



H-3401SDI

SMART SDI-12 TIPPING BUCKET RAIN GAUGE

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1.1

Introduction

The WaterLOG® H-3401SDI is a Tipping Bucket Rain Gauge with built-in SDI-12 electronics. The SDI-12 feature converts a standard tipping bucket rain gauge into a “smart” SDI-12 sensor with additional capabilities. The H-3401SDI is easy to use and works with any data recorder/logger with a SDI-12 interface. The “Serial-Digital Interface” is ideal for data logging applications with the following requirements:

- Battery powered operation with minimal current drain
- Low system cost ! Up to 200 feet of cable between a sensor and the data recorder

The H-3401SDI has the following features:

- Connects directly to any data recorder with a SDI-12 port.
- Scales the bucket tips into units of inches, meters etc
- Provides built-in accumulation of daily and total rainfall
- Provides mathematical correction for bucket volume errors due to varying rainfall rate.

1.2

Theory of Operation

The H-3401SDI has a built-in microprocessor which monitors the tipping bucket sensor. Whenever a bucket tip occurs the microprocessor wakes up from its low power sleep mode and adds an appropriate rainfall increment to the rainfall accumulators. The electronics has a filter circuit which prevents contact bounce in the bucket tip reed switch from causing false counts. In addition, the time between bucket tips is measured, bucket tips which occur less than 500mS apart are ignored. This helps protect from false counts of a poorly adjusted bucket mechanism.

The H-3401SDI protects its rainfall accumulations with a software flag or “signature.” If the power is interrupted momentarily the H-3401SDI will resume operation using the accumulation values in memory. If the power is lost long enough to destroy the signature, when the power is restored the H-3401SDI resets the rainfall accumulators to 0000. To intentionally reset the H-3401SDI’s accumulators, disconnect the power for 5 to 10 seconds or use the extended “aXRA” command.

The H-3401SDI provides daily rainfall accumulation values which are useful for data loggers which do not have special provisions for computing daily rainfall. The H-3401SDI has a built-in real-time-clock which triggers a “daily reset time” event. When this event occurs the H-3401SDI automatically updates its “yesterday’s total accumulation” value using “today’s total accumulation”, then zeros the “today’s total accumulation” value.

During normal operation, the data recorder sends an address together with a command to the H-3401SDI sensor. The H-3401SDI wakes up from its low power sleep mode and stores the requested data in its data buffer. Once the data is ready, the data recorder collects the data from the H-3401SDI’s data buffer.

1.3

Smart Bucket Theory

0.01 inch

Tipping bucket rain gauges have a reputation for being inaccurate. Inaccuracies can be caused by algae in the bucket, evaporation and poor calibration. The greatest source of inaccuracy however, is the volume at which the tipping bucket mechanism tips is sensitive to rainfall rate. This occurs because the water droplets cause surface waves in the bucket and high rainfall rates cause superposition or "pile up" of extra water in the bucket before it actually tips over. The following graph shows the relationship between bucket volume and rainfall rate of a typical tipping bucket. In this example the bucket volume/tip changes from .01 in/tip to .013 in/tip (a 30% change) as the rainfall changes from 0 to 25 in/hour. To overcome this problem the microprocessor in the H-3401SDI uses an electronic timer to precisely measure the time between bucket tips. This time value corresponds to the current rainfall rate. On a bucket-by-bucket basis the microprocessor uses a built-in polynomial to correct for the intensity sensitivity of the bucket mechanism. For example, bucket tips which are 50 seconds apart (1 in/hr) are computed with a 0.01in/tip accumulation. Bucket tips 2 seconds apart (25 in/hr) produce a .012in/tip accumulation.

