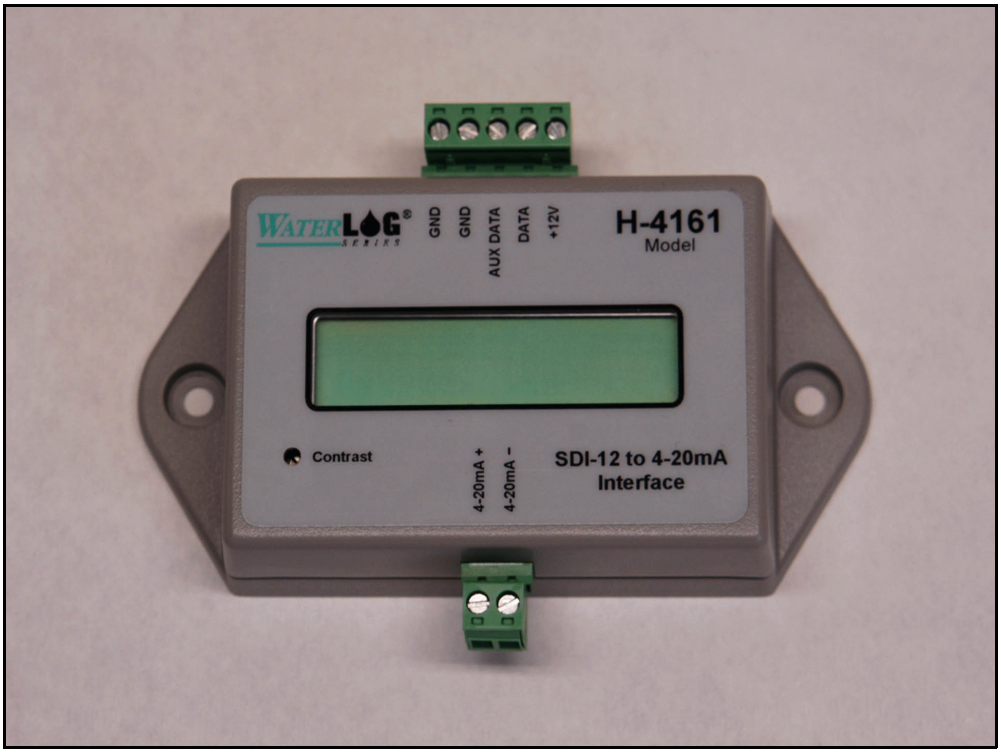
Model
H-4161

SDI-12 to 4-20mA Interface

WATERLOG® SERIES

Owner's Manual
Version 1.3



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Chapter 1
Introduction

1.0 Introduction

The ***WATER*LOG®** H-4161 is a SDI-12 to two-wire 4-20mA interface module. The H-4161 can be programmed to either monitor communications between a data logger and its attached sensors or to initiate measurements by itself. The measurement data is scaled as needed and output to a precision two-wire 4-20mA current transmitter.

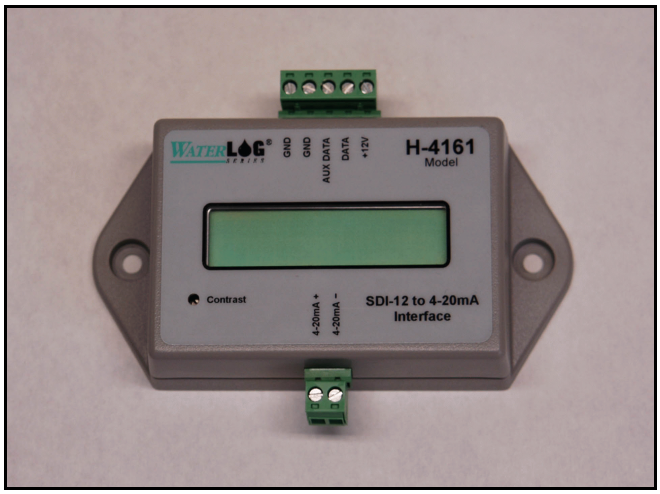

Figure 1 H-4161 SDI-12 to 4-20mA Interface

The "SDI-12 Serial-Digital Interface" is ideal for data logging applications with the following requirements:

- Battery powered operation with minimal current drain
- Low system cost

The H-4161 has the following features:

- Precision 16-bit 4-20mA current output
- 1000V output isolation from the SDI-12 bus
- Can monitor the SDI-12 bus for a specified sensor address and data parameter
- Can initiate measurements to an attached sensor
- Programmable "Max" and "Min" data set points for automatic data scaling
- Manual "set" of the 4-20mA output using an extended SDI-12 command
- Two SDI-12 ports

1.1 Description

The H-4161 includes a microprocessor, LCD display, 16-bit digital-to-analog converter, 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. Data collected from the SDI-12 bus is scaled by the microprocessor into a 16-bit value and loaded into the digital-to-analog converter. The digital-to-analog converter directly controls the current transmitter.

The H-4161 has two SDI-12 ports. The primary SDI-12 port provides data monitoring and communication with the H-4161 device itself. When programmed to initiate measurements, the H-4161 makes measurements and collects the data from a sensor connected to the auxiliary SDI-12 port.

1.2 Display

The H-4161 has a 2-line x 16-character Liquid Crystal Display (LCD) which shows the current measurement data. Line-1 displays the most recently captured SDI-12 data parameter. If the sensor buffer is invalid (no data captured or the previous measurement failed) the message "no data" is shown instead of a number. Line-2 displays the current setting of the 4-20mA output. Note: the mA value is the desired loop current setting which the microprocessor loads into the digital to analog converter. If the 4-20 mA loop is open, or insufficient loop voltage is present the actual loop current may be zero or may not match the value on the display.

```
SDI = xxx.xx  ft -
Iout = xx.xx  mA
```

The character on the right hand side of Line-1 is an activity "spinner". Every time a measurement is captured or initiated, the spinner changes (rotates). This indicator shows measurements are being made even if the measurement data is static (not changing).

1.3 Connectors

The H-4161 has a 5-terminal connector for making +12V and SDI-12 connections. The primary SDI-12 terminal is connected to the data logger and it's attached sensors. If the H-4161 is to initiate measurements, the auxSDI-12 terminal is connected to the SDI-12 sensor to be monitored. The 2-terminal connector is for making connections to the 4-20mA loop.

