Bad Multi-Temperature Condition indicates that one or more faults have been detected while attempting to read a multi-temperature device or process multi-point temperature data. Refer to the MT Status word in the Multi-Temperature data to determine the exact nature of the Multi-Temperature error.

If a Bad Multi-Temperature condition exists AND if the APTB3 is also configured to obtain Product Temperature from a multi-temperature device, then the Temperature Over Range and the Temperature Under Range bits will also be set in the device status word.

**Switch Status** – This register contains the current ON/OFF status of the optional 4 switch inputs in the lower 4-bits of the register. A bit value of 1 indicates that the switch is OPEN and a 0 indicates that the switch is CLOSED. The data will appear as follows (in hexadecimal notation):

0000	All 4 switches normally CLOSED
0001	Switch #1 is OPEN
0002	Switch #2 is OPEN
0004	Switch #3 is OPEN
0008	Switch #4 is OPEN

If multiple switches are open, this will be indicated by a hex value that represents the sum of the data value for each individual switch. For example, a value of 000F indicates that all 4 switches are open.

## GSI ASCII Protocol

The GSI ASCII protocol consists of a 4-character ASCII poll from the host and a 16-character response from the APTB3.

### Host Poll

The Host poll consists of a 3-digit transmitter ID followed by a carriage return as shown below:

**ABC<CR>**

Where:

A	Hundreds ID digit
B	Tens ID digit
C	Unit ID digit

For example:

**012<CR>**

is a poll transmitter ID of 12.

### APT3 Response

If an APTB3 detects a poll for its ID, it will respond with a 16-character string as follows:

**ELLLLLLSTTTXAAA<C/R>**

Where:

E	Error Code
LLLLLL	Level Data
S	Temperature Sign/Status
TTT	Temperature Data
X	Temperature Tenths and Switch Status
AAA	Echo of Transmitter ID

The Error Code in position E will either be a 0 (Hex 30) or a 4 (Hex 34). A value of 0 indicates Good Level Data while a value of 4 indicates Bad Level Data.

Level data is transmitted as a 6-digit value in the character positions indicated by LLLLLL. The format of the data is specified in the GSI ASCII protocol configuration. If the resultant data format requires less than 6 characters, the data will be right-justified in this 6-character field and the leading characters will be set to 0 (Hex 30).

Fractional level data is transmitted with two characters for feet (00 to 99) in the first two positions, two characters for inches (00 to 11) in the next two positions, and 16ths (00 to 15) in the last two positions. For example, a 6-character string of 120513 represents 12 Feet, 5-13/16 Inches.

Decimal level data is transmitted as hundredths of feet with an implied decimal point. This requires 4 characters to transmit a number from 0000 to 9999 representing 00.00 to 99.99 feet. These 4 characters will be front-filled with 0's to complete the 6-character level field as follows: 000000 to 009999.

Metric level data is transmitted in whole mm utilizing 5 characters with front-filled 0s in the 6-character level field. For example, a value of 012345 is 12,345 mm or 12.345 meters.

The Temperature Sign/Status character will be one of the following ASCII characters:

+	Good Positive Temperature	Hex 2B
-	Good Negative Temperature	Hex 2D
\$	No Temperature Option	Hex 24
<	Under Range Error	Hex 3C
>	Over Range Error	Hex 3E

The \$ character for No Temperature will be set if either the APTB3 Temperature Configuration is set for No Temperature or if the GSI ASCII protocol is configured for No Temperature. In either case, the temperature bytes in the message will be set to 0.

The Hundreds, Units, and Tens digits of the absolute value of temperature will be transmitted in the 3-character field represented by TTT. The engineering units and any scaling or adjustment will be as specified in the GSI ASCII protocol configuration.

The Temperature Tenths and Switch Status character can have 3 different formats depending on the setting for this character in the GSI ASCII protocol configuration.

If the character contains a combination of Temperature Tenths and Switch Status, the high-order 4 bits will be used for tenths of temperature and the low-order 4 bits will be used for switch status, 1 switch per bit. In this case the high-order 4 bits can contain a value from 0 to 9 (binary 0000 to 1001) and the low-order 4 bits can contain a value from 0 to 15 (binary 0000 to 1111). The combination of these 8 bits can result in any hex value from 00 to 9F, some of which are not printable-ASCII characters.

If the character is only used to transmit Temperature Tenths, it will contain a hex digit from 30 to 39 representing a value of 0 to 9.

If the character is only used to transmit Switch Status, it will contain a hex digit from 30 to 3F representing a value from 0 to 15 for the 16 possible combinations of switches being OPEN or CLOSED.