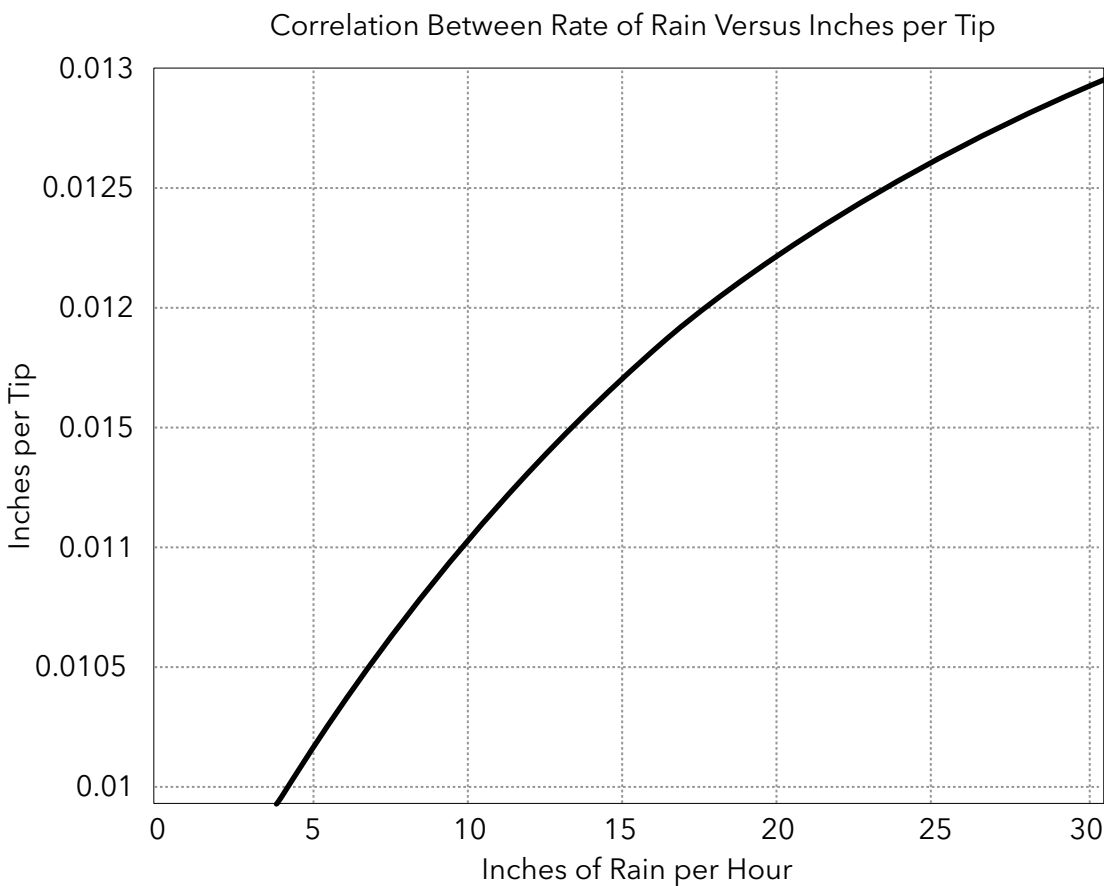


Figure 1: 0.01" Bucket Tip Mechanism Sensitivity

0.2mm

The following graph shows the relationship between bucket volume and rainfall rate of a typical tipping bucket. In this example the bucket volume/tip changes from 0.2mm/tip to 0.26mm/tip (a 30% change) as the rainfall changes from 0 to 500 mm/hour.