1.4 Monitor SDI-12 Communications (Module Mode = 0)

During normal operation the data recorder sends commands to one or more SDI-12 sensors and subsequently collects data from the sensors. As a "data monitor", the H-4161 passively monitors the communication between the data recorder and its SDI-12 sensors. The H-4161 waits for, and collects a specified data parameter from a specified sensor. The data is scaled and used to update the H-4161's 4-20mA output. In this mode the H-4161 monitors, but does not transmit data to the SDI-12 bus. The data recorder must initiate any sensor measurements.

The data recorder can also communicate with the H-4161 directly as a normal SDI-12 "sensor". Using extended SDI-12 commands, the data recorder/user can manually set the 4-20mA output, observe the last data collected or configure the H-4161.

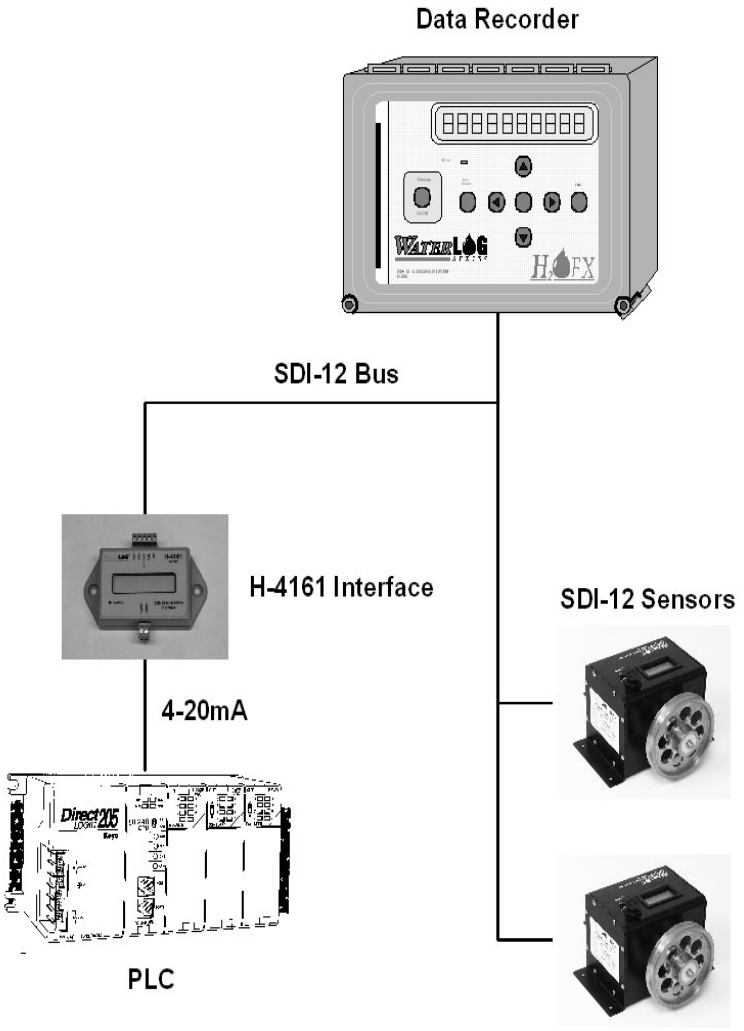

Figure 2 The H-4161 monitors the SDI-12 bus for a selected parameter

1.3 Initiate Measurements (Module Mode = 1)

Applications often arise where is it desired to connect a SDI-12 sensor directly to a 4-20mA input device such as a PLC without the use of a data logger. When programmed to initiate measurements, the H-4161 sends 0M! (or 0M1 to 0M9) commands to the sensor attached to the auxSDI-12 port and collects the measurement data. The data is scaled and used to update the H-4161's 4-20mA output.

The *Initiate Measurement* mode also provides support for a hybrid architecture employing both a data logger and PLC. Both the primary and auxSDI-12 ports can be used. For example, the following illustration shows a dam equipped with sixteen SDI-12 gate position sensors (inclinometers). Each gate is equipped with a H-4161 module which initiates measurements and sends 4-20mA data to the PLC. All 16 channels make simultaneous measurements. The radial architecture provides near real-time gate position data to the PLC. The system also has a data logger which periodically collects the gate position and other data on a timed schedule. The data logger sends "aM!" measurement commands to each H-4161 and collects the resulting data, channel-by-channel. The measurement data collected in response to the "aM!" command will be the data from the most recent measurement made by the H-4161 to the sensor on the auxSDI-12 port (no actual "measurement" is made). The H-4161 supports simultaneous SDI-12 commands/responses on both the primary and auxSDI-12 ports. The data logger can collect gate position data without disturbing any measurements currently in progress with the gate position sensors.

