

Model H-4191

RS-232 to SDI-12 Interface Module



Owner's Manual

Version 1.1
(for Revision-C or greater)



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1.0 Introduction

The *WATERLOG*® H-4191 is a RS-232 to SDI-12 gateway (interface) module. When connected to a personal computer or RS-232 terminal the H-4191 can be used to test and monitor SDI-12 sensors and data recorders. The H-4191 allows a programable logic controller (PLC), remote terminal unit (RTU) or other data collection device with a RS-232 interface to access SDI-12 sensors. The H-4191 provides the RS-232 to SDI-12 electrical interface, generates the critical bus timing, parity and command retries needed for the SDI-12 bus protocol..

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
- Digital sensors output data directly in user units
- Sensors are interoperable and available from many different manufacturers

The H-4191 has the following features:

- Provides both electrical and protocol interface functions between RS-232 & SDI-12
- Works with any sensor command/response message including vendor specific extended commands.
- Buffers the command so no special timing is required.
- Generates proper parity for the SDI-12 bus.
- Automatically sends SDI-12 retries.
- Passes the sensor service request to the host.
- Supports optional CTS/RTS hardware flow control for a slow host device.
- Low power mode facilitates use with a RS-232 data radio.
- LED shows when the H-4191 is awake.
- Built in “sensor” can measure the battery voltage.
- Auto-Scan feature supports low-power operation with telemetry radios

The H-4191 is packaged in a rugged plastic enclosure with screw mount ears. Connectors located on each end provide easy hookup.

1.1 Applications

Figure 1 shows a monitoring application where a laptop computer is used to monitor the SDI-12 communication between a data recorder and two SDI-12 sensors. Figure 2 shows the connections when using the H-4191 as a gateway between a PLC and two SDI-12 sensors.

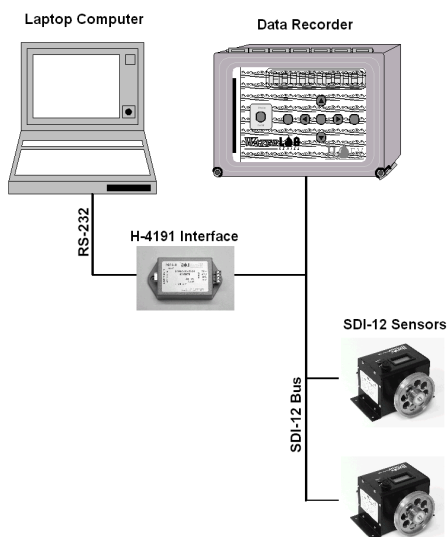


Figure 4 Monitor a data recorder

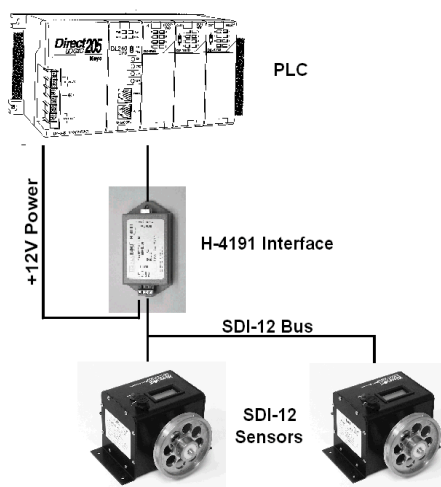


Figure 3 Interface between a PLC and two SDI-12 Sensors

1.2 Operation

The H-4191 has a microprocessor with both RS-232 and SDI-12 interface ports. The H-4191 normally operates as a SDI-12 master device: it issues SDI-12 commands and collects responses. Under certain conditions the H-4191 can respond to host commands itself as a “pseudo” SDI-12 sensor (see Section 1.7).

The RS-232 interface port is connected to a personal computer or other “host” device. The H-4191 provides two way communication between the RS-232 host and the SDI-12 bus. During normal operation, the host device sends an address together with a command to a SDI-12 sensor. The sensor then replies with a “response”.