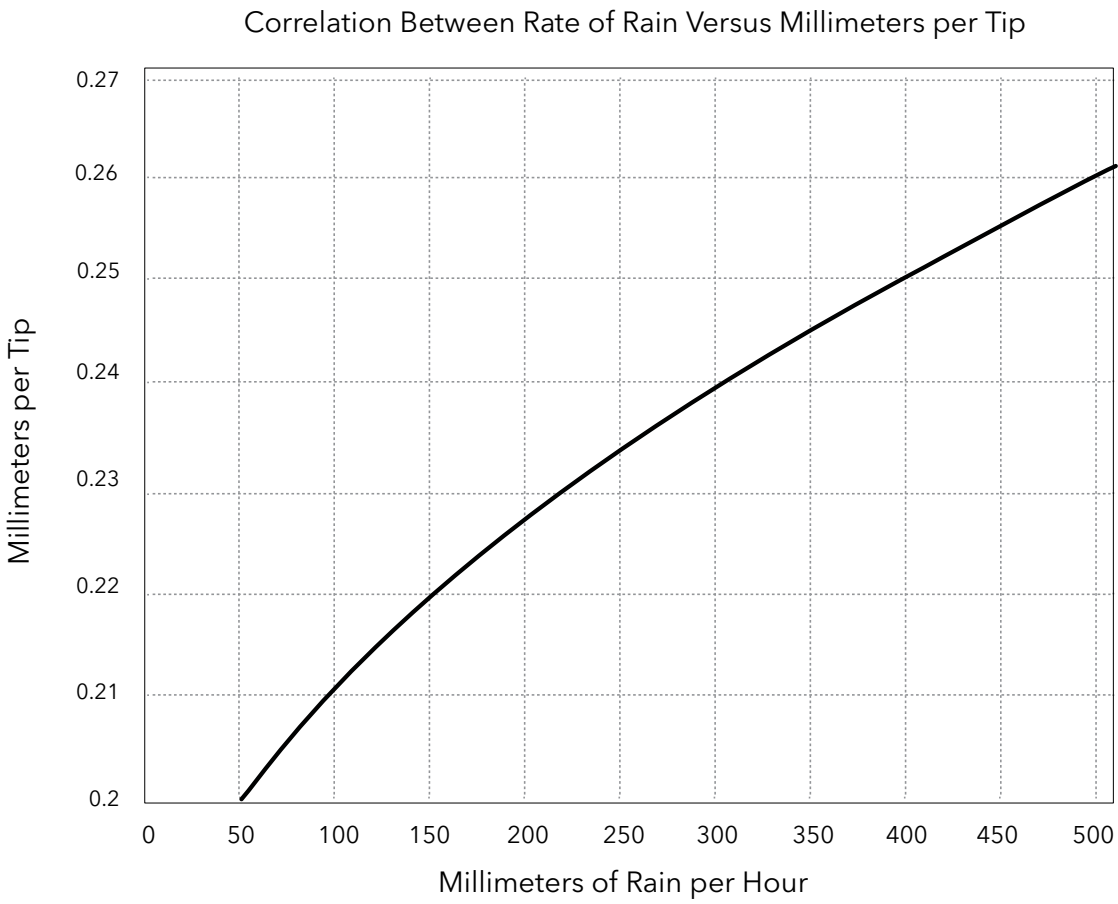
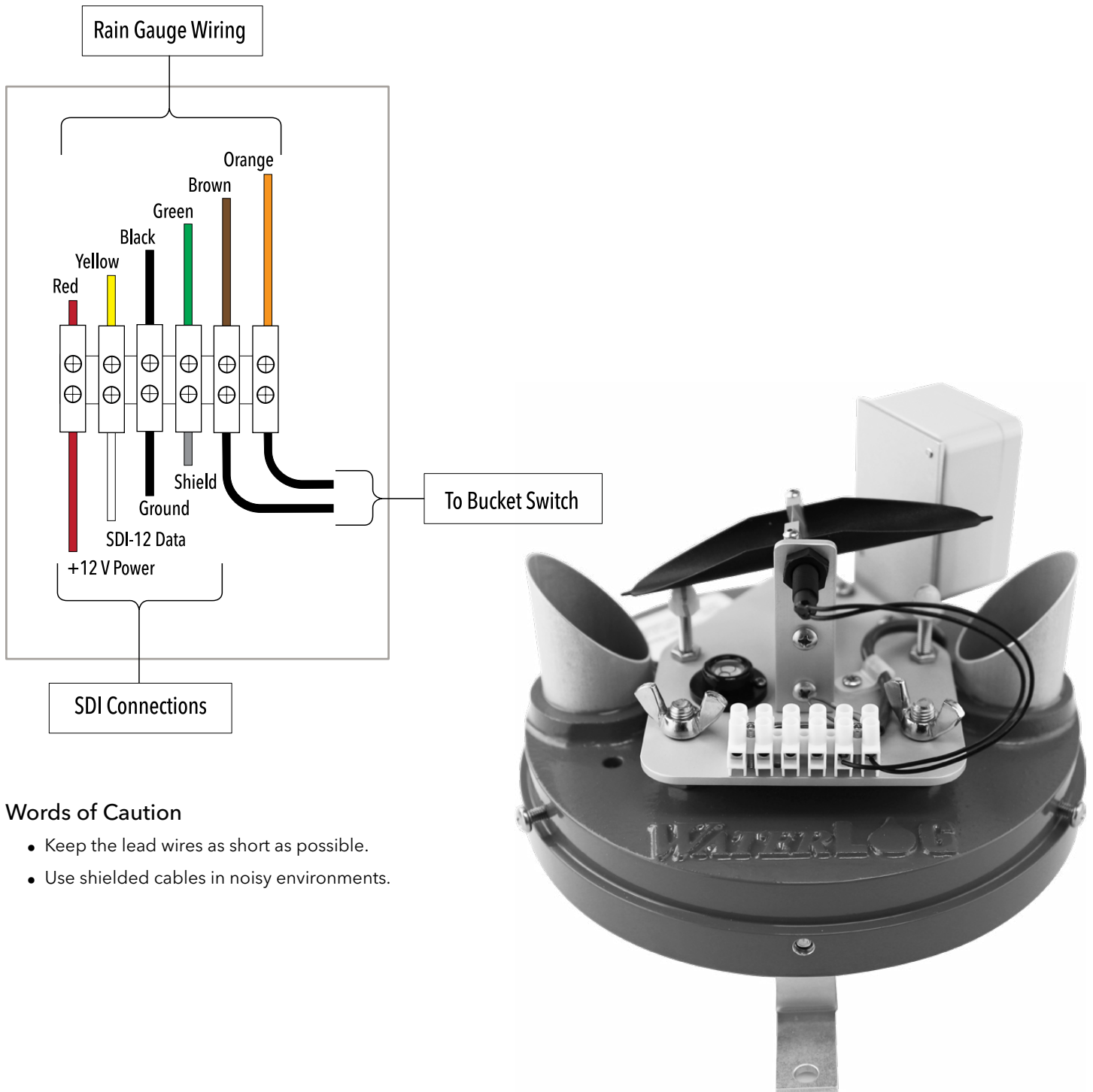


Figure 2: 0.02mm Bucket Tip Mechanism Sensitivity

1.4

Making Connections to the H-3401SDI

The H-3401SDI has a 6-pin wiring terminal block for connecting the data logger and power. The terminal block has screw clamp terminals which work with both large and small wires and provide reliable long-term connections. To open the terminal ports to insert or remove a wire, insert a small flat screwdriver blade in the circular opening and tighten or loosen the screw to open or close the terminal port.



Words of Caution

- Keep the lead wires as short as possible.
- Use shielded cables in noisy environments.

Figure 3: Internal View of H-3401SDI Rain Gauge

1.5

Installation

Install the H-3401SDI in an open location where it will not be in the rain shadow of trees or buildings. A rooftop location helps prevent vandalism and the accumulation of leaves and debris. Bolt or screw the 3-mounting feet to the structure to prevent upset in high winds. Adjust the three self-leveling wingnuts on the raingage board until the "bulls eye" level is centered.

1.6

Programming Your Data Recorder

You must prepare your data recorder to receive and record the H-3401SDI data. Since data recorders differ widely, refer to your recorder manufacturer's directions. In general, program the data recorder to input five values via the SDI-12 port. Usually only one or two of the parameters is actually recorded. Your data recorder must issue an "aM!" command then collect the data with a "aD0" command, as explained in Chapter 2. The H-340SDI places five data values in its data buffer:

+AA.AAA+BBB+CC.CCC+DD.DDD+EE.EEE

Where:

+AA.AAA = Rainfall accumulation since last measurement (mm/in of rain)

+BB = Number of raw bucket tips since last measurement (counts)

+CC.CCC = Total rainfall accumulation since reset. (mm/in of rain)

+DD.DDD = Total rainfall accumulation today (mm/in of rain)

+EE.EEE = Total rainfall accumulation yesterday (mm/in of rain)

All five of these parameters are automatically reset at power-up, or manually with the extended SDI-12 "aXRA" Reset Accumulators command.