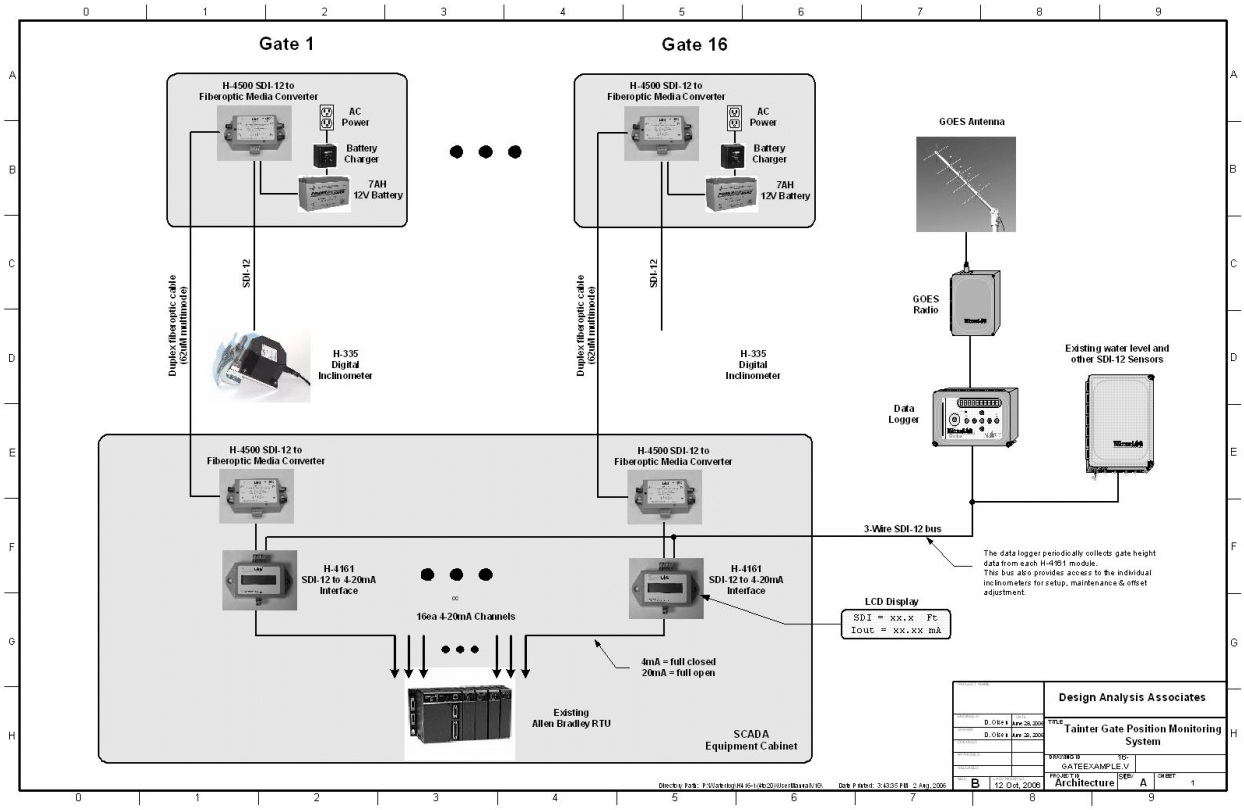

Figure 3 Example architecture with sixteen 4-20mA channels and a data logger

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Chapter 2
Installation And Maintenance

2.1 General Installation Recommendations
The enclosure and connectors are not weather tight. The H-4161 must be installed in a protected location or a weather tight enclosure. The enclosure has a 5-terminal connector for making power and SDI-12 connections and a 2-terminal connector for connecting the 4-20mA output connections. The connectors can be detached while making the connections.

Caution:	Remove all power from the unit before making any connections.

Before beginning the installation take a minute to plan out your station grounding and wiring scheme.

2.2 Making Power and SDI-12 connections
Connect the +12V and GND terminals to a 12V power source. If the H-4161 is to be used to *Monitor*, connect the primary SDI-12 data terminal to the SDI-12 bus between your data logger and its sensors. If the H-4161 is to be used to *Initiate*, connect the auxSDI-12 terminal to the sensor to be monitored. The sensor address of the sensor connected to the auxSDI-12 terminal should be "0" (this can be changed by editing the AutoScan address). The sensor address must be set before connecting the sensor to the H-4161.

2.3 Making the 4-20mA connections
The H-4161 has a 2-wire "self powered" current loop transmitter. Current loop sensors output a current rather than a voltage. The 4-20mA output will drive standard industrial telemetry and process control instrumentation. Use shielded twisted-pair cable and take precautions to protect the wiring from noise and interference. Your loop power source, loop receiver and the H-4161's output should all be connected in series. The loop power supply must be sufficient to maintain 5.5V to 35V across the H-4161s output terminals, in addition to whatever voltage is needed to maintain 20mA across the loop receiver and interconnect wiring. The gauge station +12.0V SDI-12 power source will work if the resistance of your loop receiver and wiring is less than 250 ohms.

$$5.5V + (250\Omega * 20mA) = 10.5V$$

- Make certain their is 5.5 to 35V across the 4-20mA output terminals.
- Make certain the H-4161 is receiving +12V power from the SDI-12 data bus.
- Use shielded, twisted-pair cables for the 4-20mA connections in noisy environments.

Note:
The SDI-12 logic and the 4-20mA interface are isolated from each other by digital optical isolators. The SDI-12 logic is powered from the +12V input terminal, the 4-20mA circuitry is self-powered from the 4-20mA loop. When the H-4161 is first powered up, the output current is set to 4.0mA. It remains at 4.0mA until the first successful data collection sequence. 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 undefined. When the loop power is restored, the 4-20mA output will be at an unknown value. Once a fresh SDI-12 data collection is made the digital-to-analog converter will be loaded with new valid data.

Caution:
Some Programmable Logic Controllers and telemetry devices "multiplex" their 4-20mA inputs such that the current loop(s) are momentarily opened as the controller makes it measurement scan. The H-4161 will NOT work with equipment of this type because the optically isolated transmitter in the H-4161 will loose it's current setting whenever the loop is momentarily opened.

2.4 Programming the H-4161
The H-4161 comes from the factory with the following settings:

H-4161 device address	0
Max setpoint:	20.00
Min setpoint:	4.00
Monitored Address:	Z
Monitored Parameter:	1
AutoScan Address	0
AutoScan Command:	0 (0M!)
Module Mode:	0 (monitor)
Measurement Rate:	0 (seconds)

These setups are stored in Flash memory within the H-4161 and will not be lost if the power is removed. The extended commands for changing these settings are described in detail in Chapter 3.

2.5 Programming the Sensor Address
The H-4161 comes from the factory with its sensor address set to "0". If more than one sensor is to be connected to the SDI-12 bus, make certain each sensor has a unique sensor address, including any H-4161 modules. The H-4161 is not a traditional sensor and does not 'make measurements". However, to facilitate programming the H-4161 it must have a unique address.

2.6 Programming the *Max* and *Min* data setpoints
Captured SDI-12 data is scaled into 4-20mA units using the programmable *Max* and *Min* data setpoints. This feature makes it easy to setup the H-4161 for your application. For example, if you are monitoring stream stage which could be up to 10 feet, program the *Max* setpoint to 10.00. Perhaps the stream never falls below 5 feet and you would like to narrow the dynamic range of the 4-20mA output for more resolution. In this case program the *Min* setpoint to 5.00. A captured SDI-12 data value of 5.00 will produce a 4.0 mA output and data value of 10.00 will produce 20.0mA. If the stage rises above 10.0 feet the output will clamp at 20mA or if the stage falls below 5 feet the output will clamp at 4.0mA. The extended commands to examine or change the *Min* and *Max* values are explained in Chapter 3.

