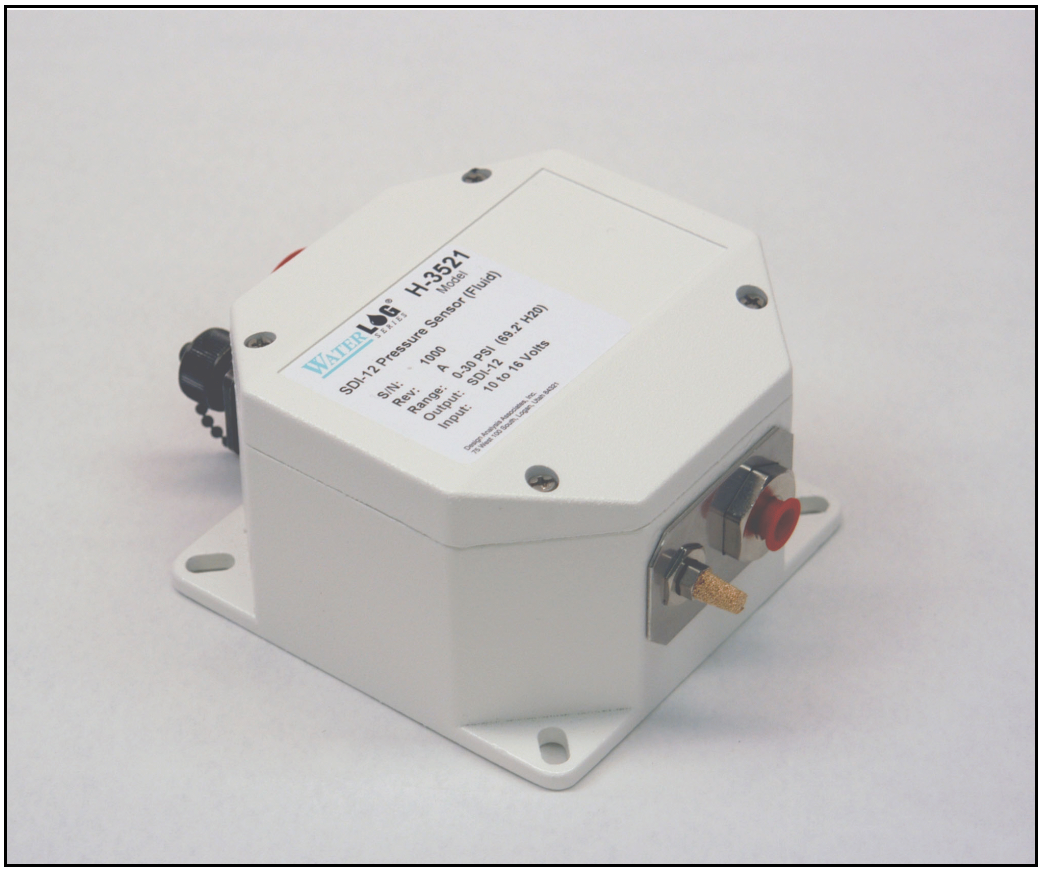
Model
H-3521

Liquid & Gas Compatible Pressure Sensor with SDI-12, 4-20mA and Modbus Outputs

WATERLOG® SERIES

Owner's Manual

Version 1.5



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Chapter 1
Introduction

1.0 Introduction

The ***WATER*LOG®** H-3521 is a digital pressure transducer specifically designed for water level monitoring. The H-3521 directly measures water or other fluid pressure over a broad temperature range. Typical applications include monitoring snow pillows to measure snow pack, measurement of water in accumulating rain gauges, and fluid pressure in weirs and dams. The H-3521 can be used in a gas-purge bubbler installation however, Design Analysis Associates, Inc., manufactures other instruments specifically for that application.

The H-3521 has RS-232, SDI-12 and Modbus "smart" digital interfaces together with a 4-20mA analog output. The sensor makes multiple pressure measurements, averages the results and converts the measurement data into units of PSI, Feet, Meters or other engineering units.

The H-3521 is easy to use and works with any SDI-12 data recorder. The "Serial-Digital Interface" is ideal for data logging applications with the following requirements.

- Battery powered operation with minimal current drain
- Pressure measurement data is transmitted digitally over long cable lengths without error
- Multiple sensors on a simple three-wire cable
- Up to 250 feet of cable between a sensor and the data recorder
  (Use of H-423, SDI-12 to RS485 converter extends the range to 1000's of feet)
  (H-4500 fiberoptic media converter works up to 1.2 miles)

The H-3521 has the following features:

- Simple to install, use, and maintain (no on-site calibration required)
- Performs extremely accurate measurements.
- Linear deviation is less than 0.05%
- Resolution is 1 part in 1,000,000
- Accuracy over temperature range exceeds ±0.02 ft. of water
- Enclosure is nonconductive and corrosion proof
- Stainless steel sensor diaphragm
- Sensor has an atmospheric vent for compensation of barometric pressure changes
- Low current operation (less than 1 milliamp typical standby)
- Simple RS-232 menu interface for quick and easy setup.(No external module required)
- Outputs a 4-20mA signal.(no external module required)
- Extended SDI-12 commands for setting the Stage to the current water elevation.

1.1 Unpacking

The following is a list of items you should have received:

- ***WATER*LOG®** H-3521 pressure transducer
- Main interface cable
- RS-232 communications cable(optional)
- Owner's Manual

1.2 Check The Model Number

Before installing your new ***WATER*LOG®** H-3521, check the information on the label of the sensor enclosure. Check the model number, the range, and the output type to be sure that you have received the instrument you ordered. The label will look similar to the following:

H-3521
Model

Fluid Pressure Sensor

S/N 1103
Range: 0-15 PSI (34.6' H20)
Output:: SDI-12, RS-232, Modbus, 4-20mA
Input: 10 to 16.0 Volts

This example shows that the ***WATER*LOG®** H-3521 measures pressure within the range from zero to 15-psi.

Chapter 2
Installation

2.1 Installing the *WATER*LOG® H-3521

The ***WATER*LOG®** H-3521 is a digital pressure transducer specifically designed for water level monitoring. The H-3521 directly measures water or other fluid pressure over a broad temperature range. Typical applications include monitoring snow pillows to measure snow pack, measurement of water in accumulating rain gauges, and fluid pressure in weirs and dams. Before proceeding with the installation, please consider several site preparation and maintenance issues:

Figure 4 Sensor and Cable

2.2 Water Depth

The following chart shows the maximum pressure to which the H-3521 is factory calibrated. The sensor can survive temporary operation up to twice the maximum rated pressure for you model's range. However, any measurements made beyond the rated pressure will be inaccurate. The H-3521 will be damaged if it is subjected to twice the maximum rated pressure.

Model	Pressure Range	Water Depth Range *	Accuracy
H-3521-15	0 to 15 psi	0 to 34.60 ft.	±0.01 ft
H-3521-30	0 to 30 psi	0 to 69.20 ft.	±0.02 ft.

* NOTE: Depth calculations are derived from the standard equation that one PSI is generated by a column of water 27.680 inches deep at 39.4°F.

2.3 General Installation Recommendations

The H-3521 pressure transducer is not recommended for use in applications where silt and mud are problematic. In addition, if the sensor is used in a shallow water application and happens to dry out with mud coating the sensor diaphragm, the diaphragm compliance will be altered and the factory calibration spoiled.

The H-3521 sensor will be permanently damaged if it is frozen. Transducers which are installed in geographical areas with harsh winters should be removed for the winter unless they are installed in a heated shelter or are used with ethylene glycol or other antifreeze media.

2.4 Instrument Shelter

The sensor should be installed in a protected, dry, location such as an instrument shelter. The installation should provide easy access and facilitate regular inspection and maintenance. Care should be taken to place it where it will not be jarred or dropped, the H-3521 is a precision instrument. Normally the H-3521 is mounted with the 4-corner feet on a level surface. Normally the H-3521 is used to measure the hydrostatic head of a water source. The instrument should be fastened to a gauge station shelf or fixed such that the elevation cannot accidently change.

Because the surface of the water being measured is exposed to atmospheric pressure, the pressure sensor must provide correction for changes in barometric air pressure. To provide the best accuracy possible, the H-3521 uses an atmospheric referenced pressure sensor design. The internal pressure sensor in the H-3521 has a vent tube connected to the back side its pressure diaphragm. The vent tube is routed to a sintered bronze filter next to the pressure port. Make certain the gauge station enclosure is open to the atmosphere. If the sensor is placed in a cabinet or sealed enclosure, the cabinet must have a screened vent or other opening to the atmosphere.

2.5 Making Connections to the Pressure Port

The H-3521 has a 1/8" female NPT pressure port for making connections to your pressure source. Apply Teflon tape or anaerobic thread dope to help prevent leaks. The pressure port has a stainless steel plate to prevent the port fitting from spinning in the housing. Make certain the "keeper" plate is in proper position. Whenever possible, use a backup wrench to avoid damaging the enclosure. Before tightening the pressure port connection, bleed any air from the supply line. Trapped air in the supply line will slowly dissolve into the water, as it does the density of the water column changes from air to water and the pressure offset will drift.

Figure 5 Pressure & Vent Ports

2.6 Connecting Your Data Logger

The H-3521 has RS-232, SDI-12 and Modbus "smart" digital interfaces together with a 4-20mA analog output. The H-3521 is a SDI-12 V1.3 compliant sensor excluding the CRC commands. It connects directly to any data recorder with SDI-12 capability. The instrument housing has both a 7 pin main interface connector and a 3 pin RS-232 communication connector.

Figure 6 Connector & Terminal Strip

7-pin Circular Connector			3-pin Circular Connector		
Pin	**Color**	**Function**	**Pin**	**Color**	**Function**
1	Orange	RS485+(Modbus)	1	N/A	RS232(TxD)
2	Brown	RS485-(Modbus)	2	N/A	RS232(RxD)
3	Blue	4-20mA+	3	N/A	GND
4	Green	4-20mA-			
5	Black	GND			
6	Red	+12V Power			
7	Yellow	SDI-12 Data			

2.6.1 SDI-12 Interface

The user must connect pins 5,6, and 7 to the data recorder or the user can power the H-3521 separate of the data recorder and connect just the SDI-12 data line(pin 7).