NOTE: *There are also some additional measurement commands, M1, M1C, C1 and C1C that will return the following data.*

+AA.AAA+BBB+CC.CCC

or

+AA.AAA+BBB+CC.CCC+KKKK

Where:

+AA.AAA = Uncompensated rainfall accumulation since last measurement (mm/in of rain)

+BB = Number of raw bucket tips since last measurement (counts)

+CC.CCC = Uncompensated total rainfall accumulation since reset. (mm/in of rain)

+KKKK = CRC

1.7

Programming the H-3401SDI

The H-3401SDI comes from the factory with the following settings:

SDI Address: 0

Slope: 1.0

Daily Reset Time: 00:00:00

Time of day: 00:00:00

With these values the data will be in units of inches of rainfall. The setup is stored in EEPROM within the H-3401SDI and will not be lost if the power is disconnected. The extended commands for changing the slope and sensor address are described in detail in Chapter 2. If more than one sensor is to be connected to the SDI-12 bus, make certain each sensor has a unique sensor address.

In some cases the user may wish to preset the H-340's Total Accumulation value to match the current rainfall of the water year. The H-340 has an offset value stored in memory which is automatically added to the Total Accumulation value. The offset value can be written or read with two extended SDI-12 commands ("aXWO" and "aXRO"), see Chapter 2 for details. Please note both the Total Accumulation and Offset values are reset at power-up, or with the extended SDI-12 Reset Accumulators ("aXRA") command. To change the Total Accumulation to a new value you must first reset the accumulators with the "aXRA" command, then set the offset with the "aXWO" command.

1.8

Factory Calibration

The H-3401SDI is calibrated in the factory with an apparatus which provides a constant 4in/hour flow rate. The water exiting from the bottom of the rain gauge is captured in a precision graduated cylinder. After 100 bucket tips or more have occurred, the flow is stopped and the volume in the graduated cylinder is measured. The procedure is as follows:

Issue an extended "aXRA!" (reset accumulator) SDI-12 command. Empty the graduated cylinder. Start the water flow into the funnel. Wait until at least 100 bucket tips have occurred (1% resolution). Stop the water flow. Observe and record the water volume in the graduated cylinder. Use the formula below to compute the actual rainfall accumulation. Issue a SDI-12 "aM!" measure command and record the "smart bucket" accumulation. Compare the difference between the smart bucket rainfall reading he rainfall volume in the graduated cylinder. Adjust the counterweight as needed and repeat until the two values are identical or within an acceptable difference.

The rainfall "volume" equation below converts the volume in the graduated cylinder (mL) into the equivalent rainfall (in inches) captured by an 8 inch diameter funnel.

$$\text{Rainfall in} = \frac{NmL \times \frac{L}{1000mL} \times 61.025 \frac{\text{in}^3}{L}}{\pi(4.0 \text{ in})^2} = NmL \times 1.21405 \times 10^{-3} \text{ in}$$

$$\text{Rainfall mm} = \frac{NmL \times \frac{L}{1000mL} \times 0.001 \frac{\text{m}^3}{L}}{\pi(4.0 \text{ in})^2} = NmL \times 30.83633 \times 10^{-3} \text{ mm}$$

Other related equations of interest:

$$\text{Rate} \frac{\text{in}}{\text{hr}} = \frac{\text{Rainfall in}}{N \text{ min}} \times 60 \frac{\text{min}}{\text{hr}}$$

$$\text{Rainfall} \frac{\text{in}}{\text{tip}} = \frac{\text{Rainfall in}}{N \text{ tips}}$$

$$\text{Rate} \frac{\text{mm}}{\text{tip}} = \frac{\text{Rainfall mm}}{N \text{ tips}}$$

1.9

User Calibration

The "smart bucket" processor uses a fixed polynomial to compute each bucket volume as a function of rainfall rate. The factory calibration should be sufficiently accurate for all rainfall rates from 0 to 25 inches/hour (0 to 500 mm/hour). If the user requires an exact calibration at a rate other than 4.0 inches/hour (101.6 mm/hour), or if the tipping bucket mechanism is damaged or changed the bucket mechanism may need to be recalibrated. The procedure for adjusting the stopping posts is included below. Please note that the "smart bucket" feature is calibrated somewhat differently than a normal tipping bucket device. With a simple tipping bucket, a known amount of water is passed through the gauge and the number of bucket tips is recorded. The stopping posts are then adjusted for the desired number of tips. With the H-3401SDI "smart bucket" feature, the number of bucket tips is not used in the calibration, instead, the SDI-12 measurement value is used. This is different because the H-3401SDI's microprocessor is using a non-linear polynomial expression to compute the volume. With the aid of the polynomial you can get an accurate field calibration without using the constant flow apparatus which is used at the factory. Just remember to use the SDI-12 "aM" measurement values and not the number of bucket tips.