2.7 Programming the *Module Mode* setting
The H-4161 can either "monitor" SDI-12 communication between a data logger and its sensors, or "initiate" measurements to a dedicated sensor connected to the auxSDI-12 terminal. The H-4161 comes

from the factory with *Module Mode* = 0 (monitor). The extended commands to examine or change the *Module Mode* are explained in Chapter 3.

2.8 Programming the *Monitored Address* setting

As a data monitor, the H-4161 passively monitors communication between the data recorder and its SDI-12 sensors. The H-4161 waits for, and collects data from a specified sensor. The data recorder must initiate any sensor measurements. The H-4161 comes from the factory with the *Monitored Address* = Z. If you wish to monitor data from another sensor you must change the monitored address to the desired value. This setting is not used if *Module Mode* = 1 (initiate). The extended commands to examine or change the *Monitored Address* are explained in Chapter 3.

2.9 Programming the *Monitored Parameter* setting

Each SDI-12 sensor can make up to nine separate measurements or "parameters". The data recorder collects the measurement data using "aD0!" - "aD9!" commands. The *Monitored Parameter* setting controls which of the nine data parameters is to be monitored by the H-4161. The H-4161 also monitors the data sent in response to the new concurrent SDI-12 V1.2 "aR0" data collection commands. The H-4161 comes from the factory with *Monitored Parameter* = 1. This setting should work with most sensors. The extended commands to examine or change the *Monitored Parameter* are explained in Chapter 3.

2.10 Programming the *AutoScan Address* setting

When the *Module Mode* =1 (initiate), the H-4161 actively initiates measurements and collects the response from the sensor attached to the auxSDI port. The H-4161 normally issues an "0M!" command to the auxSDI port. If desired, the H-4161 can be programmed to issue other addresses such as "2M!". The extended commands to examine or change the *AutoScan Address* are explained in Chapter 3.

2.11 Programming the *AutoScan Command* setting

When the *Module Mode* =1 (initiate), the H-4161 actively initiates measurements and collects the response from the sensor attached to the auxSDI port. The H-4161 normally issues an "aM!" command to the auxSDI port. If desired, the H-4161 can be programmed to issue other commands such as "aM1!" ("aM1" to "aM9!"). The extended commands to examine or change the *AutoScan Command* are explained in Chapter 3.

2.12 Programming the *Measure Rate* setting

When *Module Mode* = 1 (initiate), the H-4161 initiates measurements to the sensor attached to the auxSDI port. The measurement interval is controlled by the *Measure Rate* setting. If the *Measure Rate* is set to a value less than the time it take to make the actual measurement, measurements will be made back-to-back, as fast as possible. The H-4161 comes from the factory with *Measure Rate* = 0 (seconds). This setting is not used if *Module Mode* = 0 (monitor).

2.13 Testing with *Module Mode* = 0 (monitor)

Use the following procedure to verify your H-4161 is working properly. These tests will also help you understand how the H-4161 works.

1. Make the connections to the SDI-12 input and the 4-20mA output. Connect the sensor to be monitored to your data logger. Your loop power source, loop receiver and the H-4161's output should all be connected in series. In addition, temporarily connect a current meter in series with the 4-20mA loop.

- Make certain there is 5.5 to 35V across the 4-20mA output terminals.
- Make certain the H-4161 is receiving +12V power from the SDI-12 data bus.

Use the Transparent SDI-12 mode of your data recorder to issue and monitor the following SDI-12 commands

2. Check to see if you can communicate with the H-4161.
Issue a "**0I!**" Identify command.
The H-4161 should respond with: "**012 DAAH-4161001S#000000V10<CR><LF>**"

3. Check to see if the H-4161's self-test is ok.
Issue a "**0V!**" Verify command.
The H-4161 should respond with: **00011<CR><LF>**
Issue a "**0D0**" command to collect the data.
The H-4161 should respond with: **0+1<CR><LF>**

4. Check to see if the H-4161's 4-20mA output is working by using the "Set Milliamp" command.
Issue a "**0XSM10.0!**" command.
The H-4161 should respond with: **I-Out=10.0<CR><LF>**
This sets the H-4161s output to 10.0mA .
Check to see if the current meter you installed in Step 1 shows 10.0 mA flowing in the loop.
Experiment with different current settings using the XSMnnn command. Make certain your loop works at the 4.0 and 20.0 mA endpoints.

Next, check to see if the H-4161 can successfully capture sensor data from your SDI-12 sensor and scale it into 4-20mA.

5. Program the *Max* and *Min* setpoint as needed for your application, set the *Monitored Address* setting as needed. In these examples the address of the sensor to be monitored is "Z". Experiment with the "aXSCSddd" command to make certain your *Max* and *Min* settings are correct.

6. Issue a "**ZM!**" measurement command to cause your SDI-12 sensor to make a measurement. Your sensor should respond with **Zttttnn<CR><LF>**

where: a is the SDI-12 sensor address
ttt is a three digit integer 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 specifying the number of values that will be placed in the data buffer

7. Issue an "**ZD0!"** command to collect data from your SDI-12 sensor. The H-4161 monitors and captures the response. Your SDI-12 sensor should respond with **"Z+nnn.n<CR><LF>**" or similar.

8. Issue a "**0M!**" command to "measure" the data value collected by the H-4161. The H-4161 should respond with: **00001<CR><LF>**

9. Issue a "**0D0!**" command to collect the captured data value from the H-4161. The H-4161 should respond with: **0+nnn.nn<CR><LF>**

+nnn.nn is the data value captured from your sensor by the H-4161, this value should match the data value measured by your sensor in Step 7. The value must be between the Min and Max set point settings of the H-4161 or the output will be clamped at either 4.0mA or 20mA respectively.

Use the following equation to calculate the current which should be output by the H-4161. Compare this value with the reading displayed by the current meter installed in Step 1. Note, if the loop power is removed or applied after the data collection sequence of Step 7 was completed, the output of the H-4161 will be a random current value until a new measurement sequence is performed.

$$Output_{mA} = (Xdata - MIN)\left(\frac{16}{MAX - MIN}\right) + 4mA$$

where: Xdata = nnn.nn as measured by your sensor
MAX = the Max setpoint of the H-4161
MIN = the Min setpoint of the H-4161

2.14 Testing with *Module Mode* = 1 (initiate)

Use the following procedure to verify your H-4161 is working properly. These tests will also help you understand how the H-4161 works.