The last 3 characters of the APTB3 response are an echo of the transmitter ID that it received from the Host.

## Varec Mark-Space Protocol

### Mark-Space Protocol Variants

The APTB3 supports both of the primary Mark-Space protocol variants, commonly known as "1800 Format" and "1900 Format". The difference between these two formats is the manner in which temperature is transmitted in the Mark-Space protocol. The 1800 Format allows a device to transmit a temperature range of -199 to +199 degrees. The 1900 Format allows a device to transmit a temperature range of -799 to +799.

The APTB3 also supports both the 56-bit and the 40-bit Mark-Space protocol variants. Both of these variants are available in either "1800 Format" or "1900 Format" mode. If the APTB3 is configured to transmit temperature, it will utilize the 56-bit response; if not, it will utilize the 40-bit response. If the protocol is configured for temperature but the board itself is configured for No Temperature, the APTB3 will transmit a 56-bit response with the temperature data positions all set to 0.

## Temperature Scaling Options

The APTB3 supports 7 temperature scaling options as described in the HHT configuration section. These options are: No Adjustment, Add 100 degrees, Subtract 100 degrees, Add 200 degrees, Subtract 200 degrees, Add 300 degrees, or Subtract 300 degrees.

The purpose of these adjustments is to enable the APTB3 to transmit a wider range of temperatures than the protocol format would otherwise permit. While available for both the 1800 Format and the 1900 Format mode, these adjustments are generally only required for the 1800 Format which is limited to a range of -199 to +199.

A standard APTB3 is capable of measuring temperatures from -82 to +388 F (-63 to +198 C) with platinum RTDs or -40 to +440 F (-40 to +227 C) with copper RTDs. These entire ranges of possible temperatures can be transmitted to the host via the "1900 Format"; however, only a portion of the range can be transmitted via the "1800 Format" since that format only supports temperature ranges of -199 to +199.

Some examples of how the temperature scaling allows various temperature ranges to be transmitted via the "1800 Format" are:

- With no adjustment, the APTB3 would be able to transmit temperatures from -82 to +199 with platinum RTDs or -40 to +199 degrees with copper RTDs. Any other valid temperature outside these ranges will be reported as an Overrange or Underrange condition.
- With a -100 adjustment, the APTB3 would be able to transmit temperatures from -82 to +299 (transmitted as -182 to +199). Any other valid temperatures outside these ranges will be reported as an Overrange or Underrange condition.
- With a -200 adjustment, the APTB3 would be able to transmit temperatures from +1 to +399 (transmitted as -199 to +199). Any other valid temperatures outside these ranges will be reported as an Overrange or Underrange condition.
- With a -300 adjustment, the APTB3 would be able to transmit temperatures from +101 to +440 (transmitted as -199 to +140). Any other valid temperatures outside these ranges will be reported as an Overrange or Underrange condition.
- Positive adjustments are less typically used, but are handled in a similar fashion.

## Communication Options

The APTB3 supports both HI Speed (4 mSec bit times) and LO Speed (14.3 mSec bit times) as specified by settings in the Varec Mark-Space Protocol Configuration. These settings only apply to the data transmitted by the APTB3. The APTB3 auto-detects the bit-times of the data that it receives from a Host and therefore can receive data from either a HI Speed Host or a LO Speed Host.

Mark-Space networks typically require some amount of response delay from the slave devices to give the Host time to switch from transmit mode to receive mode. To accommodate these system variations, the APTB3 can be set for response delays of 20, 30, 40, 50, or 60 mSec. (Actual timing of these response delays is +/- 5 mSec.)

The Varec Mark-Space protocol is usually Odd Parity. In case a Host system does not have parity handling capability, the APTB3 supports either None or Odd parity for Varec Mark-Space protocol. (If the parity is set to anything other than None or Odd, APTB3 will use Odd parity).

## Encoder Error Handling

If the APTB3 detects an encoder error, it will send a value of hex FFFF (for fractional and decimal formats) or 3FFFF (for metric formats) to the Host in the level bytes of the Mark-Space data stream. The Host must interpret this value as an invalid gray code, reject the level data, and presume that an encoder error occurred.

## GPE TP600 Protocol

The APTB3 is capable of automatically detecting most TP600 protocol variants based on the transmitter ID formatting in the Host poll. However, some aspects of TP600 protocols cannot be automatically determined from the Host poll alone. Such variants must be stipulated in the GPE TP600 Protocol Specification.

Some TP600 Host systems expect to receive composite level data (overall level with individual digits for hundreds, tens, units, tenths, hundredths, and thousandths). Other TP600 Host systems expect to receive individual fine and coarse level data from the transmitter.