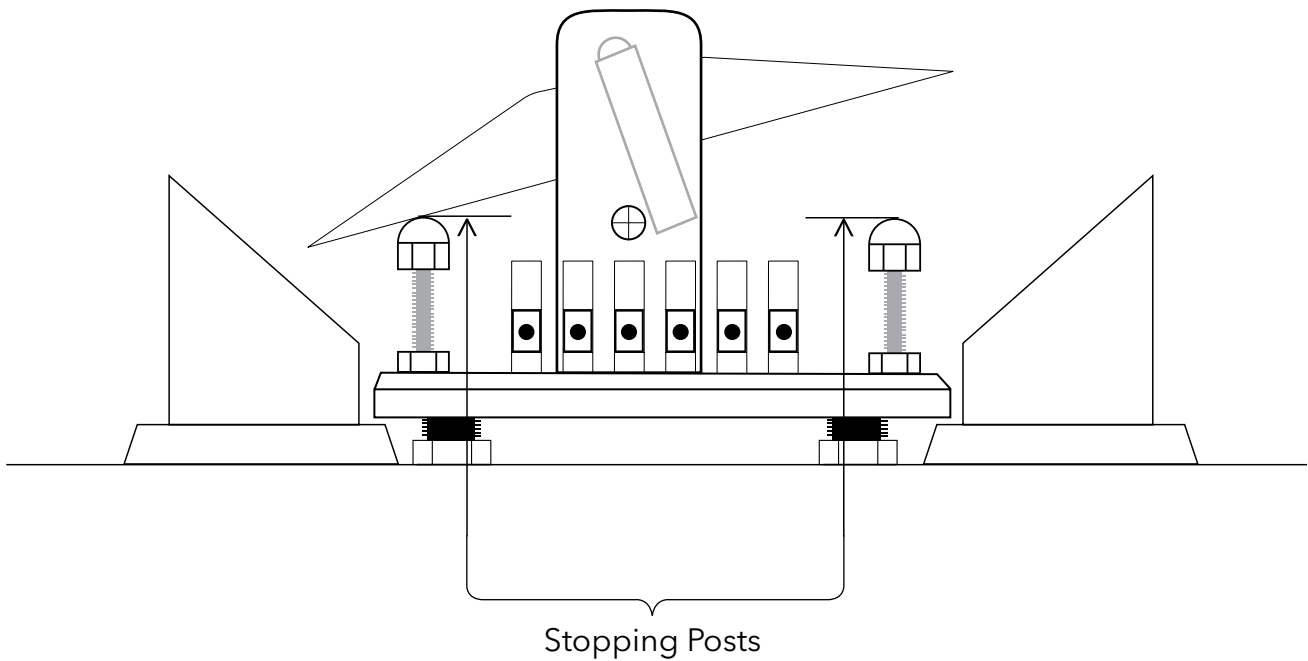


Figure 4: H-3401SDI Internal Structural Components used in Calibration of Sensor

1.10

Adjusting the Tipping Bucket Mechanism

Adjusting the tipping mechanism on the H-3401SDI consists of adjusting the stop posts to reduce or increase the volume of water the bucket can hold before it tips. As the stop post rises the volume of water the bucket on the opposite side decreases.

1. To adjust for too many tips (need more rainfall volume), lower the stop post on the opposite side of the bucket that is tipping too early. Re-lock the nut.
2. To adjust for too few tips (need less rainfall volume), raise the stop post on the opposite side of the bucket that is tipping too late. Re-lock the nut.
3. To adjust for equal amounts of water in each bucket, use a pipet to put a set amount of water into each bucket ensuring the bucket tips with a specific volume of water in the bucket. Adjust the stop post heights to ensure the buckets tip at the proper volume of water: 0.01" – 8.24 mL, 0.2mm – 6.49 mL, 0.1mm – 3.24 mL.

2.1

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-3401SDI sensor. Included is a description of the commands and data format supported by the H-3401SDI.

Refer to the document "A SERIAL DIGITAL INTERFACE STANDARD FOR HYDROLOGIC AND ENVIRONMENTAL SENSORS". Version 1.3 January 12, 2009 Coordinated by the SDI-12 Support Group, 165 East 500 South, River Heights, Utah 84321

During normal communication, the data recorder sends an address together with a command to the H-3401SDI sensor. The H-3401SDI 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", "AZ", "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

To enhance the error detection capability in SDI-12 data collection systems, a variation of the Start Measurement Commands (M!, M1! ... M9!), Start Concurrent Measurement Commands (C!, C1! ... C9!), and Continuous Measurement Commands (aR0! ... aR9!) request that the data be returned with a 16 bit Cyclic Redundancy Check (CRC) appended to it. These commands use the existing command letters with a C appended, namely: aMC!, aMC1! ... aMC9!, aCC!, aCC1! ... aCC9!, and aRC0! ... aRC9!. When these commands are used, the data returned in response to the D commands, or R commands, have a CRC code appended to it.