1. Make the connections to the +12V power and the 4-20mA output. Connect the sensor to be monitored to the auxSDI-12 port. Make certain the address of this sensor is "0". If you wish to experiment with the measure rate or other settings, connect a data logger to the primary SDI-12 data port. Your loop power source, loop receiver and the H-4161's output should all be connected in series. In addition, temporarily connect a current meter in series with the 4-20mA loop.

- Make certain there is 5.5 to 35V across the 4-20mA output terminals.
- Make certain the H-4161 is receiving +12V power from the SDI-12 data bus.

Use the Transparent SDI-12 mode of your data recorder to issue and monitor the following SDI-12 commands

1. Set *Module Mode* = 1 (See chapter 3).

2. Program the *Max* and *Min* setpoint as needed for your application, set the *Monitored Parameter* setting as needed.

3. Check to see if the H-4161's 4-20mA output is working by using the "Set Milliamp" command.
Issue a "**0XSM10.0!**" command.

The H-4161 should respond with: **I-out=10.0<CR><LF>**
This sets the H-4161s output to 10.0mA . Check to see if the current meter you installed in Step 1 shows 10.0 mA flowing in the loop.
Note: your setting will soon be overwritten when the next initiated measurement is made.

Experiment with different current settings using the XSMnnn command. Make certain your loop works at the 4.0 and 20.0 mA endpoints. Experiment with the "aXSCSddd" command to make certain your *Max* and *Min* settings are correct.

4. The H-4161 should be making measurements to the sensor attached to the auxSDI-12 port in a tight loop. Check the 4-20mA output for the expected response.

5. Change the *Measure Rate* as needed. Check for the expected response with an oscilloscope or other means to detect when a measurement is initiated.

2.15 Transparent Mode

When the *Module Mode* = 1 (Initiate), the H-4161 actively initiates measurements and collects the response from the sensor attached to the auxSDI port. During setup and testing it may be useful for the user to access the sensor attached to the auxSDI port without changing the wiring or connectors. When activated (see Chapter 3), the Transparent mode causes the H-4161 to stop making measurements on the auxSDI port and to make a virtual connection between the primary and auxSDI ports. While the *Transparent Mode* is active, all communication to/from the H-4161's address is passed thru to the auxSDI port. The "aM!", "aD0!" and other internal commands of the H-4161 are disabled and the H-4161 is essentially replaced by the sensor attached to the auxSDI port.. The *Transparent Mode* is automatically deactivated when the H-4161 detects an access to any sensor address other than its own. Note: the sensor address character of each command is forced to "0" by the H-4161 before being forwarded to the auxSDI port.

Chapter 3
SDI-12 Command and Response Protocol

3.0 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-4161 sensor. Included is a description of the commands and data format supported by the H-4161.

Refer to the document "A SERIAL DIGITAL INTERFACE STANDARD FOR HYDROLOGIC AND ENVIRONMENTAL SENSORS." Version 1.2 April 12, 1996 Coordinated by the SDI-12 Support Group, 135 East Center, Logan, Utah.

During normal communication, the data recorder sends an address together with a command to the H-4161 SDI-12 interface. The H-4161 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.

3.1 Command Summary

The H-4161 supports the following SDI-12 commands:

Standard Commands:

aM! Make measurement
aM1! Make special measurement
aD0! Send Data
aV! Verify
aI! Send Identification
a! Send Acknowledge
aAn! Change Address

Extended Commands:

aXTEST! Displays the current module settings
aXHELP! Displays the supported commands
aXRMM! Read Module Mode (0=Monitor, 1=Initiate)
aXWMMn! Write Module Mode (0=Monitor, 1=Initiate)
aXRMA! Read Monitored Address (0-9, A-Z, a-z)
aXWMAn! Write Monitored Address (0-9, A-Z, a-z)
aXRMP! Read Monitored Parameter (1 to 9)
aXWMPn! Write Monitored Parameter (1 to 9)
aXRAA! Read AutoScan address (0 to 9)
aXWAAn! Write AutoScan address (0 to 9)
aXRAC! Read AutoScan command setting (0 to 9)
aXWACn! Write AutoScan command setting (0 to 9)
aXRMR! Read Measure Rate (seconds)
aXWMRdd! Write Measure Rate (seconds)
aXSTM! Set Transparent Mode

aXRIH! Read High (max) data value for 20.0mA
aXWIHdd! Write High (max) data value for 20.0mA
aXRIL! Read Low (min) data value for 4.0mA
aXWILdd! Write Low (min) data value for 4.0mA
aXSCSdd! Set Current Stage (for testing 4-20mA)
aXSMdd! Set Milliamp output (for testing 4-20mA)

Factory use only:

aXSDACdd! Set the DAC to dd counts (for testing 4-20mA)
aXSCL! Set Calibration Low (DAC=0x04000)
aXSCH! Set Calibration High (DAC=0x18000)
aXRCL! Read DAC Calibration Low
aXWCLdd! Write DAC Calibration Low
aXRCH! Read DAC Calibration High
aXWCHdd! Write DAC Calibration High

3.2 Measure Command

The H-4161 is not a normal SDI-12 sensor and does not make sensor “measurements”. Instead, the Measure command copies the most recently captured SDI-12 data parameter. If the module mode is “Monitor”, the aM! can be used to read the most recent data the H-4161 has captured. If the module mode is “Initiate”, the aM! command reads the most recent measurement made on the auxSDI port.

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

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>" may be 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.

The aM! command takes 0 seconds to complete and places 1 value in the sensor buffer, no service request is sent.

Example of a H-4161 "aM!" command:

Command	Response	Time	Values	Description
"aM!"	"a0001<cr><lf>"	0 sec	1	Make measurement

Subsequent Command	Response
"aD0"	a+AA.AAA<cr><lf>

where: AA.AAA = Most recent measurement (feet, inches, meters etc.)

The “aM1!” command is similar to the “aM!” command, however it places additional information in the sensor buffer. If a data parameter has not been captured, the message “no data” is placed in the sensor buffer.