1.2.1 Commands

The RS-232 host interface is fixed at 9600 baud. The H-4191 inputs SDI-12 commands (ASCII characters) from the host and places the character string in a buffer. Up to 128 characters can be buffered. The command can be sent at any speed, even hand-typed commands will work. The backspace character (08h) is supported and deletes the previous character in the buffer. Note: the SDI-12 protocol requires upper case characters. When the H-4191 detects the “!” SDI-12 command terminator character the H-4191 generates a SDI-12 break and transmits the contents of the buffer to the SDI-12 port in a contiguous burst with the proper parity and bus timing. The H-4191 also accepts the <CR> character (ENTER Key) as a command terminator and substitutes the <CR> character with the required “!” SDI-12 command terminator. This makes the H-4191 easier to use for computer users who more commonly complete a message with the ENTER Key. If you use the ENTER Key to terminate the message, do not type the “!” character.

The H-4191 automatically generates SDI-12 compliant parity and timing. After transmitting the command, the H-4191 waits for up to 40mS for a sensor response. If the sensor response fails to arrive, the H-4191 performs a retry sequence specified by the SDI-12 protocol. The H-4191 generates up to four breaks with up to four retries per break (16 retries total). The number of retries can be programmed (see Chapter 2).

1.2.2 Sensor Response

The response from a SDI-12 sensor is input by the H-4191 at 1200 baud and output to the RS-232 port at 9600 baud. Any sensor service requests or other SDI-12 bus traffic are also forwarded from the SDI-12 port to the RS-232 port. This feature allows the H-4191 to be used to passively monitor the activity on a SDI-12 bus between a data recorder and its sensors.

1.3 Making Connections

Connect the RS-232 port of the H-4191 to the serial port of your personal computer or other host device with a standard 9-pin RS-232 cable (provided). The H-4191 has a female connector and is a DCE (modem) device. The cable has 9-pin RS-232 connectors which can be plugged directly into a PC serial port without the use of gender or null-modem adapters. Program your host device for 9600 baud, 8-bit, no parity, full-duplex communication. The host device must assert either CTS or DSR to awaken the H-4191 from its low power sleep mode.

RS-232 Connector				
Pin	Name	Direction	Description	Function
1	nc		not used	
2	TxD	Output	Transmit Data	Transmit data to host device
3	RxD	Input	Receive Data	Receive data from host device
4	DSR	Input	Data Set Ready	Awakens the H-4191 when asserted.
5	GND		Ground	Ground
6	nc		not used	
7	CTS	Input	Clear To Send	Awakens the H-4191 when asserted. Controls TxD if RTS/CTS flow control is on.
8	RTS	Output	Request To Send	Asserted when awake and output buffer is not full
9	nc		not used	

The H-4191 has a 4-position terminal strip for making connections to the SDI-12 bus. The H-4191 is powered from the +12V power terminal.



1.4 Testing the Interface

You can test the H-4191 with a simple RS-232 terminal or computer using a terminal program such as *SimpleTerm*, *Xtalk* or *Hyperterminal*. The terminal program must assert either the CTS or DSR (or both) input signals to the H-4191 to awaken it from sleep. The red LED on the H-4191 will be illuminated when it is awake and ready to communicate. The interface is a full-duplex connection, depending on the settings of your terminal program you may or may not be able to see what you are typing on your screen. If you make a mistake while typing the command, use backspace key to delete the previous keystroke. If you make a mistake and are not sure what is in the H-4191's buffer, press the "!" or ENTER Keys to flush the buffer and start over.

When the H-4191 is first powered up it transmits a "H-4191 Initialized" debugging message to the RS-232 port.

1.4.1 H-4191 Initiates the Commands

Try the following commands. The sensor address in these examples is "0" and the sensor is a Design Analysis H-350 pressure sensor. If your sensor has a different address use the appropriate address.

1. Check to see if you can communicate with the sensor.

Issue a "OI!" Identify command.

The sensor should respond with: "012 DAA H-350001S#000000V10<CR><LF>"

2. Make a measurement.

Issue a "OM!" command.

The sensor should respond with: "00153<CR><LF>"

After 14 seconds the sensor will send a service request: "0<CR><LF>"

Issue a "OD0" command to collect the data.