2.2

Master SDI-12 Command List

Standard SDI-12 commands

Command	Description
aM!	Make Measurement
aM1!	Make Uncompensated Measurement
aMC!	Make Measurement with CRC
aMC1!	Make Uncompensated Measurement with CRC
aC!	Make Concurrent Measurement
aC1!	Make Uncompensated Concurrent Measurement
aCC!	Make Concurrent Measurement with CRC
aCC1!	Make Uncompensated Concurrent Measurement with CRC
aD0!	Send Data
aR0!	Make Continuous Measurement
aR1!	Make Uncompensated Continuous Measurement
aRC0!	Make Continuous Measurement with CRC
aRC1!	Make Uncompensated Continuous Measurement with CRC
aV!	Verify Sensor
aAn!	Change Sensor Address
al!	Send Identification
a!	Send Acknowledge

Extended SDI-12 commands unique to the H-3401SDI

Command	Description
aXRS!	Read <i>Slope</i>
aXWSddd!	Write <i>Slope</i>
aXRO!	Read <i>Offset</i>
aXWOddd!	Write <i>Offset</i>
aXGDRT!	Get daily reset time
aXSDRTddd!	Set daily reset time (Format = HHMMSS)
aXGT!	Get the current time
aXSTddd!	Set the current time (Format = HHMMSS)
aXRA!	Reset accumulators
aXRBT!	Read Bucket Type
aXWBTd!	Write Bucket Type (1=0.01" 2=0.2mm 3=0.1mm)
aXTEST!	Initiate a repeating test printout
aXHELP!	Print a command listing

2.3

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.

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>" 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 anytime after the service request is received or the specified processing time has elapsed.

Example of a H-340SDI "aM!" command

Command	Response	Time	Values	Description
aM!	a0015<cr><lf>	1 sec	5	Return current accumulations
Subsequent Command				
aD0	a+AA.AAA+BB+CC.CCC+DD.DDD+EE.EEE<cr><lf>			
Where				
AA.AAA = Rainfall accumulation since last measurement (mm/in of rain)				
BB = Number of bucket tips since last measurement (raw count)				
CC.CCC = Total accumulation since reset (mm/in of rain)				
DD.DDD = Total accumulation today (mm/in of rain)				
EE.EEE = Total accumulation yesterday (mm/in of rain)				

2.4

Uncompensated Measure Command

The Uncompensated Measure Command causes a measurement sequence to be performed without using the compensation based on the rainfall rate. 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", "R", or "V" command is executed.

Command	Response	Description
aM1!	attn<cr><lf>	Initiate measurement
Where		
<p>a is the sensor address ("0-9", "A-Z", "a-z", "*", "?").</p> <p>M is an upper-case ASCII character.</p> <p>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.</p> <p>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.</p>		

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 anytime after the service request is received or the specified processing time has elapsed.

Example of a H-340SDI "aM1!" command

Command	Response	Time	Values	Description
aM1!	a0013<cr><lf>	1 sec	3	Return current accumulations
Subsequent Command				
aD0	a+AA.AAA+BB+CC.CCC<cr><lf>			
Where				
AA.AAA = Rainfall accumulation since last measurement (mm/in of rain)				
BB = Number of bucket tips since last measurement (raw count)				
CC.CCC = Total accumulation since reset (mm/in of rain)				

2.5

Concurrent Measurement Command

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.	
nnn	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.

2.6

Uncompensated Concurrent Measurement Command

An uncompensated concurrent measurement is one which occurs while other SDI-12 sensors on the bus are also taking measurements and does not use the compensation for rainfall rate. This command is similar to the "aM1!" 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", "R" or "V" command is executed.

Command	Response	Description
aC1!	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.	
nnn	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.

2.7

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! – 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 (a<CR><LF> only), it means that the measurement was aborted and a new "M" command must be sent.

Example of a H-340SDI "aD0!" command

Previous Command	Response
aM!	a0015<cr><lf>
Subsequent Command	Response
aD0	a+AA.AAA+BB+CC.CCC+DD.DDD+EE.EEE<cr><lf>
Where	
AA.AAA = Rainfall accumulation since last measurement (mm/in of rain)	
BB = Number of bucket tips since last measurement (raw count)	
CC.CCC = Total accumulation since reset (mm/in of rain)	
DD.DDD = Total accumulation today (mm/in of rain)	
EE.EEE = Total accumulation yesterday (mm/in of rain)	

2.8

Continuous Measurements

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

The H-3301/3311 supports the aR0! and aR1! continuous measurement commands.

Example of a H-3401SDI "aR0!" command

Command	Response
aR0!	a+AA.AAA+BB+CC.CCC+DD.DDD+EE.EEEXXX<cr><lf>
AA.AAA = Rainfall accumulation since last measurement (mm/in of rain) BB = Number of bucket tips since last measurement (raw count) CC.CCC = Total accumulation since reset (mm/in of rain) DD.DDD = Total accumulation today (mm/in of rain) EE.EEE = Total accumulation yesterday (mm/in of rain)	

Example of a H3401SDI "aR1!" command

Command	Response
aR01!	a+AA.AAA+BB+CC.CCC<cr><lf>
AA.AAA = Rainfall accumulation since last measurement (mm/in of rain) BB = Number of bucket tips since last measurement (raw count) CC.CCC = Total accumulation since reset (mm/in of rain)	

2.9

Measurements with CRC

To enhance the error detection capability in SDI-12 data collection systems, a variation of the Start Measurement Commands (M!, M1! ... M9!), Start Concurrent Measurement Commands (C!, C1! ... C9!), and Continuous Measurement Commands (aR0! ... aR9!) request that the data be returned with a 16 bit Cyclic Redundancy Check (CRC) appended to it. These commands use the existing command letters with a C appended, namely: aMC!, aMC1! ... aMC9!, aCC!, aCC1! ... aCC9!, and aRC0! ... aRC9!. When these commands are used, the data returned in response to the D commands, or R commands, have a CRC code appended to it.