2.6.2 RS-232 Output

When the user wakes up the H-3521 with this port the H-3521 makes a new measurement and updates the outputs (if enabled) and then prints out the measured stage and temperature value. If the user sends a carriage return(CR) following the wake up then the H-3521 simple menu interface is initiated and the H-3521 waits for a command. After 3 minutes of inactivity the menu mode times out and the H-3521 returns to sleep.

2.6.3 4-20mA Output

Current loop sensors output a current rather than a voltage. The 4-20mA output will drive standard industrial telemetry and process control instrumentation. Since the signal to noise margin of 4-20mA is not large, take care to protect the wiring from noise and interference. The loop power supply must be sufficient to maintain 8.5 to 35V across the H-3521's output terminals, in addition to whatever voltage is needed to maintain 20mA across the loop receiver and interconnect wiring. The +12.0V SDI-12 power source will work only if the resistance of your loop receiver and wiring is less than 150 ohms.

$$8.5V + (150ohms * 20mA) = 11.5V$$

The 4-20mA output is reverse diode protected. The H-3521 is not loop powered, continuous +12V instrument power must be supplied.

- Make certain there is 8.5 to 35V across the 4-20mA output terminals.
- Make certain the H-3521 is receiving +12V power.
- Use shielded 4-20mA cables in noisy environments.

2.6.4 Modbus Interface

Modbus is an industry standard serial digital interface for interconnecting Programmable Logic Controllers (PLCs), intelligent sensors and other devices. The H-3521 is a Modbus slave and has a serial RS-485 port for connecting to a Modbus compatible host device. See Appendix B for the Modbus register definitions. Continuous +12Volt power must be supplied to the H-3521.

To activate the Modbus interface, issue an extended SDI-12 command or use the RS-232 menu interface and set *Power_Mode*=4. See section 4/5 for details. This setting causes the H-3521 to remain awake and monitor the RS-485 port for Modbus messages. This setting can be made at the factory if requested.

2.7 Wiring and Installation Precautions

- The H-3521 requires that the water be at ground potential. Mother Nature takes care of this for surface and ground water.
- Make certain the pressure port connection is tight
- Make certain the sintered bronze vent port is not painted or covered

2.8 Programming Your SDI-12 Data Recorder

You must prepare your data recorder to receive and record the H-3521 data. Since data recorders differ widely, refer to your recorder manufacturer's directions. In general, program the data recorder to input four values via the SDI-12 port. Usually only one or two of the parameters are actually recorded. Your data recorder must issue an "aM!" command, then collect the data with a "aD0" command, as explained in Chapter 4. The H-3521 places four parameters in its data buffer:

a+AA.AAA+BB.BBB+CC.C+DD.D<cr><lf>

Where:

a	= SDI-12 address 0-9, A-Z
AA.AAA	= Stage (feet, inches, meters etc.)
BB.BBB	= Pressure (PSI)
CC.C	= Temperature (C)
DD.D	= Input Supply Voltage (Volts)

2.9 Programming the SDI-12 Address

If more than one sensor is to be connected to the SDI-12 bus, make certain each sensor has a different sensor address. The H-3521 comes from the factory with its address set to "0". The address can be edited using the RS-232 menu interface or using an extended SDI-12 command. Refer to chapters 4 and 5 for more details.

2.10 Programming the H-3521 Sensor

The H-3521 comes from the factory with the following programmable settings:

SDI Address:	0
Slope:	2.3067 (feet of H_20)
Offset :	0.00
MeanCount:	16
Power_Mode:	0 (Sleep)
4-20ma_Hi:	20.0 (Ft)
4-20mA_Lo:	4.0 (Ft)

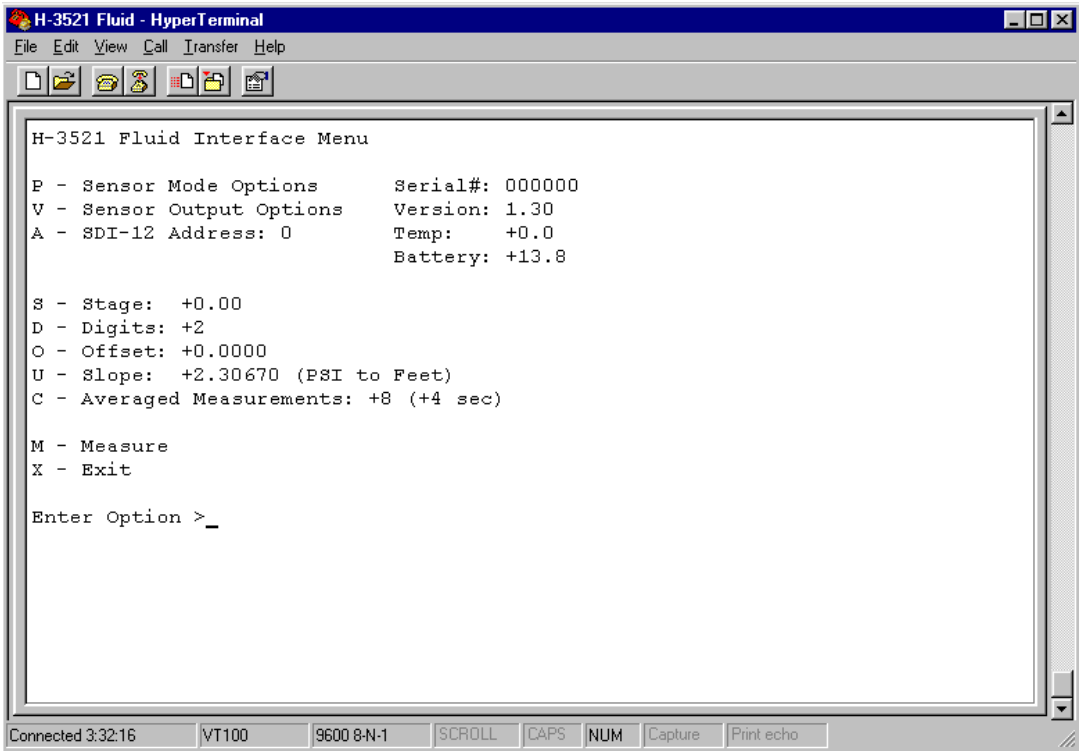
With these values the *Stage* will be in units of feet when used in clean water. The slope can be changed to accommodate other engineering units such as inches or meters. The setups are stored in EEPROM within the H-3521 and will not be lost if the power is disconnected. The extended commands for changing these setups are described in detail in Chapter 5 and most of these

settings can also be changed using the simple RS232 menu, see Chapter 4.

MeanCount is the number of raw pressure measurements averaged together to make one measurement sequence. This setting determines how long the sensor will take to make a measurement. *MeanCount* can be changed as described in chapters 4 and 5.

2.10.1 Setting the Stage

Many applications use the pressure sensor to measure water level in a gauge or reservoir. The sensor translates water pressure to water level. When the H-3521 is first installed, you will want to adjust the *Offset* such that the measurement data (*Stage*) corresponds to the current water elevation or stage as determined with a staff gauge or other datum.



One of the ways to do this is by using the RS232 simple menu interface via *Hyperterminal* or other similar terminal program. See chapter 4 section *Connecting to the H-3521*. Once you have established connection your screen will look similar to the screen image below. When the user sets the stage, the H-3521 makes a fresh measurement and automatically updates the *Offset* as needed to produce the desired *Stage*. To set the stage using the RS-232 menu press 'S' for "S - Stage:" and enter in the current stage value and then press enter. Then press the 'M' key for "M - Measure" and verify that the set stage command did execute. You should see that the offset value has changed. The other way to set the stage is to send the extended SDI-12 "Set Current Stage" command. The "aXSCSdd.d!" command is discussed in more detail in section chapter 5.

Example of a H-3521 Fluid Extended "Set Current Stage" command:

Command	Response	Time	Values	Description
"aXSCS2.3!"	"a0061<cr><lf>"	6sec	1	Set the *Stage* to 2.3

Subsequent Command	Response	Description
"aD0"	a+12.80<cr><lf>	The new *Offset*

2.10.2 4-20mA Output

The H-3521 has a 12-bit digital-to-analog converter (DAC), precision voltage reference and a 4-20mA current transmitter. The SDI-12 and 4-20mA sections are isolated from each other with a high voltage digital opto-coupler. The *Stage* is scaled into a 12-bit value and loaded into the digital-to-analog converter to control the current transmitter. The 4-20mA output is updated whenever a measurement is made. If no measurements are made, the 4-20mA output becomes "stale". For industrial applications where the H-3521 is connected to a SCADA or PLC system instead of a SDI-12 data logger, the H-3521 can be programmed to automatically make continuous measurements. To program the H-3521 to make continuous measurements, issue an extended SDI-12 command and set *Power_Mode*=3. See Chapter 4 for details. This setting can be made at the factory if requested.

Note: When the H-3521 is first powered up, the output current is set to 4.0mA. It remains at 4.0mA until the first measurement sequence. The digital-to-analog converter is powered from the loop side of the opto-isolator. If the loop power is disconnected or is applied after the SDI-12 side is powered up, the data in the digital-to-analog converter will be lost. When the loop power is restored, the 4-20mA output will be at an unknown value. Once a fresh SDI-12 measurement is made, the digital-to-analog converter is loaded with new valid data.