Host systems that require individual fine and coarse level data must interpret those individual values and compute the overall level. The most common, and default, mode for APTB3 is to transmit composite level data. If a Host requires individual fine and coarse values, the GPE TP600 Protocol must be properly configured for this option.

## L&J Tankway Protocol

APTB3 supports both the legacy L&J Gray Code Tankway protocol and the newer L&J 32nds Tankway protocol. It is impossible to distinguish the desired protocol from the Host polls, so the desired variant must be specified in the L&J Tankway Protocol configuration.

When the 32nds Tankway variant is selected, the internal APTB3 level data in 16ths is converted to 32nds by simply multiplying the 16ths value by a factor of two. To accommodate different techniques that the host system might use to convert 32nds to decimal feet (or other units), the APTB3 offers two options for transmitting 32nds data: (1) “truncated” mode in which the APTB3 always transmits even values (16ths times two) or (2) “rounded” mode in which the APTB3 always transmits odd values (16ths time two plus one).

There is no provision within the L&J Tankway protocol for transmitting a level status to flag bad level data. Therefore the APTB3 utilizes the following methods to inform the host when the level is invalid:

- An invalid gray code value will be transmitted when the L&J Gray Code protocol is selected. This value will be 144 (hex 90) in both byte positions of the level data (overall value of 37008 or hex 9090).
- A full-scale value of 65535 (hex FFFF) will be transmitted when the L&J 32nds protocol is selected. This value will be transmitted for both the “truncated” and the “rounded” modes.

The L&J Tankway protocol includes a sign bit in the temperature data word. Normally this bit is set to indicate a positive temperature value. The APTB3 also supports the ability to select “inverse” temperature sign indication – in this mode the sign bit will be set when the temperature value is negative.

The L&J Tankway protocol includes two bits to indicate switch status. The status of the low-order two bits of the 4 possible discrete switch inputs to an APTB3 will be transmitted in these two bit positions. User options allow the bits to indicate either an open or a closed condition.

The L&J Tankway protocol includes an Out-of-range bit to flag bad temperature status. The APTB3 will set this bit if it detects either a temperature overrange or a temperature underrange condition.

If the APTB3 encoder configuration is set to “No Temperature”, the APTB3 will still respond to any L&J Tankway polls for temperature, but it will set the temperature data value to 0. The Sign and Out-of-range bits will also be set to 0.

## Upgrading the APTB3 Firmware

The APTB3 firmware is stored in non-volatile flash memory which can easily be reprogrammed when new firmware releases become available. There are several alternatives for loading a new program into the APTB3 as described in this section.

### JTAG Programmer

Connector J9 is a 2x10 dual in-line header for using a JTAG Programmer to load a new program into the APTB3.

You will need a JTAG Programmer, the Silicon Labs IDE Toolkit, and the appropriate binary image file to download a new program using this technique. The IDE Toolkit is available for free download from the Silicon Labs website at [www.silabs.com](http://www.silabs.com).

### Hyperterm Programming

An alternate method of loading a new program into the APTB3 is provided via the J7 HHT/Laptop communication connector. Using this connection, a new program can be downloaded to the board. This technique loads a file stored in Intel Hex format rather than a binary image file. You will need Hyperterm or another similar terminal emulation program and the appropriate program file.

The APTB3 firmware contains a special Boot Load Program to communicate with Hyperterm for this purpose. It will accept the downloaded records in the Intel Hex program file and store the new program instructions in the proper flash memory locations. There are two ways to initiate the Boot Loader:

#### MODBUS Initiation

If you are using a MODBUS program, such as GSI Test, you can activate the Boot Loader with a MODBUS write command.

Write the hex value AA50 or AA51 to MODBUS register 32752 (hex 7FF0) using Function Code 16. Write a value of AA50 if you want to continue at 9600 baud. Write a value of AA51 if you want to continue at 115200 baud.

After receiving an acknowledgement from the APTB3 that your write command was successful, you will have approximately 20 seconds to exit the MODBUS program and start a terminal emulation program such as Hyperterm.

#### Hyperterm Initiation

The second method of activating the Boot Loader is by using a terminal emulation program such as Hyperterm. Type the letter "X" or the letter "Y" three times in rapid succession (less than 1 second per character). Type an "X" if you want to continue at 115200 baud. Type a "Y" if you want to continue at 9600 baud.