All Measure and Concurrent Measure Commands support the CRC functionality. In order to have the CRC appended to the data of, for example, the "aM!" command the command would change to "aMC!" The Concurrent Measurements also support the CRC, so for a CRC to be appended onto the "aC1!" command, the variant would be "aCC1!"

2.10 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 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.	

Example of a H-340SDI "aV!" command

Command	Response	Time	Values	Description
aV!	a0013<cr><lf>	1 sec	3	Return fixed and diagnostic data for testing purposes
Subsequent Command		Response		
aD0	a+123.456+78.9+y<cr><lf>			
Key	Description	Units		
+123.456 +78.9 y	Fixed test data Fixed test data ROM checksum test	0 = Failed, 1 = Passed		

2.11 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", "*", "?").

2.12

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
a!	allccccccmmmmmvvxx...xx<cr><lf>
Where	
a	is the sensor address ("0-9", "A-Z", "a-z", "*", "?").
l	is an upper-case ASCII character
ll	is SDI-12 version compatibility level, e.g. version 1.2 is represented as "12".
ccccccc	is an eight character vendor identification to be specified by the vendor and usually in the form of a company name or its abbreviation.
mmmmmm	is a six character field specifying the sensor model number.
vvv	is a three 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 H-340SDI "a!" command

Command	Response
a12!	DAA H - 340vvvS#nnnnnn<cr><lf>
H-3401SDI 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.

2.13 Change Sensor Address

The Change Sensor Address Command allows the sensor address to be changed. The address is stored in non-volatile EEPROM within the sensor. The H-3401SDI will not respond if the command was invalid, the address was out of range, or the EEPROM programming operation failed.

Command	Response	Description
aAn!	n<cr><lf>	Change sensor address
Where		
a	is the 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", "a-z", "*", "?").	

NOTE: To verify the new address use the "Identify Command" or "Acknowledge Command"

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

2.14 Extended "Read Slope" Command

The H-3401SDI processes the rainfall accumulation values with a "mX" equation. The slope (m) term is programmable, allowing the user to scale the rainfall value into other engineering units. This command allows the user to read the current slope term. At the factory the slope is set to 1.000 which provides output data in "inches" of rainfall.

Command	Response	Description
aXRS!	a0011<cr><lf>	Read slope
Where		
a	is the sensor address ("0-9", "A-Z", "a-z", "*", "?").	
XRS	are upper case characters.	

This command takes 001 seconds to complete and places 1 value in the data buffer.

Use the "aD0" command to collect and view the data.

Example of a H-3401SDI Extended "Read Slope" command

Command	Response	Time	Values	Description
XRS!	a0011<cr><lf>	1 sec	1	Read slope
Subsequent Command				
aD0	a+1.000<cr><lf>			

2.15

Extended "Write Slope" Command

The H-3401SDI processes the raw rainfall values with a "mX" equation. The slope (m) term is programmable, allowing the user to scale the rain fall value into other engineering units. This command allows the user to write (change) the current slope term. At the factory the slope is set to 1.000 which provides output data in "inches" of rainfall. The new value is stored in non-volatile EEPROM within the sensor. Once the new slope value is written to the EEPROM, a copy is sent to the sensor data buffer for verification. This data can be viewed by using a subsequent "D" command. To verify the Slope any other time, use the "Read Slope" command.

Command	Response	Description
aXWSddd!	a0011<cr><lf>	Write slope
Where		
a	is the sensor address ("0-9", "A-Z", "a-z", "*", "?").	
XWS	are upper case characters.	
ddd	is the new slope value. The input format is very flexible. Some examples are shown below.	
	20.0	
	0.195	
	-500	
	5.93E-4	

This command takes 001 seconds to complete and places 1 value in the data buffer.

Use the "aD0" command to collect and view the data.

Example of a H-3401SDI extended "Write Slope" command

Command	Response	Time	Values	Description
aXWS1.234!	a0011<cr><lf>	1 sec	1	Set slope to 1.234
Subsequent Command				
aD0	a+1.234<cr><lf>			

2.16

Extend "Read Offset" Command

The H-3401SDI maintains an offset value in RAM which is automatically added to the Total Accumulation value. The offset value can be used to match the H-340's Total Accumulation to the current water year rainfall. This command allows the user to read the current offset value. The offset is automatically set to zero at power-up or with the "aXRA" command.

Command	Response	Description
aXRO!	a0011<cr><lf>	Read offset
Where		
a	is the sensor address ("0-9", "A-Z", "a-z", "*", "?").	
XRO	are upper case characters.	

This command takes 001 seconds to complete and places 1 value in the data buffer.

Use the "aD0" command to collect and view the data.

Example of a H-3401SDI Extended "Read Offset" command

Command	Response	Time	Values	Description
aXRO!	a0011<cr><lf>	1 sec	1	Read offset
Subsequent Command	Response			
aD0	a+0.000<cr><lf>			

2.17 Extended "Write Offset" Command

The H-3401SDI maintains an offset value in RAM which is automatically added to the Total Accumulation value. The offset value can be used to match the H-3401SDI's Total Accumulation to the current water year rainfall. This command allows the user to write (change) the current offset. The offset is automatically set to zero at power-up or with the "aXRA" command. To change the Total Accumulation to a new value you must first reset the accumulators with the "aXRA" command, then set the offset with the "aXWO" command.