The sensor should respond with: "0+4.56+0.0000+0.2<CR><LF>"

1.4.2 H-4191 Monitors the SDI-12 Bus

The H-4191 can be used to passively monitor the activity on a SDI-12 bus. You can observe both the commands from the data recorder and the responses from the sensors. The communications between a data recorder and a Model H-350 pressure sensor would appear as follows:

OM!00153

OD0!0+4.56+0.0000+50.0

In this example the data recorder issued a "OM!" command, the sensor responded with "00153<CR><LF>" (sensor 0, measurement time = 015 sec, 3 parameters will be returned). Next, the data recorder issued a "OD0!" command and the sensor responded with "0+4.56+0.0000+50.0<CR><LF>" (sensor 0, stage = 4.56, PSI = 0.0, temperature = 50.0).

When monitoring traffic between a data recorder and its SDI-12 sensors, the display may sometimes have spurious characters which prefix the command. For example:

```
p0M!00153  
p0D0!0+4.56+0.0000+50.0
```

The lower case “p” in this example was caused by the break pulse generated by the data recorder. A “break” is a 12mS or longer pulse on the data line which wakes the sensors from their low power sleep mode. The serial asynchronous receiver transmitter (UART) in the H-4191 misinterprets the break as a random character.

1.5 Low Power Operation

The H-4191 normally reverts to a low power or “sleep” mode. If either the DSR or CTS RS-232 inputs are active (asserted) the H-4191 awakens, powers up its RS-232 transceiver and is available for full operation. The red LED on the side of the enclosure is illuminated when the H-4191 is awake. Most PC terminal programs automatically assert both DSR and CTS by default. When the H-4191 is connected to a PC the H-4191 will normally awaken and remain awake as long as it is connected.

1.6 Operation with a Radio

Applications often arise where a SDI-12 sensor must be physically located hundreds or thousands of feet from the data logger. Transparent wireless SDI-12 bridges are available for these applications. Unfortunately, transparent bridges can miss or drop measurements because of corrupted radio packet transmissions. Wireless bridges are problematic because the SDI-12 protocol provides insufficient time to make retries or other recovery.

When coupled with a data radio, the H-4191 can be used to construct a “non transparent” wireless SDI-12 link. With this architecture the H-4191 is permanently connected to one or more sensors at the remote site. A pair of RS-232 data radios are installed between the data logger and the remote H-4191. The radios are normally programmed for “sleep & sniff” low power operation. When properly configured, the data logger, radios and H-4191 module can provide a low-power wireless SDI-12 bridge capable of performing retries.

The data logger must be setup to initiate and collect SDI-12 commands/responses from a RS-232 port instead of its normal SDI-12 port. SDI-12 commands from the data logger are forwarded via the radios to the remote H-4191. When the remote data radio receives an inbound data packet, it pulses the CTS input which awakens the H-4191 in preparation to receive the inbound message. When the H-4191 detects the “!” character, it transmits the contents of its buffer to the remote SDI-12 bus in a contiguous frame with proper parity and bus timing. The H-4191 waits for and collects any sensor response and forwards it to the radio. The sensor response is sent over the radios back to the data logger. If one or more of the radio transmissions is lost or corrupted, the data logger can retry the entire sequence as needed.

The H-4191 has an internal inactivity timer which keeps the module awake to process the service request and receive subsequent radio packets. If both the RS-232 and SDI-12 ports become

inactive (and both CTS and RTS are not asserted) for longer than 10-seconds, the timer expires and the H-4191 enters its low power sleep mode. The H-4191 examines the “aTTTN<CR><LF>” sensor response initiated by an “aM!” measure command and initializes a second “keep-awake” timer to TTT + 3-seconds. This ensures the H-4191 will remain awake to process the service request. When the service request actually arrives, the keep-awake timer is zeroed. While the keep-awake timer is running the H-4191 sends a null (00h) to the radio once/second to keep the radio link awake while waiting for the service request.

Be aware that with a point-to-multipoint telemetry architecture, the data logger must take care to not generate excessive retries when attempting to recover a missed measurement. During a retry the transmissions are seen by all of the remote stations in the system and will cause them to stay awake to process the communications. If one remote station were to quit working for some reason, the extra retry communications causes stress on the batteries of the remaining stations. If excessive retries are done, the remote stations can fail one by one in a cascade of increasing retries.