Since the port is already operating at 9600 baud, typing 3 "Y's" will immediately activate the Boot Loader. If you choose to operate the Boot Loader at the faster rate of 115200, the following message will be displayed to give you time to change the speed of your terminal emulator before the Boot Loader is activated:

```
BOOT LOADER WILL START IN 15 SECONDS  
SWITCH BAUD RATE TO 115200 NOW!
```

#### Boot Loader Operation

Whether you start the Boot Loader Program with a MODBUS write command or with a 3-character sequence from Hyperterm, its operation is the same. It will first give you an opportunity to change your mind by displaying the following message:

```
The Boot Loader is Now Active  
Are you SURE you want to Reload Memory?  
Press Y to continue, any other key to Exit
```

If you really want to reload the flash, press the Y key (upper or lower case). If you press any other key, the Boot Loader will exit and the normal application program will start. There is a 30-second timeout for this user prompt. If no keyboard entry is made for 30 seconds, the Boot Loader will exit and start the normal application.

If you press the Y key, the Boot Loader will present the following Confirmation Message:

```
Last Chance to reconsider  
Press Y to continue, any other key to Exit
```

Press the Y key (upper or lower case) if you want to reload the flash. Any other entry will terminate the Boot Loader. The Boot Loader will also terminate if no entry is made for 30 seconds.

If you press the Y key for the second time, the Boot Loader will present the following message to let you know that it is erasing the flash memory:

```
Erasing flash, please wait...
```

Erasing the flash memory will take approximately 2-3 seconds. After this process is complete, the following message will appear:

```
Flash Erased! Send New Data Now
```

At this time, you should use the “Transmit Text File” feature of your terminal emulator program to select the appropriate file for downloading into the PM. This file must be a text file in Intel-Hex format.

The reprogramming process will take approximately 20 seconds after the file is selected and downloading has started. When downloading is complete, the following completion message will appear:

```
FLASH SUCCESSFULLY REPROGRAMMED!
```

If this message appears, the Boot Loader will restart the application immediately after displaying this message.

If any problems occur during the file download process, one of the following error messages may appear:

```
**ERROR! Corrupt Hex File**  
  
**ERROR! Checksum Mismatch**
```

If either of these messages appears, something was wrong with the file that you tried to download. Try the program reload process again with the same file. **If the errors persist (or if you are unable to reactivate the Boot Loader), it will be necessary to utilize the JTAG programming device to reload the firmware.**

Note: Although the program download process should only take about 20 seconds, Hyperterm is rather quirky and sometimes may take several minutes to complete the download. If you have such a problem running Hyperterm on your computer, you may want to try a different terminal emulation program. Sometimes, activating the local echo mode of Hyperterm will improve its transmission characteristics.

Note: The Boot Loader will only reprogram the application area of flash memory. The area of memory used by the Boot Loader itself and the area used to store configuration parameters will not be erased by the Boot Loader and cannot be reloaded with this procedure. If it is ever necessary to erase or reload those areas of flash, the JTAG programming device must be used.

# GSI Config

GSI Config is a configuration program that can be used to configure a number of GSI products, including the APTB3. GSI Config can perform most of the same configuration functions as a GSI-HHT device.

## Starting GSI Config

GSI Config must be installed on a computer with a standard RS232 serial communication port. Connect a GSI DB9-to-Modular adapter plug to the computer's RS232 port and use the same 6-wire modular cable as for a GSI-HHT device to connect the adapter plug to the J7 (modular) connector on the APTB3 card.

Launch the GSI Config program and wait for the Device Setup window to appear. Ensure that the Current Comm Port number (usually 1 for COM1) properly matches the communication port number of your computer's serial port.

The program should start in Auto Discovery mode, displaying a message indicating that automatic device discovery is enabled. Click on the Green "MODBUS RTU Serial" button in the Device Setup window to initiate the automatic discovery process. GSI Config will display a message indicating that it is searching for devices and, if it is able to detect your APTB3 card, it will pop up a Field Data window with a blue progress bar as it downloads the current configuration information from the APTB3. After download is complete, the program will switch to its configuration window.

If automatic discovery fails, you can try to use the manual connection mode. Click on the Manual menu option of the Device Setup window and select Manual Config. Select the APTB device selection and ensure that the Device ID is set to 247. Also check the Port Settings to be sure that the comm port is set for 9600 baud, No Parity, 1 Stop Bit, and 8 Data Bits. If you are using a USB serial adapter rather than a built-in serial port, be sure to select the USB Device option. Once all these settings are confirmed, click the Green "MODBUS RTU Serial" button and GSI Config will attempt to communicate with the APTB3 using your manual settings. The Field Data pop up window will appear and if the program is able to communicate with the board, the progress bar will increment to the right. If the program is unable to communicate with the board, the communication attempt will time out and the program will display its configuration window with a No Data Received Message.