2.10.3 Programming the 4-20mA Output Range

The H-3521 scales the current *Stage* data to drive the 4-20mA output. The *4-20mA_Hi* and *4-20mA_Lo* settings control how the *Stage* data is processed. The *4-20mA_Lo* should be set to the desired *Stage* corresponding a 4.00mA output. The *4-20mA_Hi* should be set to the desired *Stage* corresponding to a 20.00mA output. For testing purposes, the H-3521 comes from the factory with *4-20mA_Hi* = 20.0 and *4-20mA_Lo* = 4.00. See Chapter 4 for details on programming these settings. The extended "aXS!" command allows convenient testing of the 4-20mA output. This command allows the user to temporarily force the *Stage* to a test value. For example, the user can force the *Stage* to several different values while calibrating or monitoring the attached 4-20mA instrumentation. Once a fresh measurement is made via a SDI-12 measurement , the temporary *Stage* data is overridden.

2.11 Testing

Before installing the H-3521 in your field location, you may wish to first test the sensor and data logger in your shop or lab. This allows you to become familiar with H-3521 and the data logger in a controlled environment. The H-3521 can be tested with a pressure standard or water filled standpipe. However, for this test to work correctly, the standpipe must be connected to the chassis ground of the data recorder. The wire establishes a ground connection between the water and the data logger. Water and other conductive objects isolated by a plastic bucket or table surface pick up AC noise from nearby lighting and power lines. The AC noise is coupled by the water to the stainless diaphragm in the pressure sensor. If a plastic or non-conductive tube is used to connect to the pressure source to the H-3521, the sensor will be electrically isolated from the water media. The AC noise may affect the pressure measurement due to large voltages between the water media and the sensor (data logger) ground. This precaution is not necessary for field installations because surface water and ground water are not isolated from earth ground.

Chapter 3
Maintenance

3.1 Maintenance

Sustained operation of the H-3521 pressure sensor is almost maintenance-free. As with any precision instrument, the calibration should be checked on a regular basis. The instrument has no filters or user serviceable internal parts.

3.2 Precautions

- Check for leaks, make certain the connections to the pressure port are tight.
- Make certain the atmospheric vent is not covered or blocked.
- Make certain the gauge station enclosure is open to the atmosphere. If the sensor is placed in a cabinet or sealed enclosure, the cabinet must have a screened vent or other opening to the atmosphere.

3.3 Offset Drift

Unlike sensors which measure dry gas pressure (H-350/H-350LITE) the H-3521 does not have an internal valve for measuring and removing long term offset drift. The pressure sensor is very stable however, as with any pressure sensor, long term offset drift will occur. We recommend that the sensor be factory calibrated on a yearly basis in order to maintain the highest level of accuracy. As an alternative, the sensor offset can be adjusted in the field using a pressure standard or known hydrostatic pressure as a reference and using the *Offset* or *Set Current Stage* commands.

3.4 Trouble Shooting

Experience over the years with pressure sensors has identified several common problems:

No SDI-12 response or intermittent data

1. Check all wiring including power and ground connections. Battery connections can become corroded. Check for corrosion in the connectors and terminal strips.

2. The H-3521 measures and reports it's internal power supply voltage along with *Stage* and *Pressure*. Make a measurement and check to see if the voltage is between 10.0 and 16.0 Volts.

3. Check the connections between your data recorder and the H-3521 sensor.

4. Verify that there is not another SDI-12 sensor on the SDI-12 bus with the same SDI-12 address as the H-3521. Try communicating with the H-3521 without any other SDI-12 devices on the bus. Sending a "*!" or "?!" should cause the H-3521 to return its own address as long as there are no other SDI-12 devices on the SDI-12 bus.

Chapter 4
Simple Menu Interface

4.0 Simple Menu Interface

The H-3521 has a RS-232 interface which is convenient for setup and testing. This chapter is a description of the Simple Menu interface. Included is a description of the menu and each setup option.

4.1 Connecting to the H-3521

The Simple Menu interface is designed to work with a terminal program such as Hyper-Terminal, Procom or other similar terminal programs. The following table shows the settings that are needed for communication with the H-3521.

COMMUNICATION SETTING	**H-3521 SETTINGS**
BAUD RATE:	9600
DATA BITS:	8
STOP BITS:	1
PARITY:	None
DUPLEX:	Full
TERMINAL EMULATION:	VT-100
FLOW CONTROL:	Software (Xon / Xoff)

After the computer is connected, pressing any key ONCE! (while the H-3521 is in sleep mode) will cause the H-3521 to wake up, make a new measurement and print the following message:

```
Stage = +/-X.XX
Temp = +/-XX.X
```

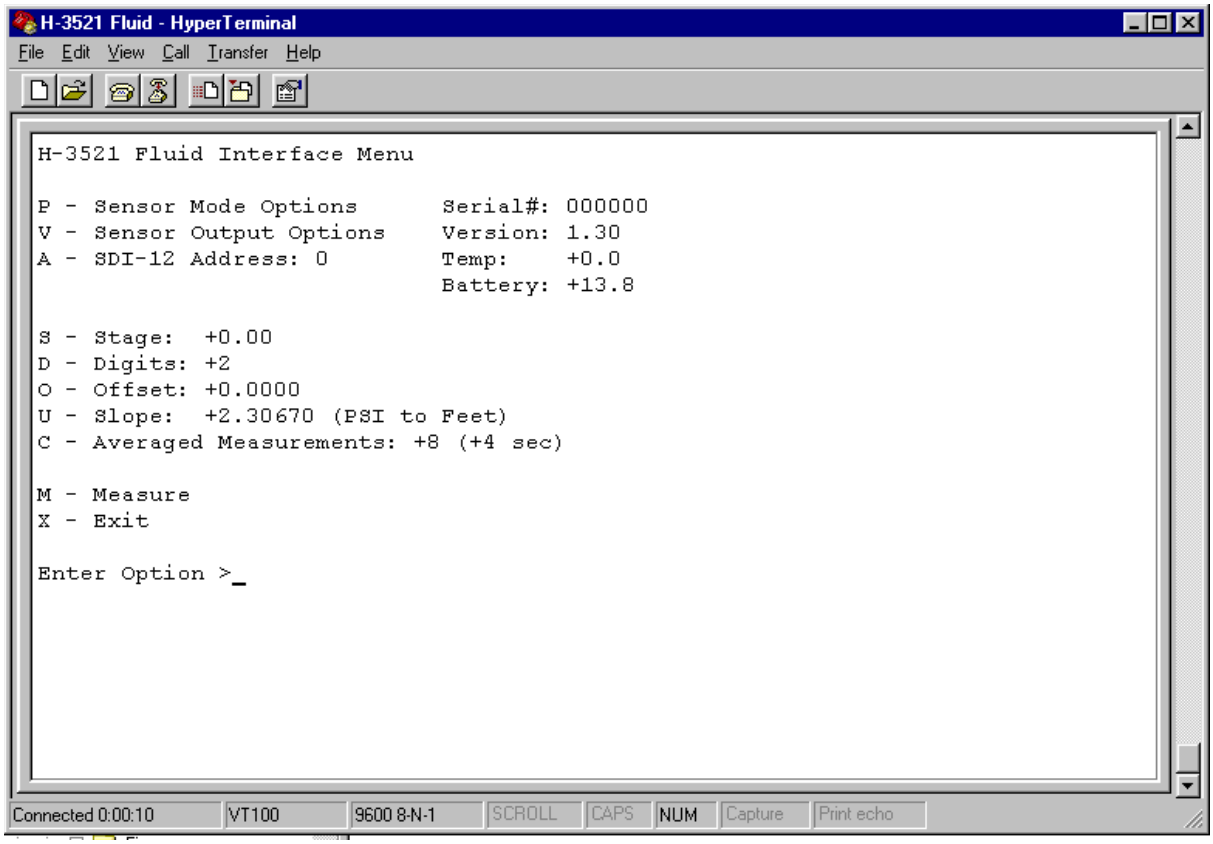
When the ENTER key is pressed after the H-3521 is awake it will invoke the H-3521 Simple Menu. You will see a “Measuring...” message displayed as the H-3521 makes a fresh measurement. Then the H-3521 will display the Simple Menu as shown on the following page.

4.2 General Operations

The H-3521 settings can be made either via the Simple Menu or with extend SDI-12 commands. This chapter focuses on the Simple Menu interface.

The menu displays a list of available options. The right column is status information and cannot be edited. At the bottom of the screen is an "`Enter Option >`" prompt. Enter the desired menu option here, the ENTER key does not have to be pressed.

Some options, when selected act as a toggle and will change when selected. These options only have two choices such as: On/Off. Options with brackets "`[ ]`" allow the user to set or change a value. After entering the requested value within the brackets, press ENTER to make the change. If you do not want to edit the option that has been selected, press the ESC key and the edit will be aborted.



4.3 Menu Options

4.3.1 P - Sensor Mode Options

In this sub-menu you can view the current H-3521 power mode settings or other modes if available and change the modes if desired. Refer to section 4.4 for the Sensor Mode Options sub-menu options.

4.3.2 V - Sensor Output Options

In this sub-menu you can view the current H-3521 output options and enables. In this sub-menu you can change these options and enables. Refer to section 4.5 for the Sensor Output Options menu options.

4.3.3 A - SDI-12 Address

This option is for editing the SDI-12 sensor address of the H-3521. The following prompt appears the bottom of the menu.

```
Enter Option >Enter New SDI-12 Address [ ]
```

Enter the desired SDI-12 sensor address (0-9, a-z, A-Z), the menu will refresh with the new address.

4.3.4 S - Stage

This option is for displaying the last measured stage value and also for setting the current stage. The following prompt at the bottom of the menu.

```
Enter Option >Enter Stage Value[        ]
```

Enter the stage setting you desire and press the ENTER key. The message `"Calculating New Offset..."` will then be displayed. The H-3521 makes a new measurement and then calculates the offset needed to obtain the desired stage setting. When the measurement is complete the offset value will have changed. You must make a new measurement "M" to see the results of the new offset.