When sleep & sniff radios are employed the host data logger should prefix outbound commands with 4 or 5 0xFF characters. The 0xFF characters are automatically discarded by the H-4191. When the remote H-4191 module(s) are awakened by the radio asserting RTS or CTS the H-4191 may miss the first few characters while completing its power-up housekeeping. The 0xFF preamble characters allow time for the H-4191 to power up and be ready to input and process the command payload.

The H-4191 also supports a very low power simplex mode for use with telemetry radios where the H-4191 initiates SDI-12 measurements itself and “pushes” the data to the data logger or host. See the Chapter 3 (Auto-Scan) for further details.

1.7 Sensor “Z”

When implementing a wireless SDI-12 bridge as described in the previous section it is useful for the data logger to be capable of monitoring the battery voltage in the remote station. In addition to functioning as a RS-232 to SDI-12 gateway, the H-4191 has a built-in “sensor” which responds to SDI-12 address “Z”. The “Z” sensor can measure the H-4191's +12V input voltage, is used to facilitate turning flow control On or Off and is useful for testing and maintenance. The “Z” sensor responds to all SDI-12 compliant commands, however, it is only accessible via the RS-232 port. The built-in sensor will not respond to a data logger connected to the SDI-12 port. The sensor address can be changed from “Z” to another value if needed with the extended Change_Address_Command. See Section-2 for further details.

1.8 RS-232 Hardware Flow Control

The RS-232 port of the H-4191 supports optional RTS/CTS hardware flow control for slow PLC's or RTU's which cannot input or receive the entire SDI-12 response message. The H-4191 monitors its CTS input and transmits RS-232 characters only if CTS is asserted. The H-4191 can buffer up to 128 SDI-12 response characters, any additional input characters will be lost.

While the H-4191 is busy sending a SDI-12 command or doing retries, it can buffer up to 128 characters from the RS-232 port. The H-4191 de-asserts the RTS output when the buffer is within 4-characters of becoming full.

The H-4191 comes from the factory with the RTS/CTS hardware flow control set to Off. An extended SDI-12 command allows the hardware flow control feature to be turned On or Off. The On/Off setting is stored in Flash memory internal to the H-4191 and remains in effect even if the power is lost. See Chapter 2 for details.

Chapter 2

SDI-12 Command and Response Protocol

2.0 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 **WATERLOG**® Series Model H-4191 sensor. Included is a description of the commands and data format supported by the H-4191.

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-4191 SDI-12 sensor. The H-4191 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.

2.1 Command Summary

The H-4191 supports the following SDI-12 commands:

Standard Commands:

aM!	Make battery voltage measurement
aR0!	Make battery voltage measurement
aD0!	Send Data
aV!	Verify
aI!	Send Identification
a!	Send Acknowledge
aAn!	Change Address

Extended Commands:

aXHELP!	Display the supported commands
aXRFM!	Read hardware flow control mode (0=no, 1=yes)
aXWFMn!	Write hardware flow control mode (0=no, 1=yes)
aXRRT!	Read max retries (0=no retries)
aXWRTn!	Write max retries (0=no retries)
aXRASM!	Read AutoScan mode (0=off, 1=on)
aXWASMn!	Write AutoScan mode (0=off, 1=on)
aXRASI!	Read AutoScan interval (0 to 65535 seconds)
aXWASIn!	Write AutoScan interval (0 to 65535 seconds)
aXFAS!	Force AutoScan sequence
aXRTL!	Read AutoScan task list
aXWTL!	Write AutoScan task list
aXTCOP!	Test the COP timer

2.2 Measure Command

The Measure Command causes a measurement sequence to be performed. 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.

<u>Command</u>	<u>Response</u>	<u>Description</u>
"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>" 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-4191 "aM!" command:

<u>Command</u>	<u>Response</u>	<u>Time</u>	<u>Values</u>	<u>Description</u>
"ZM! "	"Z0021<cr><lf> "	2 sec	1	Make measurement

<u>Subsequent Command</u>	<u>Response</u>
"ZD0 "	Z+12.01<cr><lf>

Where: +12.01 is the battery voltage

2.3 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.

<u>Command</u>	<u>Response</u>	<u>Description</u>
"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.

2.4 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.