If the program is unable to communicate with the board, connect a GSI-HHT to the board to ensure that the J7 port on the board is operating properly. If the HHT works properly, then there is an issue with the GSI Config program or its settings or the serial port on the computer. If the HHT does not work either, then there is probably a problem with the APTB3 board.

## Using GSI Config

The GSI Config configuration window has a list of menu options on the far right of the screen and a list of configuration items for each menu selections on the left. The two main menu selections are the "Scan and Format Configurations" and the "Port 1 Configurations" selections. The "Analog Configurations" are only needed if you are monitoring one or more 4-20 mA transmitter devices with your APTB3 card.

There are a variety of additional configuration options that can be ignored unless your application actually requires the use of those features. These include Digital Inputs, Digital Outputs, Analog Outputs, Port 3 Communication to an external device, Multipoint Temperature, and other Advanced Tank Gauging features.

When a list of configurable items is shown on the left side of the window, you can double click on the label for a help window about that item. For example, if you double-click on the "Host Data Fmt" item, a pop up window will explain that that item allows you to specify the format for storing level and temperature in the standard APTB3 MODBUS data registers.

Most data entry fields only require the entry of a simple numeric value, but some fields require a more complex numeric value, so to simplify the computation of the appropriate value, you can double click in those fields for a pop up window of selectable items that will allow the program to compute the appropriate data value for you.

After entering or verifying all the data entry fields for a given menu selection, be sure to click on the "Write Page" button to upload that set of data to the APTB3 card before selecting a different menu option. If the program is able to write the information to the APTB3 card, a "Data Uploaded Successfully" message will appear.



## Scan and Format Configurations

The Scan and Format Configurations menu selection has the following options:

### **Host Data Format**

This option specifies the data storage formats for Level and Temperature data. It only applies if you are using MODBUS communication with an RS485 personality module AND if you are using the standard APTB3 register map starting at register 0. If you are not using that particular protocol configuration, you can simply ignore this setting.

Note: These configuration settings apply to Product Level, Product Temperature, BS&W, Average Wetted Temperature, and all individual Multipoint Temperatures.

If you are using this protocol, double click in the data field for a list of configuration options. The data format is as follows:

#### **Bit Structure: AAAA TTTT BBBB LLLL**

LLLL = Level Units:

- 0000 = 16ths
- 0001 = mm
- 0010 = feet
- 0011 = inches

BBBB = Level Data Formats

- 0000 = No Scaling (Long Int)
- 0001 = 1/10 Scaling (Long Int)
- 0010 = 1/100 Scaling (Long Int)
- 0011 = 1/1000 Scaling (Long Int)
- 0100 = Floating Point

TTTT = Temperature Units:

- 0000 = °F
- 0001 = °C

AAAA = Temperature Data Formats

- 0000 = No Scaling (Long Int)
- 0001 = 1/10 Scaling (Long Int)
- 0010 = 1/100 Scaling (Long Int)
- 0011 = 1/1000 Scaling (Long Int)
- 0100 = Floating Point

### **Classic APTB Data Format**

This option only applies if you are using MODBUS communication with an RS485 personality module AND if you are using the legacy APTB register map starting at register 100. If you are not using that particular protocol, you can simply ignore this setting.

Note: The standard APTB3 register map starting at register 0 and the legacy APTB register map starting at register 100 are available simultaneously. If you want to access both register maps from your host computer, it will be necessary to configure both of the above menu selections.

If you are using this protocol, double click in the data field for a list of configuration options. The data format is as follows:

**Bit Structure: AAAA TTTT BBBB LLLL**

LLLL = Level Units:

0000 = 16ths

0001 = mm

BBBB = Level Data Format

Unused for now, leave at 0000

Classic APTB Level is always Unsigned Integer

TTTT = Temperature Units:

0000 = °F

0001 = °C

AAAA = Temperature Data Format

0000 = No Scaling (Integer)

0001 = Legacy APTB Temp Scaling w/+100 deg offset

0010 = Legacy APTB Temp Scaling w/-100 deg offset)

**Encoder Configuration**

This option allows you to specify the type of encoder that is being used with the APTB3 card or whether level is to be obtained from a 4-20 mA transmitter rather than an encoder.