4.3.5 D - Digits

This option is for displaying the current stage digits to the right of the decimal and also for editing the number of digits to the right of the decimal. After pressing the D key the user will see the following prompt at the bottom of the menu.

```
Enter Option >Stage Digits [   ]
```

4.3.6 O - Offset

This option is for displaying the current stage offset value and also for editing the stage offset value manually. The following prompt appears at the bottom of the menu.

```
Enter Option >Enter Offset Value[        ]
```

Enter the desired stage offset value and press the ENTER key to input the value. The

screen will refresh and show the new offset. You must make a new measurement "M" to see the results of the new offset.

4.3.7 U - Slope

This option is for displaying the current stage slope and also for editing the stage slope. The following prompt at the bottom of the menu.

```
Enter Option >Enter Slope Value[        ]
```

Enter the new stage slope and press the Enter key to input the value. The screen will refresh and show the new slope. You must make a new measurement "M" to see the results of the new stage slope.

Note: When the stage slope is set to 2.3067 then the label (PSI to Feet) is appended to the slope value and when the slope is set to 0.70308 then the label (PSI to Meters) appears.

4.3.8 C - Averaged Measurements

This option is for displaying the current Averaged Measurements/Meancount value and for editing the value. The option also displays the estimated time that the measurement will take due to the amount of averaging. The following prompt at the bottom of the menu.

```
Enter Option >Averaged Measurements [   ]
```

Enter the new averaged measurements/meancount and press the ENTER key. Refer to Chapter 5 for more details on the meancount value.

4.3.9 M - Measure

Pressing the M key causes the H-3521 to make a new measurement and refresh the screen with the new measurement data. The user will see the following message after pressing the M key.

```
Enter Option >Measuring...
```

4.3.10 X - Exit

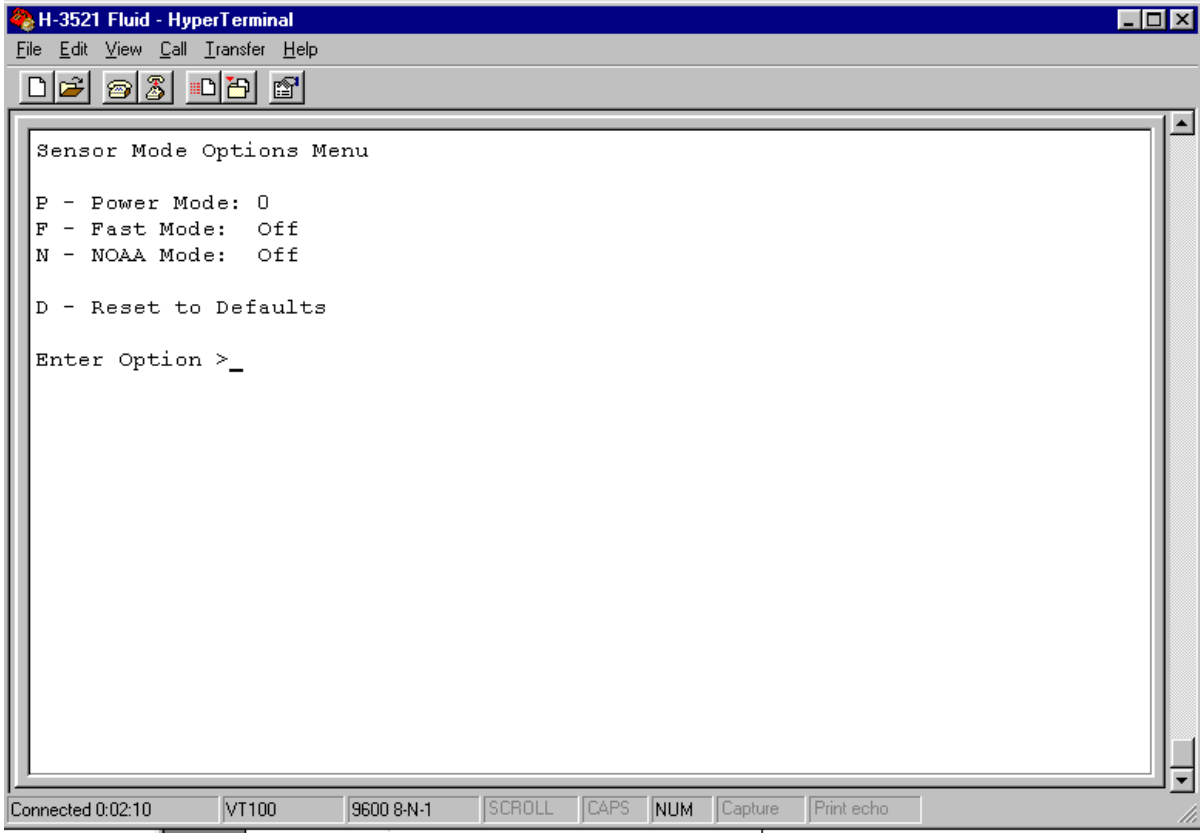
Pressing the X key causes the H-3521 to exit the Simple Menu mode. The user will see the following message after pressing the X key.

```
Enter Option >

H-3521 Fluid Off
```

4.4 Sensor Mode Options Menu

This setup menu is for viewing and editing the H-3521 power modes and other mode enables.



4.4.1 P - Power Mode

This option is for changing the H-3521 power mode. The following prompt at the bottom of the menu.

```
Enter Option >Power Mode Value(0-4) [ ]
```

Enter in the desired power mode.

```
Power Modes:
```

0 = Sleep between measurements
1 = Sleep with sensor bias On (reserved for factory use)
2 = Sleep with sensor bias and reference On (reserved for factory use)
3 = Wait mode. Make measurements and update all outputs based on the measure rate
4 = Wait mode. Power profile for Modbus

The menu will refresh with the new power mode.

4.4.2 F - Fast Mode

This option is the enable for putting the H-3521 in a special mode called Fast Mode. Fast Mode causes the H-3521 to complete measurements in 1 second vs. the normal mode which takes about 6 seconds. This mode is not recommended because the atmospheric pressure and temperature values are only updated every 3 minutes and the H-3521 does

not average as many measurements. When in this mode the Meancount/Averaged measurements value are not used. But if there is an application where the user needs the H-3521 to measure that fast this mode does work. Therefore, the user may lose some accuracy using this mode because the H-3521 is calibrated in the normal mode with the atmospheric pressure and temperature measured every measurement. After pressing the F key the screen will refresh with the option changed.

4.4.3 N - NOAA Mode

This options is the enable for putting the H-3521 in NOAA Mode. NOAA Mode causes the H-3521 to complete measurements in less than 1 second. This mode is for NOAA applications where the data collection platform requests a measurement/second for 3minutes and then requests no measurements for 3 minutes. When in this mode the Meancount/Averaged measurements variable is not used. But this is a requirement for NOAA application. After pressing the N key the screen will refresh with the option changed.

4.4.4 R - Measure Rate

This option is a hidden menu option that is **only** available when the H-3521 is on power mode 3. This option is viewing and editing the current measure rate value. After pressing the R key the user will see the following prompt at the bottom of the menu.

```
Enter Option >Measure Rate(0-255)[   ]min
```

Then the user can enter in the desired measure rate. After entering the desired measure rate press the ENTER key to submit the value and then the screen will refresh with the option changed if the value was valid. If the user does not want to change the measure rate then press the ESC key to abort.

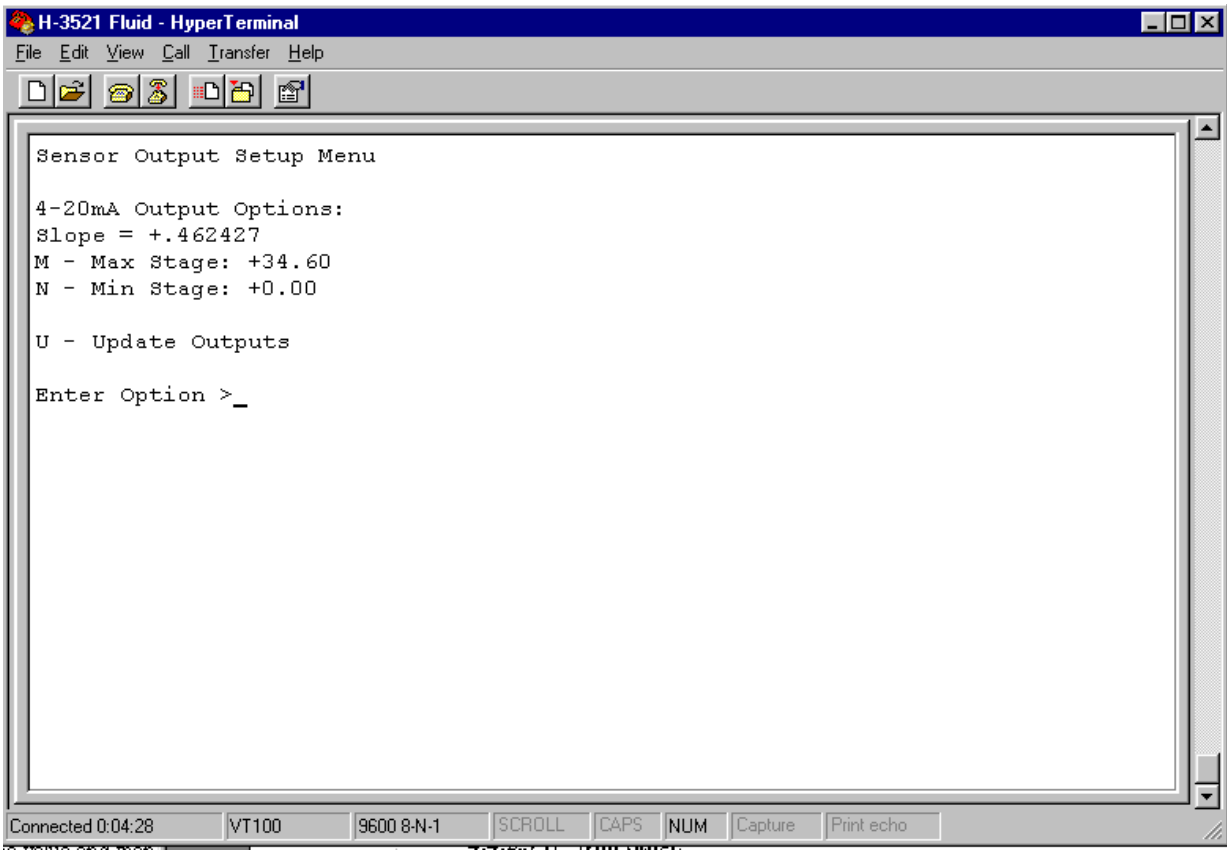
4.4.5 D - Reset to Defaults

This option will reset the H-3521 back to factory user defaults. The following message will be displayed.

```
Enter Option >Resetting to Defaults...
```

4.5 Sensor Output Options Menu

This setup menu is for viewing and editing the current settings of the 4-20mA output.