During debug and testing this feature is useful for determining if the H-4161 is properly and reliably capturing the monitored parameter. The recommended test procedure is to configure the data logger to make a H-4161 “aM1!” measurement at the completion of the sensor scan. Configure the data logger to record both the captured measurement and the calculated (desired) mA parameters. During the sensor scan the data logger first initiates a measurement and collects measurement data from the sensor being monitored. The H-4161 independently captures and processes the monitored parameter. At the completion of the sensor scan the data logger issues an “aM1!” command to the H-4161 and collects the response. The captured parameter value should always match the data value the data logger previously collected from the sensor. Examine the logged data to make certain the data is being captured and processed into the proper mA setting.

Example of a H-4161 "aM1!" command:

Command	Response	Time	Values	Description
"aM!"	"a0014<cr><lf>"	1 sec	4	Make measurement

Subsequent Command	Response
"aD0"	a+AA.AAA+BB.BBB+CC.CC+DD.DD<cr><lf>

where:
- AA.AAA = Most recent measurement (feet, inches, meters etc.)
- BB.BBB = Calculated (desired) mA setting for this measurement
- CC.CC = Current Min (low) data setting (see “aXRIL!” command)
- DD.DD = Current Max (high) data setting (see “aXRIH!” command)

3.3 Concurrent Measurement Command

This is a new command for the 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.

3.4 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!"	"apd.d<cr><lf>"

Where:

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

D0 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 the "aD0!" returns no data ("a<cr><lf>" only), it means that no measurement data is available (or the measurement was aborted) and a new "M" command must be sent. If the module mode is "MONITOR", an "a<cr><lf>" response indicates no measurement has been captured. If the module mode is "INITIATE", an "a<cr><lf>" response indicates the most recent measurement on the AuxSDI port has failed.

Example of a H-4161 "aD0!" command:

Previous Command	Response
"aM!"	"a0001<cr><lf>"

Subsequent Command	Response
"aD0"	a+AA.AAA<cr><lf>

Where:

AA.AAA = Most recent measurement (feet, inches, meters etc.)

3.5 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", "*", "?").

3.6 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+x+y<cr><lf>

Key	Description	Units
+123.456	Fixed test data	
+78.9	Fixed test data	
x	Memory checksum	0-65535
y	ROM checksum test	0 = Failed, 1 = Passed

3.7 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!"	"allccccccccmmmmmmvvvxx...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:

"a12 DAA H-4161vvvS#nnnnnnVkkk<cr><lf>"

H-4161 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

3.8 Change Sensor Address Command

The Change Sensor Address Command allows the sensor address to be changed. The address is stored in non-volatile Flash memory within the sensor. The H-4161 will not respond if the command was invalid, the address was out of range, or the Flash 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"

3.9 Extended Set_Current_Stage Command (for testing the 4-20mA output)

During installation and testing it is convenient to force set the H-4161's output to a particular value. The "aXSCSddd" command allows the user to force the current measurement data *(Stage*) to a particular setting. The H-4161 processes the *ddd* value using the current *Max* and *Min* settings and updates the 4-20mA output. Both the Stage and mA output values are printed on the LCD display. The H-4161 comes from the factory with the *Max* set to 20.00 and the *Min* to 4.00. With these settings the value ddd is conveniently the same as what the output current (in milliamps) will be. For example, if an "aXSCS10.0!" is issued, the output current will be 10.0mA. The data value must be between the current *Max* and *Min* settings or the output will be clamped at 4.00mA or 20.0mA

This command is useful for testing the *max* and *min* settings over the dynamic range of your SDI-12 sensor. For example: if *Max*=10.0 and *Min*=0.0, an "aXSCS5.0 will set the output current to 12.0mA.

Note: if the module mode is INITIATE, the output setting will be overwritten when the H-4161 initiates a measurement on the auxSDI port.

Example of a H-4161 Extended "Set Current Stage" command:

Command	Response	Description
"aXSCS2.3!"	"Stage_F = 2.3<cr><lf>"	Set the *Stage* to 2.3

3.10 Extended Set_Milliamp Command (for testing the 4-20mA output)

During installation and testing it is often convenient to force set the H-4161's output to a particular value. The "aXSMddd" command allows the user to force the output to a particular milliamp setting. The value is not processed with the module's *Max* and *Min* settings. For example: "aXSCS5.0" will set the output current to 5.0mA, regardless of the *Max* or *Min* settings

Note: if the module mode is INITIATE, the output setting will be overwritten when the H-4161 initiates a measurement on the auxSDI port.

Example of a H-4161 Extended "Set Milliamp" command:

Command	Response	Description
"aXSM5.6!"	"I-Out = 5.6mA<cr><lf>"	Set the output to 5.6 milliamps

3.11 Extended Read/Write *Max* (High) and Read/Write *Min* (Low)

The H-4161 processes the captured SDI-12 data with a linear mx+b equation to scale the data into values between 4.0 and 20.00 suitable for the 4-20mA output. The slope(m) and offset(b) terms are automatically computed using user programmable *Max* and *Min* settings. This makes it easy to scale the measurement data into the proper 4-20mA output. These four commands allow the user to read or write the current *Max* or *Min* settings. The settings are stored in non-volatile Flash memory. Once the new *Max* or *Min* value is written to the Flash memory, 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 "XRIH" or "XRIL" commands. This command takes 1 second to complete and places 1 value in the data buffer.

Command	Response	Description
"aXRIH!"	"a0011<cr><lf>"	Read current *max* (high) data setting
"aXRIL!"	"a0011<cr><lf>"	Read current *min* (low) data setting
"aXWIHddd!"	"a0011<cr><lf>"	Write *max* (high) data setting
"aXWILddd!"	"a0011<cr><lf>"	Write *min* (low) data setting

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 *max* or *min* value (For example: 20.0, 195)

Example of a H-4161 Extended Read High (max) command:

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

Command	Response	Description
"aD0!"	"a+50.0<cr><lf>"	*Max* is 50.0

Example of a H-4161 Extended Write High (max) command:

Command	Response	Time	Values	Description
"aXWIH1.234!"	"a0011<cr><lf>"	1 sec	1	Write *Max*

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

3.12 Extended Read/Write Module Mode command

The H-4161 operates in one of two modes: MONITOR or INITIATE. When the *Module Mode* = 0 (monitor), the H-4161 passively monitors the communication between the data recorder and it's SDI-12 sensors. The H-4161 waits for, and collects a specified data parameter from a specified sensor. The data is scaled and used to set the H-4161's 4-20mA output. When the *Module Mode* =1 (initiate), the H-4161 actively initiates measurements and collects the response from the sensor attached to the auxSDI port. The specified data parameter is scaled and used to set the H-4161's 4-20mA output.