Double click in the data field for a list of configuration options. The data format is as follows:

**Bit Structure: AAAA BBBB CCCC DDDD**

DDDD = Encoder Type/Level Source:

0000 = GSI Encoder - CCW Count Up or AIN1 = dec ft

0001 = GSI Encoder - CW Count Up or AIN1 = inches

0010 = Varec Encoder - CCW Count Up or AIN1 = 16ths

0011 = Varec Encoder - CW Count Up or AIN1 = meters

CCCC = Encoder Data:

0000 = English Fractional Gray Code

0001 = English Decimal Gray Code

0010 = GSI Metric or Varec Metric <20m Gray Code

0011 = Varec Metric >/= 20m

0100 = Use AIN1 for Level instead of Encoder

0101 = Use Capacitive Encoders Style A

0110 = Use Capacitive Encoders Style B

BBBB

Unused for now, leave at 0000

AAAA

Unused for now, leave at 0000

**Temperature Configuration**

This option allows you to specify the type of RTD connected to the APTB3 card or whether temperature is to be from a 4-20 mA transmitter rather than an RTD. You can also stipulate that no temperature device is being used.

Double click in the data field for a list of configuration options. The data format is as follows:

**Bit Structure: AAAA BBBB CCCC DDDD**

DDDD = Temperature Enable/Disable:

0000 = Temperature Enabled (or AIN2 = °F)

0001 = No Temperature (or AIN2 = °C)

CCCC = Temperature Source Type:

0000 = Platinum RTD at J5 or J5A (100 ohm @ 32°F)

0001 = Copper RTD at J5 or J5A (100 ohm @ 77°F)

0010 = Use AIN2 for Temperature rather than an RTD

0011 = Use an MTG Gauge to Compute Average Wetted Temp

BBBB = Temperature Range

0000 = Standard (-82°F to +388°F)

0001 = Extended (-82°F to +602°F)

AAAA

Unused for now, leave at 0000

## **Analog Output Configuration**

This is an overall configuration option allows you to specify if the board is equipped with Analog Outputs. If it is equipped with Analog Outputs, each output must be individual configured.

Double click in the data field for a list of configuration options. The data format is as follows:

### **Bit Structure: AAAA BBBB CCCC DDDD**

DDDD = Analog Outputs Enable/Disable:

0000 = Analog Outputs Disabled

0001 = Analog Outputs Enabled

CCCC

Unused for now, leave at 0000

BBBB

Unused for now, leave at 0000

AAAA

Unused for now, leave at 0000

## **HHT Update Time**

This option allows the user to specify the refresh rate for the displays on the HHT or BlueHHT app. The entry is in tens of milliseconds and the default value is 50 (500 mSec).

## **Cap Encoder Poll Rate**

This option allows the user to specify the rate at which the APTB3 reads capacitive encoders. The entry is in tens of milliseconds and the default value is 10 (100 mSec).

## **Cap Encoder Hysteresis**

This option allows the user to specify the amount the fine encoder must change before the cap encoder readings will be processed. The encoders are 14-bit devices, so there are 16,384 counts per revolution. The fine encoder makes one revolution per foot, so each count represents 1/16384 foot. This resolution is much greater than the accuracy of the mechanical gauges, so there is no point in processing the encoder data unless the shaft rotates by some reasonable amount from the last reading. One 16<sup>th</sup> inch is represented by 85.3 counts, one 32<sup>nd</sup> inch is represented by 42.7 counts, and one 64<sup>th</sup> inch is represented by 21.3 counts. Similarly, 8 counts represents 1/2048 feet or about 0.0005 feet and 16 counts represents 1/1024 feet or just under 0.001 feet.

The purpose of the hysteresis factor is to avoid level changes due to single-bit uncertainty of the fine encoder and avoids unnecessary data processing if the shaft is not rotating by a measurable amount. A value should be chosen that provides for maximum hysteresis while still allowing the desired level precision. For example, if a resolution of 0.001 feet is desired, the maximum hysteresis value should be 16. If a resolution of 1/16 inch is desired, the hysteresis could be as high as 85.

The default value is 16.

## **Cap Encoder Delta**

The cap encoder delta is the difference in the fractional feet readings of the two encoders expressed as a number from 0 to 500. This option allows the user to specify the maximum allowable delta between the two encoders. If the APTB3 detects a delta higher than the allowed amount for 10 or more consecutive readings, it will set the Cap Synchronization Error bit in the Cap Encoder Status Word.

The default value is 300.

### Advanced Host Data Format

This option includes two consecutive configuration registers to specify the data storage formats for a variety of Advanced Tank Gauging parameters that the APTB3 can provide if it is equipped with those optional features. It only applies if you are using MODBUS communication with an RS485 personality module AND if you are using the standard APTB3 register map starting at register 0. If you are not using that particular protocol, you can simply ignore these settings.