<u>Command</u>	<u>Response</u>
"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-4191 "aD0!" command:

<u>Previous Command</u>	<u>Response</u>
"ZM! "	"Z0021<cr><lf> "

<u>Subsequent Command</u>	<u>Response</u>
"ZD0 "	Z+12.01<cr><lf>

Where: +12.01 is the battery voltage

2.5 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.

Example of a H-4191 "aR0!" command:

<u>Previous Command</u>	<u>Response</u>
"ZR0!"	"Z+12.01<cr><lf>"

Where: +12.01 is the battery voltage

2.6 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.

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

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

2.7 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.

<u>Command</u>	<u>Response</u>	<u>Description</u>
"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:

<u>Command</u>	<u>Response</u>	<u>Time</u>	<u>Values</u>	<u>Description</u>
"ZV!"	"a0013<cr><lf>"	1 sec	3	Return fixed data and diagnostic data for testing purposes.

<u>Subsequent Command</u>	<u>Response</u>
"ZD0"	Z+123.456+78.9+y<cr><lf>

<u>Key</u>	<u>Description</u>	<u>Units</u>
+123.456	Fixed test data	
+78.9	Fixed test data	
y	FLASH checksum test	0 = Failed, 1 = Passed

2.8 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.

<u>Command</u>	<u>Response</u>
"aI!"	"allccccccmmmmmmvvvxx...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".
ccccccc	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-4191vvvS#nnnnnnVkkk<cr><lf>"
```

H-4191 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

2.9 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-4191 will not respond if the command was invalid, the address was out of range, or the Flash memory programming operation failed.

<u>Command</u>	<u>Response</u>	<u>Description</u>
"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:

<u>Command</u>	<u>Response</u>	<u>Description</u>
"ZA9!"	"9<cr><lf>"	Change sensor address to "9"

2.10 Extended Read *Flow_Mode* and Write *Flow_Mode*

The RS-232 port of the H-4191 supports optional RTS/CTS hardware flow control for slow host devices which cannot input or receive the entire SDI-12 response message. The H-4191 monitors it's CTS input signal and transmits RS-232 characters only if CTS is asserted.

The H-4191 comes from the factory with the RTS/CTS hardware flow control set to OFF. These two commands allow the hardware flow control feature to be checked or turned ON or OFF. The On/Off setting is stored in flash memory internal to the H-4191 and remains in effect even if the power is lost.

Once a new setting 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 "XRFM" command.

<u>Command</u>	<u>Response</u>	<u>Description</u>
"aXRfM!"	"a0011<cr><lf>"	Read <i>Flow_Mode</i>
"aXWfMn!"	"a0011<cr><lf>"	Write <i>Flow_Mode</i>

Where: a is the sensor address ("0-9", "A-Z", "a-z", "*", "?").
XRfM are upper case characters.
XWfM are upper case characters.
n 0 = flow control OFF, 1 = flow control ON

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-4191 Extended "Read *Flow_Control_Mode*" command:

<u>Command</u>	<u>Response</u>	<u>Time</u>	<u>Values</u>	<u>Description</u>
"ZXRFM!"	"Z0011<cr><lf>"	1 sec	1	Read <i>Flow_Mode</i>

<u>Command</u>	<u>Response</u>	<u>Description</u>
"ZD0!"	"Z+0<cr><lf>"	Flow Mode = OFF

Example of a H-4191 Extended "Write *Flow_Control_Mode*" command:

<u>Command</u>	<u>Response</u>	<u>Time</u>	<u>Values</u>	<u>Description</u>
"ZXWfM1!"	"Z0011<cr><lf>"	1 sec	1	Write <i>Flow_Mode</i>

<u>Command</u>	<u>Response</u>	<u>Description</u>
"ZD0!"	"Z+1<cr><lf>"	Flow Mode = ON

2.11 Extended Read *MaxRetry* and Write *MaxRetry*

The H-4191 automatically generates SDI-12 compliant parity and timing. After transmitting the command, the H-4191 waits for up to 40mS for a sensor response. If the sensor response fails to arrive, the H-4191 performs a retry sequence specified by the SDI-12 protocol. The H-4191 generates up to four breaks with up to four retries per break (16 retries total). The number of retries can be examined or changed using these two commands.