4.5.1 Slope

This is the current slope that the H-3521 has calculated based on the max and min stage values.

4.5.2 M - Max Stage

This setting is the stage value (high) that corresponds to a 20mA output. The following message is displayed.

```
Enter 4-20mA Max Stage[      ]
```

Enter the desired *Stage* value which corresponds to a 20.00mA output and press ENTER to submit the value. Refer to Chapter-5 for more details about this setting

4.5.3 N - Min Stage

This setting is the stage value (low) that corresponds to a 4.0mA output. The following message is displayed.

```
Enter 4-20mA Min Stage[      ]
```

Enter the desired *Stage* which corresponds to a 4.00mA output and press ENTER to submit the value. Refer to Chapter-5 for more details about this setting.

4.5.4 U - Update Outputs

This option is used to force the H-3521 to make a new measurement and update any enabled outputs. The following message is displayed.

```
Enter Option >Measuring...
```

Chapter 5
SDI-12 Command and Response Protocol

5.0 SDI-12 Command and Response Protocol

This is a brief description of the Serial Digital Interface (SDI-12) Command and Response Protocol used by the ***WATER*LOG®** Series Model H-3521 sensor. Included is a description of the commands and data format supported by the H-3521.

Refer to the document "A SERIAL DIGITAL INTERFACE STANDARD FOR MICROPROCESSOR-BASED SENSORS." Version 1.3 July 25, 2004 Prepared by the SDI-12 Support Group, 165 East 500 South River Heights, Utah.(http://www.sdi-12.org)
Note: The H-3521 incorporates V1.3 with the exception of the CRC request.

During normal communication, the data recorder sends an address together with a command to the H-3521 SDI-12 sensor. The H-3521 then replies with a "response." In the following descriptions, SDI-12 commands and responses are enclosed in quotes. The SDI-12 address and the command/response terminators are defined as follows:

"a"	Is the sensor address. The following ASCII Characters are valid addresses: "0-9", "A-Z", "a-z", "*", "?". Sensors will be initially programmed at the factory with the address of "0" for use in single sensor systems. Addresses "1 to 9" and "A to Z" or "a to z" can be used for additional sensors connected to the same SDI-12 bus. Address "*" and "?" are "wild card" addresses which select any sensor, regardless of its actual address.
"!"	Is the last character of a command block.
"<cr><lf>"	Are carriage return (0D) hex and line feed (0A) hex characters. They are the last two characters of a response block.

Notes:

- All commands/responses are upper-case printable ASCII characters.
- Commands must be terminated with a "!" character.
- Responses are terminated with <cr><lf> characters.
- The command string must be transmitted in a contiguous block with no gaps of more than 1.66 milliseconds between characters.

5.1 Measure Command

The Measure Command causes a new measurement sequence to be executed. Data values generated in response to this command are stored in the sensor's buffer for subsequent collection using "D" commands. The data will be retained in the sensor until another "M", " C", or "V" command is executed.

Command	Response	Description
"aM!"	"atttn<cr><lf>"	Initiate measurement
"aM1!"	"atttn<cr><lf>"	Initiate measurement

Where:

a — is the sensor address ("0-9", "A-Z", "a-z", "*", "?").

M — is an upper-case ASCII character

ttt — is a three digit integer (000-999) specifying the maximum time, in seconds, the sensor will take to complete the command and have measurement data available in its buffer.

n — is a single digit integer (0-9) specifying the number of values that will be placed in the data buffer. If "n" is zero (0), no data will be available using subsequent "D" commands.

Upon completion of the measurement, a service request "a<cr><lf>" is sent to the data recorder indicating the sensor data is ready. The data recorder may wake the sensor with a break and collect the data any time after the service request is received or the specified processing time has elapsed.

Example of a H-3521 "aM!" command:

Command	Response	Time	Values	Description
"aM!"	"a0044<cr><lf>"	4 sec	4	Make measurement

Subsequent Command	Response
"aD0"	a+AA.AA+BB.BBBB+CC.C+DD.D<cr><lf>

Where:

AA.AA = Stage (feet, inches, meters etc.)
BB.BBBB = Pressure (PSI)
CC.C = Temperature (C)
DD.D = Power Supply Voltage (Volts)

Example of a H-3521 "aM1!" command:

Command	Response	Time	Values	Description
"aM1!"	"a0044<cr><lf>"	4 sec	4	Make measurement

Subsequent Command	Response
"aD0"	a+AA.AAAA+BB.B+CCCCCCC.CC+DDDDDDD.DD<cr><lf>

Where:

AA.AAAA	= Pressure (PSI)
BB.B	= Temperature (C)
CCCCCCC.CC	= Raw Pressure A/D Counts
DDDDDDD.DD	= Raw Temperature A/D Counts

5.2 Concurrent Measurement Command

This is a new command since the release of Version 1.2 SDI-12 Specification. A concurrent measurement is one which occurs while other SDI-12 sensors on the bus are also taking measurements. This command is similar to the “aM!” command, however, the nn field has an extra digit and the sensor does not issue a service request when it has completed the measurement. Communicating with other sensors will NOT abort a concurrent measurement. Data values generated in response to this command are stored in the sensor's buffer for subsequent collection using "D" commands. The data will be retained in the sensor until another "M", "C", or "V" command is executed.

Command	Response	Description
"aC!"	"atttnn<cr><lf>"	Initiate measurement

Where:

- a is the sensor address ("0-9", "A-Z", "a-z", "*", "?").
- C is an upper-case ASCII character
- ttt is a three digit integer (000-999) specifying the maximum time, in seconds, the sensor will take to complete the command and have measurement data available in its buffer.
- nn is a two digit integer (00-99) specifying the number of values that will be placed in the data buffer. If "n" is zero (0), no data will be available using subsequent "D" commands.

The data recorder may wake the sensor with a break and collect the data anytime after the specified processing time has elapsed.

Example of a H-3521 "aC!" command:

Command	Response	Time	Values	Description
"aC!"	"a00604<cr><lf>"	6 sec	04	Make measurement

Subsequent Command	Response
"aD0"	a+AA.AA+BB.BBBB+CC.C+DD.D<cr><lf>

Where:

- AA.AA = Stage (feet, inches, meters etc.)
- BB.BBBB = Pressure (PSI)
- CC.C = Temperature (C)
- DD.D = Power Supply Voltage (Volts)

5.3 Send Data Command

The Send Data command returns sensor data generated as the result of previous "aM!", "aC!", or "aV!" commands. Values returned will be sent in 33 characters or less. The sensor's data buffer will not be altered by this command.

Command	Response
"aD0!" through "aD9!"	"apd.d ... pd.d<cr><lf>"

Where:

a	is the sensor address ("0-9", "A-Z", "a-z", "*", "?").
D0..D9	are upper-case ASCII characters.
p	Is a polarity sign (+ or -)
d.d	represents numeric digits before and/or after the decimal. A decimal may be used in any position in the value after the polarity sign. If a decimal is not used, it will be assumed to be after the last digit. For example: +3.29 +23.5 -25.45 +300

If one or more values were specified and a "aD0!" returns no data (<CR><LF> only), it means that the measurement was aborted and a new "M" command must be sent.

Example of a H-3521 "aD0!" command:

Previous Command	Response
"aM!"	"a0064<cr><lf>"

Subsequent Command	Response
"aD0"	a+AA.AA+BB.BBBB+CC.C+DD.D<cr><lf>

Where:

AA.AA	= Stage (feet, inches, meters etc.)
BB.BBBB	= Pressure (PSI)
CC.C	= Temperature (C)
DD.D	= Power Supply Voltage (Volts)

5.4 Continuous Measurements

This is a new command for the Version 1.2 SDI-12 Specification. Sensors that are able to continuously monitor the phenomena to be measured, such as a cable position, do not require a start measurement command. They can be read directly with the R commands (R0!...R9!). The R commands work exactly like the D (D0!...D9!) commands. The only difference is that the R commands do not need to be preceded with an M command.

The H-3521 **does not** support the aR0! continuous measurement commands because the measurement and math operations require several seconds to complete..

5.5 Send Acknowledge Command

The Send Acknowledge Command returns a simple status response which includes the address of the sensor. Any measurement data in the sensor's buffer is not disturbed.

Command	Response
"a!"	"a<cr><lf>"

Where: a Is the sensor address ("0-9", "A-Z", "a-z", "*", "?").

Example of H-3521 "a!" command:

Command	Response	Time	Values	Description
"a!"	"a<cr><lf>"	0 sec	0	Return the address of sensor

5.6 Initiate Verify Command

The Verify Command causes a verify sequence to be performed. The result of this command is similar to the "aM!" command except that the values generated are fixed test data and the results of diagnostic checksum tests. The data generated in response to this command is placed in the sensor's buffer for subsequent collection using "D" commands. The data will be retained in the sensor until another "M", "C", or "V" command is executed.

Command	Response	Description
"aV!"	"atttn<cr><lf>"	Initiate verify sequence

Where:

a is the sensor address ("0-9", "A-Z", "a-z", "*", "?").