If you are using this protocol, double click in the data field for a list of configuration options. The data format of the first configuration register is as follows:

**Bit Structure: MMMM PPPP VVVV DDDD**

DDDD = Density Units:

- 0000 = kg/m<sup>3</sup> (float)
- 0001 = °API (float)
- 0010 = lbs/ft<sup>3</sup> (float)
- 0011 = SG (float)
- 0100 = kg/m<sup>3</sup> (1/10 scaling, long int)
- 0101 = °API (1/100 scaling, long int)
- 0110 = lbs/ft<sup>3</sup> (1/1000 scaling, long int)
- 0111 = SG (1/1000 scaling, long int)

VVVV = Volume Units:

- 0000 = liters (float)
- 0001 = gallons (float)
- 0010 = barrels (float)
- 0011 = m<sup>3</sup> (float)
- 0100 = liters (1/10 scaling, long int)
- 0101 = gallons (1/10 scaling, long int)
- 0110 = barrels (1/100 scaling, long int)
- 0111 = m<sup>3</sup> (1/1000 scaling, long int)

PPPP = Pressure Units:

- 0000 = In. H<sub>2</sub>O (float)
- 0001 = PSI (float)
- 0010 = BAR (float)
- 0011 = Pascal (float)
- 0100 = In. H<sub>2</sub>O (1/1000 scaling, long int)
- 0101 = PSI (1/1000 scaling, long int)
- 0110 = BAR (1/1000 scaling, long int)
- 0111 = Pascal (1/10 scaling, long int)

MMMM = Mass Units

- 0000 = kilograms (float)
- 0001 = Metric Tonnes (float)
- 0010 = Tons (float)
- 0011 = Pounds (float)
- 0100 = kilograms (1/1000 scaling, long int)
- 0101 = Metric Tonnes (1/10 scaling, long int)
- 0110 = Tons (1/10 scaling, long int)
- 0111 = Pounds (1/1000 scaling, long int)

The data format of the second configuration register is as follows:

**Bit Structure: AAAA BBBB CCCC DDDD**

DDDD = Time Base Units:

- 0000 = Seconds
- 0001 = Minutes
- 0010 = Hours

CCCC

Unused for now, leave at 0000

BBBB

Unused for now, leave at 0000

AAAA

Unused for now, leave at 0000

The Time Base Units are primarily used to specify various flow rate parameters. The user must select Time Base Parameters that will generate useful flow rate data based on the individual mass, volume or level units used for the flow rate calculations. For example, if Mass is set for kilograms and the Time Base Units is set to seconds, the Volumetric Flow Rate parameter will be in kilograms per second.

## Port 1 Configurations

The Port 1 Configurations define how the APTB3 will communicate with a host system. The following options are available:

### **Port 1 ID**

This option specifies the device ID or address of the APTB3 card.

Refer to the SHIFT-A description in the GSI-HHT section of this manual for more information on valid address settings and enter an appropriate number in the data field.

### **Port 1 Protocol**

This option specifies the protocol that the APTB3 card will use to communicate with the host system.

Refer to the SHIFT-D description in the GSI-HHT section of this manual for more information on valid protocol settings and enter an appropriate number in the data field. Ensure that you are also using the appropriate personality module for the selected protocol.

### **Port 1 Addressing Mode**

Some communication protocols have multiple options. This selection allows those options to be specified if necessary.

Refer to the SHIFT-N description in the GSI-HHT section of this manual for more information on valid protocol options. Double click in the data field for a pop up window with settings for the given protocol. If the selected protocol does not have any options, this selection can be ignored.

### **Port 1 Baud Rate**

This option specifies the speed that the APTB3 card will use to communicate with the host system.

Refer to the SHIFT-B description in the GSI-HHT section of this manual for more information on baud rate settings. If you are using Varc Mark-Space protocol, double click in the data field for a pop up window of communication speed settings for that protocol.

### **Port 1 Parity**

This option specifies the parity setting that the APTB3 card will use when communicating with the host system.

Refer to the SHIFT-C description in the GSI-HHT section of this manual for more information on valid parity settings. Note that the parity setting must be a number from 0-4 when using GSI Config.

### **Port 1 Framing**

This option specifies the number of data bits that the APTB3 card will use when communicating with the host system.

Refer to the SHIFT-C description in the GSI-HHT section of this manual for more information on valid framing settings. Note that the framing setting must be either 7 or 8 when using GSI Config.

### **Port 1 Transmit Timer**

This option specifies the delay time in mSec before the APTB3 card will reply to a host system after it detects a valid poll request.

Refer to the SHIFT-O description in the GSI-HHT section of this manual for more information on valid transmitter delay settings.