In some cases where a wild card address ("*") is employed with multiple sensors on a bus, *MaxRetry* should be set to 0 (no retries).

Once a new setting 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 "XRRT" command.

<u>Command</u>	<u>Response</u>	<u>Description</u>
"aXRRT!"	"a0011<cr><lf>"	Read <i>MaxRetry</i>
"aXWRTn!"	"a0011<cr><lf>"	Write <i>MaxRetry</i>

Where: a is the sensor address ("0-9", "A-Z", "a-z", "*", "?").
 XRRT are upper case characters.
 XWRT are upper case characters.
 n number of retries

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-4191 Extended "Read *MaxRetry*" command:

<u>Command</u>	<u>Response</u>	<u>Time</u>	<u>Values</u>	<u>Description</u>
"ZXRRT!"	"Z0011<cr><lf>"	1 sec	1	Read <i>MaxRetry</i>

<u>Command</u>	<u>Response</u>	<u>Description</u>
"ZD0!"	"Z+4<cr><lf>"	Do up to 4 retries

Example of a H-4191 Extended "Write *Flow_Control_Mode*" command:

<u>Command</u>	<u>Response</u>	<u>Time</u>	<u>Values</u>	<u>Description</u>
"ZXWRT0!"	"Z0011<cr><lf>"	1 sec	1	Write <i>MaxRetry</i>

<u>Command</u>	<u>Response</u>	<u>Description</u>
"ZD0!"	"Z+0<cr><lf>"	Retries = 0 (no retries)

2.12 Extended “XHELP”

This command is used for installation and testing. This command causes the H-4911 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.

Chapter 3

Auto-Scan Mode

3.0 Auto-Scan Mode

The Auto-Scan mode described in this chapter provides support for a simplex telemetry architecture for collecting data from remote SDI-12 sensors via a wireless link.

Wireless applications often arise where a SDI-12 sensor must be physically located hundreds or thousands of feet from the data logger. Normal communications with SDI-12 sensors requires up to five transmissions to complete a measurement sequence:

- Master transmits the SDI-12 command
- Slave transmits its response
- Slave transmits a service request
- Master transmits a SDI-12 data command
- Slave transmits its data buffer

If any of these transmissions are corrupted or lost, the sequence must be repeated or “re-tried”. This sequence must be repeated for every SDI-12 sensor attached to the H-4191. Most telemetry architectures require the radios to be setup with either a “sleep & sniff” configuration or setup with the receivers continually powered.

With the *Auto-Scan* mode, the H-4191 is configured to periodically scan the sensors attached to its SDI-12 port and transmit (push) the data to the remote host. With this architecture the receivers in the remote telemetry radios are not used and can be shut off to save power. This scheme provides for very low power operation with a solar panel. In addition, only one transmission is needed for each sensor scan. The data from all of the sensors attached to the SDI-12 port of a H-4191 is concatenated and sent in one transmission.

The pros and cons of the simplex telemetry architecture are as follows:

- The H-4191 is programmed to transmit data on a fixed schedule (such as every 15 minutes). The H-4191 does not have a real-time clock and has no knowledge of time-of-day.
- The data logger or host must accept and parse asynchronous data from the remote site(s).
- The data logger cannot schedule or synchronize the measurements.
- A data transmission includes the concatenated data from all of the SDI-12 sensors attached to the SDI-12 port.
- The remote telemetry radios can be configured with their receivers powered off.

With this telemetry architecture it is recommended the telemetry radios be configured for Acknowledged service. With acknowledged service the transmitting module listens for an ACK (acknowledgment). If the transmitting module does not receive the ACK within the allotted time, it will retransmit the packet. The retransmission is made after a random delay slot to help avoid collisions. With this scheme, reliable transmission and retries are made by the telemetry radios - not the data logger. The 10-second inactivity timer in the H-4191 allows time for the radio to perform acknowledged service transmissions at the completion of a scan.