V is an upper-case ASCII character.

ttt is a three digit integer (000-999) specifying the maximum time, in seconds, the sensor will take to complete the command and have data available in its buffer.

n is a single digit integer (0-9) specifying the number of values that will be placed in the data buffer. If "n" is zero (0), no data will be available using subsequent "D" commands

Example of a "aV!" command:

Command	Response	Time	Values	Description
"aV!"	"a0014<cr><lf>"	1 sec	4	Return fixed data and diagnostic data for testing purposes.

Subsequent Command	Response
"aD0"	a+123.456+78.9+ddddd+y<cr><lf>

Key	Description	Units
+123.456	Fixed test data	
+78.9	Fixed test data	
+ddddd	ROM checksum value	(0-99999)
+y	ROM checksum test	0 = Failed, 1 = Passed

5.7 Send Identification Command

The Send Identification Command responds with sensor vendor, model, and version data. Any measurement data in the sensor's buffer is not disturbed.

Command	Response
"aI!"	"allcccccccccmmmmmmvvvxx...xx<cr><lf>"

Where:

a is the sensor address ("0-9", "A-Z", "a-z", "*", "?").

I is an upper-case ASCII character.

ll is the SDI-12 version compatibility level, e.g. version 1.2 is represented as "12".

cccccccc is an 8 character vendor identification to be specified by the vendor and usually in the form of a company name or its abbreviation.

mmmmmm is a 6 character field specifying the sensor model number.

vvv is a 3 character field specifying the sensor version number.

xx...xx is an optional field of up to a maximum of 13 characters to be used for serial number or other specific sensor information not relevant to operation of the data recorder.

Example of a "aI!" command:

"a13 DAA H3521vvvS#nnnnnnVkkk<cr><lf>"

H-3521 implementation of the optional 13 character field:

S#nnnnnnVkkk (12 bytes total)

Where:

"nnnnnn" is a six character sensor serial number

"kkk" is a three digit sensor firmware revision level

5.8 Change Sensor Address Command

The Change Sensor Address Command allows the sensor address to be changed. The address is stored in non-volatile EEPROM within the sensor. The H-3521 will not respond if the command was invalid, the address was out of range, or the EEPROM programming operation failed.

Command	Response	Description
"aAn!"	"n<cr><lf>"	Change sensor address

Where:

a — is the current (old) sensor address ("0-9", "A-Z", "a-z", "*", "?"). An ASCII "*" may be used as a "wild card" address if the current address is unknown and only one sensor is connected to the bus.

A — is an upper-case ASCII character.

n — is the new sensor address to be programmed ("0-9", "A-Z").

NOTE: To verify the new address use the "Identify Command."

Example of a "Change Sensor Address" command:

Command	Response	Description
"aA2!"	"2<cr><lf>"	Change sensor address to "2"

5.9 Extended Set Current Stage Command

The H-3521 processes the pressure sensor input and computes *Pressure* in PSI units. *Stage* is computed with a *Stage* = *m* * *Pressure* + b equation. During installation it is convenient to quickly set the H-3521's *Stage* reading to match the current stage, elevation or pressure of the water as determined by a staff gauge or other datum. This command causes the H-3521 to make a fresh measurement and automatically update the *Offset* (b) term as needed to produce the desired *Stage*.

Command	Response	Description
"aXSCSddd!"	“a0061<cr><lf>"	Set current *Stage*

Where: a is the sensor address ("0-9", "A-Z", "a-z", "*", "?").
XSCS are upper case characters.
ddd is the new current stage value.

Example of a H-3521 Extended "Set Current Stage" command:

Command	Response	Time	Values	Description
"aXSCS2.3!"	"a0041<cr><lf>"	4 sec	1	Set the *Stage* to 2.3

Subsequent Command	Response	Description
"aD0"	a+1.80<cr><lf>	The new *Offset*

5.10 Extended Read/Write *Offset* and Read/Write *Slope*

The H-3521 processes the pressure sensor input and computes *Pressure* in PSI units. *Stage* is computed with a *Stage* = *m* * *Pressure* + b equation. The *Slope* (m) and *Offset* (b) terms are programmable, allowing the user to scale the reading into other engineering units. These commands allow the user to read or write (change) the *Slope* and *Offse*t terms. The slope is set to 2.3067 and the offset to 0.00 at the factory. With the factory default (2.3067) the *Stage* will be in units of water depth (in feet). The new values are stored in non-volatile EEPROM within the sensor. Once the new *Slope* or *Offset* value is written to the EEPROM, a copy is sent to the sensor data buffer for verification. This data can be viewed by using a subsequent "D" command. To verify these settings any other time, use the "XRS" or "XRO" commands. This command takes 001 seconds to complete and places 1 value in the data buffer. Use the "aD0" command to collect and view the new slope or offset.

Command	Response	Description
"aXRS!"	"a0011<cr><lf>"	Read *Slope*
"aXRO!"	"a0011<cr><lf>"	Read *Offse*t
"aXWSddd!"	"a0061<cr><lf>"	Write *Slope*
"aXWOddd!"	"a0061<cr><lf>"	Write *Offset*

Where: a is the sensor address ("0-9", "A-Z", "a-z", "*", "?").
XRS are upper case characters.
XRO are upper case characters.
XWS are upper case characters.
XWO are upper case characters.
ddd is the new slope or offset value (For example: 20.0, 195)

Example of a H-3521 Extended "Read *Slope*" command:

Command	Response	Time	Values	Description
"aXRS!"	"a0011<cr><lf>"	1 sec	1	Read *Slope*

Command	Response	Description
"aD0!"	"a+1.00<cr><lf>"	*Slope* is 1.00

Example of a H-3521 Extended "Write *Slope*" command:

Command	Response	Time	Values	Description
"aXWS1.234!"	"a0061<cr><lf>"	6 sec	1	Write *Slope*

Command	Response	Description
"aD0!"	"a+1.234<cr><lf>"	*Slope* is 1.234

5.11 Extended Read/Write Stage Digits

This is for reading or writing the stage digits to the right of the decimal point. The stage digits by default is set to 2.

Command	Response	Description
"aXRSD!"	"a0011<cr><lf>"	Read Stage Digits
"aXWSDd!"	"a0021<cr><lf>"	Write Stage Digits

Where:
- a is the sensor address ("0-9", "A-Z", "a-z", "*", "?").
- XRSD are upper case characters.
- XWSD are upper case characters.
- d is the new enable value(0-9)

Example of a H-3531 Extended "Read Stage Digits" command:

Command	Response	Time	Values	Description
"aXRSD!"	"a0011<cr><lf>"	1 sec	1	Read Stage Digits

Command	Response	Description
"aD0!"	"a+2<cr><lf>"	Stage digits = 2

Example of a H-3531 Extended "Write Stage Digits" command:

Command	Response	Time	Values	Description
"aXWSD3!"	"a0021<cr><lf>"	2 sec	1	Set Stage digits to 3

Command	Response	Description
"aD0!"	"a+3<cr><lf>"	Stage digits = 3

5.12 Extended Read/Write *4-20mA_Hi* and Read/Write *4-20mA_Lo*

The H-3521 scales the current *Stage* data to drive the 4-20mA output. The *4-20mA_Hi* and *4-20mA_Lo* settings control how the *Stage* data is processed. The *4-20mA_Lo* should be set to the desired *Stage* corresponding to a 4.00mA output. The *4-20mA_Hi* should be set to the desired *Stage* corresponding to a 20.00mA output. These settings are stored in non-volatile EEPROM within the sensor. Once the new value is written to the EEPROM, a copy is sent to the sensor data buffer for verification. This data can be viewed by using a subsequent "aD0" command. To verify these settings any other time, use the "XRIH" or "XRIL" commands. The H-3521 comes from the factory with *the 4-20mA_Hi* = 34.6 feet and *4-20mA_Lo* = 0.0 feet.(0-15 psi sensor range)

Command	Response	Description
"aXRIH!"	"a0011<cr><lf>"	Read *4-20mA_Hi*
"aXRIL!"	"a0011<cr><lf>"	Read *4-20mA_Lo*
"aXWIHddd!"	"a0061<cr><lf>"	Write *4-20mA_Hi*
"aXWILddd!"	"a0061<cr><lf>"	Write *4-20mA_Lo*

Where:	a	is the sensor address ("0-9", "A-Z", "a-z", "*", "?").
	XRIH	are upper case characters.
	XRIL	are upper case characters.
	XWIH	are upper case characters.
	XWIL	are upper case characters.
	ddd	is the new value.

This command takes 001 seconds to complete and places 1 value in the data buffer. Use the "aD0" command to collect and view the slope or offset.

Example of a H-3521 Extended "Read 4-20mA_Hi" command:

Command	Response	Time	Values	Description
"aXRIH!"	"a0011<cr><lf>"	1 sec	1	Read *4-20mA_Hi*
Command	Response			Description
"aD0!"	"a+34.60<cr><lf>"			4-*20mA_Hi* is 34.60

Example of a H-3521 Extended "Write 4-20mA_Hi" command:

Command	Response	Time	Values	Description
"aXWIH34.6!"	"a0061<cr><lf>"	6 sec	1	Write *4-20mA_Hi* and make new measurement
Command	Response			Description
"aD0!"	"a+34.6<cr><lf>"			*4-20mA_Hi* is 34.6

5.13 Extended Read *Power_Mode* and Write *Power_Mode*

The quadrature, 0-5V, and 4-20mA outputs are updated whenever a measurement is made. For industrial applications such as 4-20mA where the H-3521 is connected to a SCADA or PLC system and low-power is not of concern, the H-3521 can be programmed to make continuous measurements. This command is used to change the power mode. The H-3521 comes from the factory with the power mode set to the *Sleep* mode. Once a new value is written, a copy is sent to the sensor data buffer for verification. This data can be viewed by using a subsequent "aD0" command. To read or verify the value any other time, use the "XRPM" command.