These two commands allow the user to examine or change the *Module Mode*. The H-4161 comes from the factory with *Module Mode* = 0 (monitor). The *Module Mode* stored in non-volatile Flash memory. Once a new value is written to the Flash memory, a copy is sent to the sensor data buffer for verification. This setting can be viewed by using a subsequent "D" command. To verify this setting any other time, use the "XRMM" command. This command takes 1 second to complete and places 1 value in the data buffer.

Command	Response	Description
"aXRMM!"	"a0011<cr><lf>"	Read current module mode
"aXWMMn!"	"a0011<cr><lf>"	Write the module mode

Where:	a	is the sensor address ("0-9", "A-Z", "a-z", "*", "?").
	XRMM	are upper case characters.
	XWMM	are upper case characters.
	n	0 = MONITOR, 1=INITIATE

Example of a H-4161 Extended Read Module Mode command:

Command	Response	Time	Values	Description
"aXRMM!"	"a0011<cr><lf>"	1 sec	1	Read module mode

Command	Response	Description
"aD0!"	"a+0<cr><lf>"	Module Mode is MONITOR

Example of a H-4161 Extended Write Module Mode command:

Command	Response	Time	Values	Description
"aXWMM1!"	"a0011<cr><lf>"	1 sec	1	Write module mode

Command	Response	Description
"aD0!"	"a+1<cr><lf>"	Module Mode is INITIATE

3.13 Extended Set Transparent Mode command

When the *Module Mode* = 1 (Initiate), the H-4161 actively initiates measurements and collects the response from the sensor attached to the auxSDI port. During setup and testing it may be useful for the user to access the sensor attached to the auxSDI port without changing the wiring or connectors. When activated, the Transparent mode causes the H-4161 to stop making measurements on the auxSDI port and to make a virtual connection between the primary and auxSDI ports. While the Transparent Mode is active, all communication to/from the H-4161's address is passed thru to the auxSDI port. The “aM!”, “aD0!” and other internal commands of the H-4161 are disabled and the H-4161 is essentially replaced by the sensor attached to the auxSDI port.. The Transparent Mode is automatically deactivated when the H-4161 detects an access to any sensor address other than its own. Note: the sensor address character of each command is forced to “0" by the H-4161 before being forwarded to the auxSDI port.

Example of the H-4161 Extended Set Transparent Mode command:

Command	Response	Description
"aXSTM!"	"aTransparent mode ON<cr><lf>"	Transparent mode is active

3.14 Extended Read/Write Monitored Address and Read/Write Monitored Parameter

As a data monitor, the H-4161 passively monitors the communication between the data recorder and it's SDI-12 sensors. The H-4161 waits for, and collects a specified data parameter from a specified sensor. The data is scaled and used to set the H-4161's 4-20mA output. These four commands allow the user to examine or set the sensor address and the sensor data parameter to be monitored. At the factory the monitored address is set to "Z" and the monitored parameter is set to "1". For example: with these settings if a data recorder collects data from sensor "Z" with a "ZD0" command and the sensor transmits Z+123.4+24.3<cr><lf>, the value 123.4 will be captured by the H-4161. Note: the monitored address setting is not used if *Module Mode* = 1 (initiate).

Do not set the *Monitored Address* to the same address as the H-4161's address. The address and parameter settings are stored in non-volatile Flash memory. Once a new value is written to the Flash memory, a copy is sent to the sensor data buffer for verification. This setting can be viewed by using a subsequent "D" command. To verify these settings any other time, use the "XRMA" or "XRMP" commands. This command takes 1 second to complete and places 1 value in the data buffer.

Command	Response	Description
"aXRMA!"	"a0011<cr><lf>"	Read current monitored address
"aXRMP!"	"a0011<cr><lf>"	Read current monitored parameter
"aXWMAn!"	"a0011<cr><lf>"	Write current monitored address
"aXWMPn!"	"a0011<cr><lf>"	Write current monitored parameter

Where:	a	is the sensor address ("0-9", "A-Z", "a-z", "*", "?").
	XRMA	are upper case characters.
	XRMP	are upper case characters.
	XWMA	are upper case characters.
	XWMP	are upper case characters.
	n	is the new address or parameter

Example of a H-4161 Extended Read Monitored Address command:

Command	Response	Time	Values	Description
"aXRMA!"	"a0011<cr><lf>"	1 sec	1	Read monitored address
Command	Response	Description		
"aD0!"	"a+Z<cr><lf>"	Monitored address = Z		

Example of a H-4161 Extended Write Monitored Address command:

Command	Response	Time	Values	Description
"aXWMA5!"	"a0011<cr><lf>"	1 sec	1	Write monitored address
Command	Response	Description		
"aD0!"	"a+5<cr><lf>"	Monitored address = 5		

3.15 Extended Read/Write AutoScan Command

When the *Module Mode* =1 (initiate), the H-4161 actively initiates measurements and collects the response from the sensor attached to the auxSDI port. These two commands allow the user to select which “M” command is sent by the H-4161 when it initiates a measurement (“0M!”, “0M1!”, “0M2!" etc.) . The H-4161 comes from the factory with this setting set to “0" (“0M!”). Only the settings “0" to “9" are valid:

0 = 0M! (default)
1 = 0M1!
2 = 0M2!
3 = 0M3!
4 = 0M4!
5 = 0M5!
6 = 0M6!
7 = 0M7!
8 = 0M8!
9 = 0M9!

This setting stored in non-volatile Flash memory. Once a new value is written to the Flash memory, a copy is sent to the sensor data buffer for verification. This setting can be viewed by using a subsequent "D" command. To verify this setting any other time, use the "XRAC" command. This command takes 1 second to complete and places 1 value in the data buffer.

Command	Response	Description
"aXRAC!"	“a0011<cr><lf>"	Read current AutoScan command setting
"aXWACn!"	“a0011<cr><lf>"	Write current AutoScan command setting

Where:	a	is the sensor address ("0-9", "A-Z", "a-z", "*", "?").
	XRAC	are upper case characters.
	XWAC	are upper case characters.
	n	is the new parameter

Example of a H-4161 Extended Read AutoScan Command command:

Command	Response	Time	Values	Description
"aXRAC!"	"a0011<cr><lf>"	1 sec	1	Read AutoScan setting
Command	Response	Description		
"aD0!"	"a+0<cr><lf>"	Command will be “0M!”		