The Auto-Scan mode is configured with extended SDI-12 commands to the H-4191's built-in SDI-12 sensor address ("Z"). The "Z" sensor is only accessible via the RS-232 port. The built-in sensor will not respond to a data logger connected to the SDI-12 port. The sensor address can be changed from "Z" to another value if needed with the extended ChangeAddressCommand described in Section-2.

3.1 Task List

When the Auto-Scan mode is activate, the sensor scan is controlled by a "Task List" programmed into H-4191. The Task List is a simple ASCII string with SDI-12 commands in a comma separated variable (CSV) format. Depending on the task list any SDI-12 address and any command can be generated.

The format is as follows: <cmd><"!"><parameter><",">

For example: 0M!1,1M!2,5M!3

In this example a 0M! command is first sent to the SDI-12 port. The response is collected from sensor "0" and the measurement data from parameter #1 is extracted. Next, the command 1M! is sent to sensor "1" and the data from parameter #2 is extracted. Finally, the command 5M! is transmitted and the data from parameter #3 is extracted.

The data from all three measurements is concatenated into one message and sent to the telemetry radio. Each transmission is prefixed by a "#" character and ends in a <CR><LF> sequence. The measurement fields are separated by a comma. Each measurement field includes the sensor number, a "=" character, and the measurement data.

For example: "#0=+12.3,1=-4.5,2=+4.99,3=+1.2<CR><LF>"

The data logger or telemetry host can use the "#" character to frame the message and discard stray packets. It must parse the message and extract the data fields.

3.2 Operation

The Auto-Scan mode is controlled by three settings: *AutoScanMode*, *ScanInterval* and the Task-List. These settings are made with extended commands to sensor address “Z” and are described in the following sections.

The Auto-Scan mode is enabled by setting *AutoScanMode*=1. When activated, the H-4191 will awaken from low-power sleep and perform a sensor scan at the interval determined by the *ScanInterval* setting. The H-4191 has no knowledge of time-of-day and employs a non-temperature compensated time clock such that the scan time may drift a few seconds each day.

With this data acquisition architecture the data logger will normally time stamp the data, however the measurement scans cannot be synchronized with other stations or aligned to fixed points of the clock.

3.3 Extended Force Auto-Scan Command

This command is used for setup and testing and causes the H-4191 to immediately perform an Auto-Scan sequence. This command works regardless of the *AutoScanMode* setting.

<u>Command</u>	<u>Response</u>	<u>Description</u>
"aXFAS!"	"a0011<cr><lf>"	Force an Auto-Scan sequence

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

Example of a H-4191 Extended Force Auto-Scan command:

<u>Command</u>	<u>Response</u>
"ZXFAS!"	None

3.3 Extended Read *AutoScanMode* and Write *AutoScanMode*

The H-4191 comes from the factory with Auto-Scan set to OFF. These two commands allow the Auto-Scan feature to be checked or turned ON or OFF. The setting is stored in Flash memory internal to the H-4191 and remains in effect even if the power is lost.

Once a new setting 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 "XRASM" command.

<u>Command</u>	<u>Response</u>	<u>Description</u>
"aXRASM!"	"a0011<cr><lf>"	Read <i>AutoScanMode</i>
"aXWASmn!"	"a0011<cr><lf>"	Write <i>AutoScanMode</i>

Where: a is the sensor address ("0-9", "A-Z", "a-z", "*", "?").
 XRASM are upper case characters.
 XWASM are upper case characters.
 n 0 = AutoScan Off, 1 = AutoScan On

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-4191 Extended "Read *AutoScanMode*" command:

<u>Command</u>	<u>Response</u>	<u>Time</u>	<u>Values</u>	<u>Description</u>
"ZXRASM!"	"Z0011<cr><lf>"	1 sec	1	Read <i>AutoScanMode</i>

<u>Command</u>	<u>Response</u>	<u>Description</u>
"ZD0!"	"Z+0<cr><lf>"	AutoScanMode = OFF

Example of a H-4191 Extended "Write *AutoScanMode*" command:

<u>Command</u>	<u>Response</u>	<u>Time</u>	<u>Values</u>	<u>Description</u>
"ZXWASM1!"	"Z0011<cr><lf>"	1 sec	1	Write <i>AutoScanMode</i>

<u>Command</u>	<u>Response</u>	<u>Description</u>