Command	Response	Description
"aXRPM!"	"a0011<cr><lf>"	Read *Power_Mode*
"aXWPMn!"	"a0011<cr><lf>"	Write *Power_Mode*

Where:

a	is the sensor address ("0-9", "A-Z", "a-z", "*", "?").
XRPM	are upper case characters.
XWPM	are upper case characters.
n	is the new setting (0, 3 or 4):
	0 = Sleep between measurements
	1 = Sleep with sensor bias On (reserved for factory use)
	2 = Sleep with sensor bias and reference On (reserved for factory use)
	3 = Make measurements and update all outputs based on measure rate
	4 = Power profile for Modbus

This command takes 001 seconds to complete and places 1 value in the data buffer. Use the "aD0" command to collect and view the current value.

Example of a H-3521 Extended "Read *Power_Mode*" command:

Command	Response	Time	Values	Description
"aXRPM!"	"a0011<cr><lf>"	1 sec	1	Read *Power_Mode*
Command	Response			Description
"aD0!"	"a+0<cr><lf>"			Mode = Sleep

Example of a H-3521 Extended "Write *Power_Mode*" command:

Command	Response	Time	Values	Description
"aXWPM3!"	"a0011<cr><lf>"	1 sec	1	Write *Power_Mode*
Command	Response			Description
"aD0!"	"a+3<cr><lf>"			Mode 3 = Continuous mode

5.14 Extended Read *Measure Rate* and Write *Measure Rate*

When the H-3521 is put in power mode 3 it makes continuous measurements based on a measure rate. This command is for reading/writing that measure rate value. The measure rate range is 0-255 minutes. When the user sets the measure rate to 0 then the H-3521 makes continuous measurements as fast as the H-3521 will measure, which is about 6 seconds by default. The factory default is 1 minute measure rate.

Command	Response	Description
"aXRMR!"	"a0011<cr><lf>"	Read *Measure Rate*
"aXWMRnnn!"	"a0021<cr><lf>"	Write *Measure Rate*

Where:
- a — is the sensor address ("0-9", "A-Z", "a-z", "*", "?").
- XRMR — are upper case characters.
- XWMR — are upper case characters.
- nnn — is the rate in minutes that the sensor will update all outputs.

Example of a H-3521 Extended "Read *Measure Rate*" command:

Command	Response	Time	Values	Description
"aXRMR!"	"a0011<cr><lf>"	1 sec	1	Read *Measure Rate*
Command	**Response**			**Description**
"aD0!"	"a+1<cr><lf>"			Measure Rate = 1 minute

Example of a H-3521 Extended "Write *Measure Rate*" command:

Command	Response	Time	Values	Description
"aXWMR2!"	"a0021<cr><lf>"	2 sec	1	Write *Measure Rate*
Command	**Response**			**Description**
"aD0!"	"a+2<cr><lf>"			Measure Rate = 2 minutes

5.15 Extended Read *Mean_Count* and Write *Mean_Count*

The H-3521 makes multiple raw sensor measurements, discards the high and low values, integrates (averages) the measurement data and computes *Pressure* (PSI). The number of raw sensor measurements made for each SDI-12 measurement sequence is programmable. When measuring turbulent water, tides or other special applications *Mean_Count* can be changed to increase or decrease the number of pressure measurements made during the SDI-12 measurement sequence.

The H-3521 makes 7.5 pressure measurements per second (133ms/ measurement). The ttt field in the SDI-12 sensor response is computed by the H-3521 and indicates how much time the H-3521 will require to complete the measurement sequence. The ttt field will automatically change if *Mean_Count* is changed.

The H-3521 comes from the factory with *Mean_Count* set to 16. The factory default ttt field is computed internally by the H-3521 as follows:

Raw Measurements:	+2.13 sec (0.133 sec/measurement X 16 measurements)
Math Overhead:	+0.3 sec
Round Upwards	+1.0
	- - - - - - -
ttt	3.0 Seconds

The “aXRMC!” and “aXWMC!” extended commands allow the number of raw sensor measurements for each SDI-12 measurement sequence to be monitored or changed.

Once a new *Mean_Count* value is written, a copy is sent to the sensor data buffer for verification. This data can be viewed by using a subsequent "D" command. To read or verify the value any other time, use the "XRMC" command.

Command	Response	Description
"aXRMC!"	“a0011<cr><lf>"	Read *Mean_Count*
"aXWMCn!"	“a0011<cr><lf>"	Write *Mean_Count*

Where:	a	is the sensor address ("0-9", "A-Z", "a-z", "*", "?").
	XRMC	are upper case characters.
	XWMC	are upper case characters.
	n	is the number of raw measurements wanted

This command takes 001 seconds to complete and places 1 value in the data buffer. Use the “aD0" command to collect and view the current value.

Example of a H-3521 Extended "Read *Mean_Count*" command:

Command	Response	Time	Values	Description
"aXRMC!"	"a0011<cr><lf>"	1 sec	1	Read *Mean_Count*
Command	Response			Description
"aD0!"	"a+8<cr><lf>"			Count = 8

Example of a H-3521 Extended "Write *Mean_Count*" command:

Command	Response	Time	Values	Description
"aXWMC4!"	"a0021<cr><lf>"	2 sec	1	Write *Mean_Count*
Command	Response			Description
"aD0!"	"a+4<cr><lf>"			Count = 4

5.16 Extended Read/Write NOAA Mode Enable

The H-3521 can be put into a NOAA Mode. In NOAA mode the data collection platform requests data from the H-3521 every second for 3 minutes and then is idle for 3 minutes. When NOAA Mode is enabled the H-3521 measurement response time is less than 1 second. Meaning that the Data command can be sent within 1 second after the measure command is issued. When the enable value is set to a '1' the NOAA Mode is enabled and when it is set to a '0' NOAA Mode is disabled.

Command	Response	Description
"aXRNE!"	"a0011<cr><lf>"	Read NOAA Mode enable
"aXWNEd!"	"a0061<cr><lf>"	Write NOAA Mode enable

Where:		
	a	is the sensor address ("0-9", "A-Z", "a-z", "*", "?").
	XRNE	are upper case characters.
	XWNE	are upper case characters.
	d	is the new enable value (0=disabled, 1=enabled)

When the user enables NOAA Mode it takes 6 seconds because it updates the Atmospheric and Temperature values until the 3 minute no activity gap.

Example of a H-3521 Extended "Read NOAA Mode Enable" command:

Command	Response	Time	Values	Description
"aXRNE!"	"a0011<cr><lf>"	1 sec	1	Read NOAA Mode Enable
Command	Response			Description
"aD0!"	"a+0<cr><lf>"			NOAA Mode disabled

Example of a H-3521 Extended "Write NOAA Mode Enable" command:

Command	Response	Time	Values	Description
"aXWNE1!"	"a0061<cr><lf>"	6 sec	1	Enable NOAA Mode
Command	Response			Description
"aD0!"	"a+1<cr><lf>"			NOAA Mode enabled

Example of a H-3521 "aM!" command in *NOAA Mode*:

Command	Response	Time	Values	Description
"aM!"	"a0011<cr><lf>"	1 sec	1	Measure in NOAA Mode
Command	Response			Description
"aD0!"	"a+AA.AA<cr><lf>"			Returns Stage

5.17 Extended "XTEST"

This command is used for installation or production testing and requires the use of a H-4191 Sidekick interface and a PC. This command causes the H-3521 to transmit unsolicited real-time data for testing purposes. The test mode is used to help troubleshoot the installation by providing a continuous readout of pressure data. This is not compliant with the SDI-12 specification and is not used with data loggers.

To activate the test mode, send the command "aXTEST!" from the PC. The H-3521 will enter the test mode and make continuous measurements. The test mode is exited by sending a break or any new command on the SDI-12 bus. It may take a few tries to exit if the command is sent at the same time data is being sent from the H-3521. Removing power from the H-3521 also causes it to exit this mode.

Format:
SensorAdr + Stage + Pressure + Temperature +RawPressure (counts) + RawTemperature (counts)

"XTEST" displays the following data:

```
0: +1.202 +3.222 +23.0 +12345 +67890
0: +1.212 +3.232 +23.0 +12345 +67890
0: +1.222 +3.342 +23.0 +12345 +67890
0: +1.232 +3.352 +23.0 +12345 +67890
0: +1.232 +3.352 +23.0 +12345 +67890
etc.
```

5.18 Extended "XDEF"

This command is used to set all the user settings back to factory defaults. This is useful in troubleshooting when nothings seems to be working.

5.19 Extended "XCFG"

This command is used for installation or production testing and requires the use of a H-4191 Sidekick interface and a PC. This command returns the current configuration of the H-3521.

"XCFG" displays the following data:

```
H-3521 Fluid Configuration
013     DAAH-3521001S#000000V100
Power Mode = +0
NOAA Mode = Off
Mean Count = +8.
User Slope = +2.306700
User Offset = +0.000000
Max PSI = +20.0
4-20mA Slope = +.462427
```

Appendix A
Specifications

Accuracy
(Maximum percent of error in measurement)
Pressure: Less than or equal to 0.03% of full scale output (FSO) over temperature range referenced to a straight line stretched from zero PSI to maximum pressure
Temperature: Internal temperature ±1° C over temperature range

Resolution
(Smallest change detectable in output signal)
Pressure: 0.001%
Temperature: 0.001%

Linearity
Less than 0.03% deviation from a straight line referenced to end points

Pressure Hysteresis
Less than 0.02% of FSO

Long-term Stability
Accuracy drift is less than ±0.05% of FSO per year

Standard Pressure Ranges

Pressure	Depth	Accuracy
0 to 15 PSI	0 to 34.6 ft.	±0.01 ft.
0 to 30 PSI	0 to 69.20 ft	±0.02 ft.