### **Port 1 Receive Timer**

This option specifies the maximum time in mSec that the APTB3 card will wait for a complete poll request from the host system once it detects the start of a poll.

Refer to the T description in the GSI-HHT section of this manual for more information on valid host timeout settings.

### **Port 1 Bus Delay Timer**

This option specifies the delay time in mSec after asserting bus control before the APTB3 card will begin its reply to a host system in response to a valid poll request.

Refer to the S description in the GSI-HHT section of this manual for more information on bus delay settings.

### **Port 1 Retries**

This option specifies the number of successive communication failures before a field device is declared unresponsive.

### **Port 1 InterTime**

This option specifies the amount of time to wait in mSec between successive polls to the same device when multiple polls are required to obtain a complete set of data.

## **Port 2 Configurations**

Port 2 has the same configuration parameters as Port 1, but they are permanently fixed. They can be read by GSI Config, but they cannot be changed since Port 2 is a slave port intended only for diagnostic and configuration purposes. It is generally set at 9600-N-8 and supports either MODBUS at address 247 for computer communication or serial ASCII for HHT communication

## **Port 3 Configurations**

The Port 3 Configurations define how the APTB3 will communicate with an optional slave device. These parameters only apply when the APTB3 board is equipped with an optional Port 3 and is connected to a slave device. Otherwise these parameters may be ignored. The following options are available:

### **Port 3 ID**

This option specifies the device ID of the slave device connected to Port 3.

Set this parameter to 0 to disable Port 3 communication.

Valid entries for the Port 3 IDs are 1-247 to specify the MODBUS address of the slave device that will be polled by Port 3.

### **Port 3 Protocol**

This option specifies the type of device and protocol that will be used to communicate with an external device. Currently defined Protocols are:

- 0 = MTG Gauges using MODBUS-RTU Protocol (applies to any subset of MTG3012 gauges.
- 1 = MMP Gauges using MODBUS-RTU Protocol

### **Port 3 Addressing Mode**

This option defines any special addressing attributes for the slave device. This is a 16-bit encoded value allowing for multiple combinations of protocol options if needed. At the present time, this parameter is unused and should be set to 0.

### **Port 3 Baud Rate**

This option specifies the speed that the APTB3 card will use to communicate with the Port 3 slave device.

Valid settings are as follows:

- 0 = 300 Baud
- 1 = 600 Baud
- 2 = 1200 Baud
- 3 = 2400 Baud
- 4 = 4800 Baud
- 5 = 9600 Baud
- 6 = 19200 Baud
- 7 = 38400 Baud
- 8 = 57600 Baud
- 9 = 115200 Baud

### **Port 3 Parity**

This option specifies the parity setting that the APTB3 card will use when communicating with the Port 3 slave device.

Valid settings are as follows:

- 0 = None
- 1 = Odd
- 2 = Even
- 3 = Space
- 4 = Mark

### **Port 3 Framing**

This option specifies the number of data bits that the APTB3 card will use when communicating with the Port 3 slave device.

Valid settings are as follows:

- 7 = 7 Data Bits (Total of 8 if parity is used)
- 8 = 8 Data Bits (Total of 9 if parity is used)

### **Port 3 Transmit Timer**

This option specifies the polling delay time in mSec from the end of one transmitter reply (or timeout) until a poll is sent to the next slave device.

### **Port 3 Receive Timer**

This option specifies the maximum time in mSec that the APTB3 card will wait for a complete response to be received from a slave device.

### **Port 3 Bus Delay Timer**

This option specifies the delay time in mSec after asserting bus control before the APTB3 card will begin sending a poll to a slave device.

### **Port 3 Retries**

This option specifies the number of successive communication failures before a field device is declared unresponsive.

### **Port 3 InterTime**

This option specifies the amount of time to wait in mSec between successive polls to the same device when multiple polls are required to obtain a complete set of data.

## **Analog Configurations**

The APTB3 supports up to 8 individual 4-20 mA inputs that may be used for a variety of purposes. Each analog input has 5 configuration settings:

Zero	Number of ADC counts corresponding to 4mA
Scale Factor	Number of ADC counts corresponding to 20mA
Low Engineering Unit Value	The measured value corresponding to 4mA
High Engineering Unit Value	The measured value corresponding to 20mA
Offset Engineering Unit Value	An offset adjustment

Refer to the Q description in the GSI-HHT section of this manual for more information on appropriate values for these settings.

Note: Analog Input 0 can only be used for an RTD input signal. Its settings may be read with GSI Config, but they should not be changed. Doing so might cause inaccurate temperature readings.