"ZD0!"	"Z+1<cr><lf>"	AutoScanMode = ON

3.4 Extended Read *AutoScanInterval* and Write *AutoScanInterval*

The H-4191 comes from the factory with *AutoScanInterval* set to 900 seconds (15-minutes). These two commands allow the scan interval to be examined or changed. The setting is stored in Flash memory internal to the H-4191 and remains in effect even if the power is lost.

Once a new setting 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 "XRASI" command.

<u>Command</u>	<u>Response</u>	<u>Description</u>
"aXRASI!"	"a0011<cr><lf>"	Read <i>AutoScanInterval</i>
"aXWASIn!"	"a0011<cr><lf>"	Write <i>AutoScanInterval</i>

Where: a is the sensor address ("0-9", "A-Z", "a-z", "*", "?").
 XRASI are upper case characters.
 XWASI are upper case characters.
 n 0 to 65535 seconds

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-4191 Extended "Read *AutoScanInterval*" command:

<u>Command</u>	<u>Response</u>	<u>Time</u>	<u>Values</u>	<u>Description</u>
"ZXRASI!"	"Z0011<cr><lf>"	1 sec	1	Read <i>AutoScanInterval</i>

<u>Command</u>	<u>Response</u>	<u>Description</u>
"ZD0!"	"Z+900<cr><lf>"	<i>AutoScanInterval</i> = 900 seconds

Example of a H-4191 Extended "Write *AutoScanInterval*" command:

<u>Command</u>	<u>Response</u>	<u>Time</u>	<u>Values</u>	<u>Description</u>
"ZXWASI60!"	"Z0011<cr><lf>"	1 sec	1	Write <i>AutoScanInterval</i>

<u>Command</u>	<u>Response</u>	<u>Description</u>
"ZD0!"	"Z+60<cr><lf>"	<i>AutoScanInterval</i> = 60 seconds

3.5 Extended Read *TaskList* and Write *TaskList*

The Task List is a simple ASCII string with SDI-12 commands in a comma separated variable (CSV) format. These two commands allow the Task-List to be observed or programmed. The task list can be up to 32 characters. Note in the example below that a measurement sequence in the task list can include the battery voltage measurement made by the H-4191 itself (ZM!).

The aXRTL! Command works somewhat like a continuous measurement (aR0!) command where the data is sent directly in the response. No subsequent "aD0" command is needed. The response message includes the sensor address (usually "Z"), a ":TaskList=" header and then the task list characters.

Writing a new task list is complicated by the need to embed one or more "!" SDI-12 end-of-command characters within the message string. Without special care the first "!" character encountered will be interpreted as a command delimiter. To overcome this problem, use the ":" colon character as a place holder for the "!" characters. When writing the task list, the H-4191 will automatically substitute the "!" character when a ":" character is encountered.

<u>Command</u>	<u>Description</u>
"aXRTL!"	Read <i>TaskList</i>
"aXWTLdddddd!"	Write <i>TaskList</i>

Where:	a	is the sensor address ("0-9", "A-Z", "a-z", "*", "?").
	XRTL	are upper case characters.
	XWTL	are upper case characters.
	dddddd	is the ASCII task list string

Example of a H-4191 Extended "Read *TaskList*" command:

<u>Command</u>	<u>Response</u>
"ZXRTL!"	"Z:TaskList=ZM!1,0M!1,1M!2'<cr><lf>"

Example of a H-4191 Extended "Write *TaskList*" command:

<u>Command</u>	<u>Response</u>
"ZXWTLZM:1,0M:1,1M:2!"	"Z:TaskList=ZM!1,0M!1,1M!2<cr><lf>"

Appendix A

Specifications

RS-232 Port

Type: Asynchronous, 9600 baud, 8-bit, no parity (fixed)
Flow Control: RTS/CTS (optional)
Command Buffer: 60 characters

SDI-12 Port

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

Internal Voltage Monitor (Address "Z")

Range: 6-18V
Resolution: 12-bit (.004V)
Accuracy: $\pm 1\%$

Power Requirements

Voltage Input: 9 to 16.0 Volts DC
Supply Current:
 Sleep Mode 200 μ A typ
 Active 25mA typ
Surge Protection: Built in, 1.5 KVA

Environmental

Operating Temperature: -40° C to +50° C
Storage Temperature: -50° C to +70° C

Mechanical

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

Connectors:

RS-232: 9-Pin, female, D-sub, DCE connections
SDI-12 4-position terminal strip, pluggable, Phoenix Combicon™

Warranty

The **WATERLOG**® H-4191 is warranted against defects in materials and workmanship for two years from date of shipment.

Notes

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