Custom calibration ranges available from 15 - 100 PSI

Pressure Overload
Less than 2 times the rated pressure

SDI-12 Interface
Baud Rate: 1200
Protocol: SDI-12 V1.3, 7-bit even parity, 1 stop bit
Output Voltage Levels:
Minimum high level: 3.5 volts
Maximum low level: 0.8 volts

Response Time
SDI-12: 3-second measurement sequence (programmable)

RS-485 Interface
Protocol: Modbus RTU
Port: RS-485
Baud Rate: Programmable (default=9600)

RS232 Interface
Protocol: RS232, 8bit, No Parity, 1 stop bit
Baud Rate: 9600

4-20mA Output
Type: 4-20mA, optically isolated
Loop Voltage: 8.0V min, 35V max
Resolution: 4μA (12-bit DAC)

Power Requirements
Voltage Input: 10 to 16.0 Volts DC
Supply Current:
Sleep Mode 500μA typ
Active (measuring) 15mA typ
Bias Mode 1.5maA typ
Surge Protection: Built in, 1.5 KVA

Environmental
Operating Temperature: -40° C to 60° C
Compensated Range: -30° C to 60° C
Storage Temperature: -40° C to 80° C

Media Compatibility
Liquids and gases compatible with RTV, stainless steel and brass

Mechanical
Material: Fiberglass
Size: 4.76" x 4.76" x 2.5" high
Rating: NEMA-4 enclosure
Pressure Inlet: 1/8" female NPT
Atmospheric Vent: Sintered bronze, #10-32

Connectors
H-3521: Amphenol MS3102R16S-1P (7-Pin male)
Cable: Amphenol MS3106A16S-1S (7-Pin female)
(supplied with the H3521)

H-3521: Amphenol MS3102R10SL-3P (3-Pin male)
Cable: Amphenol MS3106A10SL-3S (3-Pin female)
(connector available, order separately)

The ***WATER*LOG®** H-3521 is warranted against defects in materials and workmanship for one year from date of shipment.

Notes
Specifications subject to change without prior notice due to ongoing commitment to product testing and improvement.

Appendix B
Modbus Protocol

B.1 Modbus Interface

Modbus is an industry standard field bus for interconnecting Programmable Logic Controllers (PLCs), intelligent sensors and other devices. The H-3531 FlashLite™ is a Modbus slave and has a serial RS-485 port for connecting to a Modbus compatible host device. See Chapter 2 for the proper connections. Continuous +12Volt power must be supplied to the H-3531 FlashLite™.

B.2 Modbus RTU Transmission

The H-3531 FlashLite™ supports RTU (Remote Terminal Unit) transmission mode. The host must support RTU mode to communicate with the H-3531 FlashLite™. The RTU framing format for each byte is fixed at 11-bits and is as follows: 1 start bit, 8 data bits, 1 parity bit, and 1 stop bit. The H-3531 FlashLite™ defaults to even parity but the user can change to no parity (parity fixed = 1). In RTU transmission mode all request and response bytes are sent as two 4-bit hexadecimal characters. RTU transmission mode also defines certain message frame timing constraints, this will not be discussed in this document but the user can find the RTU mode transmission specifications online at www.modbus.org.

B.3 Modbus Function codes

The H-3531 FlashLite™ supports three Modbus function codes as shown in the table below.

Table 1 - Supported Function Codes

Function Code	Description	# of Registers to R/W
03	Read Holding Registers	28
04	Read Input Registers	8
06	Write Single Holding Register	11

B.4 Holding Registers

There are 25 holding registers in the H-3531 FlashLite™, some are Read/Write registers and some are Read Only registers. The user configurable settings are found in the Holding Registers. Table 2 below shows the contents on the Holding Registers followed by a description of each register.

Table 2 - Holding Registers

Info in Register	Start Address	# of 16-bit Registers	Data Type
ID String	0 / “0000"	17	Char String
Modbus Address	18 / “0012"	1	Short Integer
Stage Units Select	19 / “0013"	1	Short Integer
Reserved	20 / “0014"	1	Short Integer
Modbus Baudrate	21 / “0015"	1	Short Integer
Parity	22 / “0016"	1	Short Integer
User Stage Offset	23 / “0017"	4	IEEE F P.
User Stage Slope	27 / “001B”	4	IEEE F.P.
User Stage Offset	31 / “001F"	2	IEEE F.P.
User Stage Slope	33 / “0021”	2	IEEE F.P.
Set Current Stage	35 / “0023”	4	IEEE F.P.
Set Current Stage	39 / “0027”	2	IEEE F.P.

B.4.0 ID String(RO)

The first registers in the Holding Registers are the ID string registers, this is the same ID string that the SDI-12 ID command returns. Refer to SDI-12 ID command to see details of the response. The ID string consists of 17, 16-bit registers. These registers can be read separately but to get the full ID string the user must read all 17-registers at once. These registers are RO (read only) registers. As shown in Table 2 the response to reading the ID string is sent as a ASCII character string. Example, to read the full ID string the host must send the request as follows: “aa0300000011crcc”

H-3531 FlashLite™ Response: “113 DAA H-3531001S#000000V011<CR><LF>0000"

B.4.1 Modbus Address(R/W)

This holding register allows the user to change the Modbus address of the H-3531 FlashLite™. The programmable address range is: 1 - 247. The assigned Modbus address factory default is: ‘1'. Address “0" is reserved for the broadcast address meaning that all Modbus sensors will respond to address “0".

B.4.2 Stage Units Select(R/W)

This holding register allows the user to change the units of the stage that is reported in the input registers. Below shows what values to write to the register to change to the desired units.

Stage Units Select Register: = 00 (stage in feet)
= 01 (stage in meters)
= 02 (stage in inches)
= 03 (stage in mm)
= 04 (stage in cm)
= 05 (raw psi)
= 05 (user defined) * *factory default*

B.4.3 Reserved(R/W)

This holding register is reserved space for future use.

B.4.4 Modbus Baud rate(R/W)

This holding register allows the user to change the baud rate of the RS-485 port. This register for H-3531 FlashLite™ defaults to 00, which is 9600 baud. When the user changes the baud rate it does not take effect until the power is cycled. The list below shows what values to write to select the desired baud rate.

Modbus Baud rate Select Register: = 00 (9600) * *factory default*
= 01 (4800)
= 02 (2400)
= 03 (1200)

B.4.5 Parity(R/W)

This holding register allows the user to change the parity bit. The list below shows what values to write to select the desired parity.

Modbus Parity Select Register: = 00 (No Parity)
= 01 (Even Parity) * *factory default*

B.4.6 User Stage Offset(R/W)

This holding register allows the user to enter a user defined stage offset. The factory default is 0. This holding register is a 64-bit holding register, therefore the value sent to write to this register must be in a 64-bit floating point number format. As shown in the table there is also a 32-bit floating point number register for this value.

B.4.7 User Stage Slope(R/W)

This holding register allows the user to enter a user defined stage slope. Writing to this register is only applicable when the Stage Units Select Register is set to 06, which indicates the user defined mode for the units. This holding register is a 64-bit holding register, therefore the value sent to write to this register must be in a 64-bit floating point number format. The factory default slope is 2.3067, which sets stage units to feet. As shown in the table there is also a 32-bit floating point number register for this value.

B.4.8 Set Current Stage(WO)

This holding register allows the user to set the current stage by writing the current stage value to this register. Reading this register is not applicable. This holding register is a 64-bit holding register, therefore the value sent to write to this register must be in a 64-bit floating point number format. As shown in the table there is also a 32-bit floating point number register for this command.

Example Reading Holding Register Command:

Format: "aabbccccddddeeee"

Where: aa = 1 byte Modbus address
bb = 1 byte function code
cccc = 2 byte start address
dddd = 2 byte quantity of registers
eeee = 2 byte crc check

example: 010300010001xxxx

Example Writing Single Holding Register Command:

Format: "aabbccccddddeeee"

Where: aa = 1 byte Modbus address
bb = 1 byte function code
cccc = 2 byte start address
dddd = 2 byte or dddddddd 4 byte register data value
eeee = 2 byte crc check

example: 010600010001xxxx

Example Reading Input Register Command:

Format: "aabbccccddddeeee"

Where: aa = 1 byte Modbus address
bb = 1 byte function code
cccc = 2 byte start address
dddd = 2 byte quantity of registers
eeee = 2 byte crc check

example: 010400010001xxxx

B.5 Input Registers

The input registers of the H-3531 FlashLite™ hold the measurement data. When the user sends a read command to read an input register the register read initiates a measurement sequence and returns the updated value. Note: The measurement sequence takes approximately 3 seconds to complete before the requested data is sent. The host must know this so that it does not timeout or send a retry. These registers are 64-bit floating point (double precision) numbers. Table 3 below shows the contents of the input register followed by a description of each register.

Table 3 - Input Registers

Info in Register	Start Address	# of 16bit Registers	Data Type
Stage	0 / “0000"	4	IEEE F.P.
Pressure	4 / “0004"	4	IEEE F.P.
Temperature	8 / “0008"	4	IEEE F.P.
Battery Voltage	12 / “000C”	4	IEEE F.P.
Stage	16 / “0010"	2	IEEE F.P.
Pressure	18 / “0012"	2	IEEE F.P.
Temperature	20 / “0014"	2	IEEE F.P.
Battery Voltage	22 / “0016”	2	IEEE F.P.

B.5.0 Stage(RO) This input register holds the current measured stage in the desired units. As shown in the table you can also read the value as a 32-bit floating point number.

B.5.1 Pressure(RO) This input register holds the current measured pressure before any slope or offset is applied, therefore it holds the raw psi value. As shown in the table you can also read the value as a 32-bit floating point number.

B.5.2 Temperature(RO) This input register holds the current measured temperature. This temperature reading is the temperature of the internal pressure sensor and may not accurately reflect air temperature. As shown in the table you can also read the value as a 32-bit floating point number.

B.5.3 Battery Voltage(RO) This input register holds the current input voltage. As shown in the table you can also read the value as a 32-bit floating point number.