Example of a H-4161 Extended Write AutoScan Command command:

Command	Response	Time	Values	Description
"aXWAC2!"	"a0011<cr><lf>"	1 sec	1	Write AutoScan setting
Command	Response	Description		
"aD0!"	"a+2<cr><lf>"	Command will be “0M2!”		

3.16 Extended Read/Write AutoScan Address Command

When the *Module Mode* =1 (initiate), the H-4161 actively initiates measurements and collects the response from the sensor attached to the auxSDI port. These two commands allow the user to select which sensor address is sent by the H-4161 when it initiates a measurement (“aM!”, “aM1!”, “aM2!" etc.) . The H-4161 comes from the factory with this setting set to “0" (“0M!”).

This setting stored in non-volatile Flash memory. Once a new value is written to the Flash memory, a copy is sent to the sensor data buffer for verification. This setting can be viewed by using a subsequent "D" command. To verify this setting any other time, use the "XRAA" command. This command takes 1 second to complete and places 1 value in the data buffer.

Command	Response	Description
"aXRAA!"	“a0011<cr><lf>"	Read current AutoScan address setting
"aXWAAn!"	“a0011<cr><lf>"	Write current AutoScan address setting

Where: a is the sensor address ("0-9", "A-Z", "a-z", "*", "?").
XRAA are upper case characters.
XWAA are upper case characters.
n is the new parameter

Example of a H-4161 Extended Read AutoScan Address command:

Command	Response	Time	Values	Description
"aXRAA!"	"a0011<cr><lf>"	1 sec	1	Read AutoScan address setting
Command	Response	Description		
"aD0!"	"a+0<cr><lf>"	Command will be “0M!”		

Example of a H-4161 Extended Write AutoScan Address command:

Command	Response	Time	Values	Description
"aXWAA2!"	"a0011<cr><lf>"	1 sec	1	Write AutoScan address setting
Command	Response	Description		
"aD0!"	"a+2<cr><lf>"	Command will be “2M!”		

3.17 Extended Read/Write Measure Rate commands

When *Module Mode* = 1 (initiate), the H-4161 initiates measurements to the sensor attached to the auxSDI port. The measurement interval is controlled by the *Measure Rate* setting. These two command allows the user to examine or change the *Measure Rate* setting. If the Measure Rate is set to a value less than the time it takes to make the actual measurement, measurements will be made back-to-back, as fast as possible. At the factory the Measure Rate is set to zero. (seconds).

The *Measure Rate* setting is stored in non-volatile Flash memory. Once a new value is written to the Flash memory, a copy is sent to the sensor data buffer for verification. This setting can be viewed by using a subsequent "D" command. To verify this setting any other time, use the "XRMR" command. This command takes 1 second to complete and places 1 value in the data buffer.

Command	Response	Description
"aXRMR!"	"a0011<cr><lf>"	Read current measurement rate (seconds)
"aXWMRnn!"	"a0011<cr><lf>"	Write measurement rate (seconds)

Where:	a	is the sensor address ("0-9", "A-Z", "a-z", "*", "?").
	XRMR	are upper case characters.
	XWMR	are upper case characters..
	nn	is the new measurement rate (seconds)

Example of a H-4161 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+0.<cr><lf>"	*Measure Rate* = 0 seconds

Example of a H-4161 Extended Write Measure Rate command:

Command	Response	Time	Values	Description
"aXWMR5!"	"a0011<cr><lf>"	1 sec	1	Write *Measure Rate*

Command	Response	Description
"aD0!"	"a+5<cr><lf>"	*Measure Rate* = 5.0 seconds

3.18 Extended “XTEST”

This command is used for installation and testing and requires the use of a H-4191 Sidekick interface and a PC. This command causes the H-4161 to display a listing of the H-4161's current settings. This is not compliant with the SDI-12 specification and is not used with data loggers.

An example of an “XTEST” printout is shown below:

```
H-4611 Settings:
  Module Mode = MONITOR
  Monitored Address = Z
  Monitored Parameter = 1
  AutoScan Address = 0
  AutoScan Command = 0
  Measure Rate (sec)= 0
  Max data (@20mA) = 20.0
  Min data (@4mA) = 4.0
```

3.19 Extended “XHELP”

This command is used for installation and testing and requires the use of a H-4191 Sidekick interface and a PC. This command causes the H-4161 to display a listing of the supported SDI-12 commands. This is not compliant with the SDI-12 specification and is not used with data loggers.

Appendix A
Specifications

4-20mA Current Transmitter

Type:	2-wire, loop powered
Isolation:	1000V r.m.s min
Loop Voltage:	5.5V min, 35V max (4 to 20mA)
Resolution:	16-bits
Non-linearity:	±0.01% of FS max
Offset drift:	±25ppm of FS/ ° C max
Range:	0.35mA to 24mA

Power Requirements

Voltage Input:	9 to 16 Volts DC
Surge Protection:	Built in, 1.5 KVA
Supply Current:	
Sleep mode	2.1 mA typ
Active	8.0mA typ

SDI-12 Ports

Baud Rate:	1200
Protocol:	SDI-12, 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 measurement sequence:

aM!:	0-seconds, 1-parameter
all other:	1, second, 1-parameter

LCD Display

Type:	2-line x 16-character, reflective
Operating Temperature:	-0° C to +50° C
Storage Temperature:	-20° C to +60° C

Operating Modes

Monitor:	Monitor the SDI-12 port for "aD0!" commands, update the 4-20mA output.
Initiate:	Initiate measurements on the AuxSDI port, update the 4-20ma output, data is available via "aM!" on the primary SDI-12 port
Transparent:	SDI-12 and AuxSDI ports are connected together

Environmental

Operating Temperature:	-20° C to +50° C
Storage Temperature:	-20° C to +60° C
Hu;midity:	Non condensing

Mechanical

Material:	ABS plastic
Size	3.75" Long x 2.65" Wide x 1.25" Deep

Connections

+12V, SDI-12, AuxSDI:	5-position plug-in terminal strip, Phoenix Combicon™ (provided)
4-20mA:	2-position plug-in terminal strip, Phoenix Combicon™ (provided)

The ***WATER*LOG®** H-4161 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.