The new value is stored in RAM within the sensor and is not preserved if the power is lost. Once the new offset value is written to the RAM, a copy is sent to the sensor data buffer for verification. This data can be viewed by using a subsequent "D" command. To verify the Offset any other time, use the "Read Offset" command.

Command	Response	Description
aXWOddd!	a0011<cr><lf>	Write offset
Where		
a	is the sensor address ("0-9", "A-Z", "a-z", "*", "?").	
XWO	are upper case characters.	
ddd	is the new offset value. The input format is very flexible. Some examples are shown below.	
	20.0	
	0.195	
	-500	
	5.93E-4	

This command takes 001 seconds to complete and places 1 value in the data buffer.

Use the "aD0" command to collect and view the data.

Example of a H-3401SDI extended "Write Offset" command

Command	Response	Time	Values	Description
aXWO1.234!	a0011<cr><lf>	1 sec	1	Set offset to 1.234
Subsequent Command	Response			
aD0	a+1.234<cr><lf>			

2.18

Extended "Get Time" Command

The H-3401SDI has a built-in real time clock. This command allows the user to read the current time of day.

Command	Response	Description
aXGT!	a0013<cr><lf>	Read time of day
Where		
a is the sensor address ("0-9", "A-Z", "a-z", "*", "?").		
XGT are upper case characters.		

This command takes 001 seconds to complete and places 3 values in the data buffer.

Use the "aD0" command to collect and view the data.

Example of a H-3401SDI extended "Get Time" command

Command	Response	Time	Values	Description
aXGT!	a0013<cr><lf>	1 sec	3	Get current time of day
Subsequent Command		Response		
aD0	a+HH+MM+SS<cr><lf>			
Where				
HH = Hours (24 hour format)				
MM = Minutes				
SS = Seconds				

2.19

Extended "Set Time" Command

The H-3401SDI has a built-in real time clock. This command allows the user to change the current time of day.

Command	Response	Description
aXSTHHMMSS!	a0013<cr><lf>	Set time of day
Where		
a is the sensor address ("0-9", "A-Z", "a-z", "*", "?").		
XST are upper case characters.		
HHMMSS is the new time in Hours:Minutes:Seconds (24-Hour format).		

This command takes 001 seconds to complete and places 3 values in the data buffer. Use the "aD0" command to collect and view the data.

Example of a H-3401SDI extended "Set Time" command

Command	Response	Time	Values	Description
aXST234537	a0011<cr><lf>	1 sec	1	Set time of day to 23:45:37
Subsequent Command	Response			
aD0	a+23+45+37<cr><lf>			

2.20 Extended "Get Daily Reset Time" Command

The H-3401SDI automatically resets the daily accumulations a certain time each day. For example, one day may be calculated from 6:00 AM of one day to 6:00 AM of the next day. This command reads the time of day at which the reset is scheduled.

Command	Response	Description
aXGDRT!	a0013<cr><lf>	Read daily reset time
Where		
a	is the sensor address ("0-9", "A-Z", "a-z", "*", "?").	
XGDRT	are upper case characters.	

This command takes 001 seconds to complete and places 3 values in the data buffer. Use the "aD0" command to collect and view the data.

Example of a H-3401SDI extended "Get Daily Reset Time" command

Command	Response	Time	Values	Description
aXGDRT!	a0013<cr><lf>	1 sec	3	Get daily reset time
Subsequent Command	Response			
aD0	a+HH+MM+SS<cr><lf>			
Where				
HH = Hours (24 hour format)				
MM = Minutes				
SS = Seconds				

2.21

Extended "Set Daily Reset Time" Command

The H-3401SDI automatically resets the daily accumulations a certain time each day. For example, one day may be calculated from 6:00 AM of one day to 6:00 AM of the next day. This command sets the time of day at which the reset is scheduled.

Command	Response	Description
aXSDRThhmmss!	a0013<cr><lf>	Set daily reset time
Where		
a	is the sensor address ("0-9", "A-Z", "a-z", "*", "?").	
XSDRT	are upper case characters.	
hhmmss	is the new time in Hours:Minutes:Seconds (24-Hour format). Use fixed format. For example 010233 for 01:02:33.	

This command takes 001 seconds to complete and places 3 values in the data buffer.

Use the "aD0" command to collect and view the data.

Example of a H-3401SDI extended "Set Time" command

Command	Response	Time	Values	Description
aXSDRT230537	a0013<cr><lf>	1 sec	3	Set daily reset time to 23:05:37
Subsequent Command		Response		
aD0	a+23+05+37<cr><lf>			

2.22

Extended "XTEST" Command

This command is primarily used for production testing and requires the use of a H-419 or SDI-12 verifier and a PC. This command causes the H-3401SDI to transmit unsolicited real-time data for testing purposes. This is not compliant with the SDI-12 specification and is not used with data loggers.

To activate the test mode, first send the command "aXTEST!", then enter the verifier's MONITOR mode. Whenever a bucket tip occurs, the H-3401SDI now transmits the time between bucket tips and the adjusted rainfall for the bucket tip. This test mode may be used to help troubleshoot the installation by providing a continuous readout of bucket tip timing and rainfall. The test mode is exited by sending any new command on the SDI-12 bus (a BREAK terminates). It may take a few tries to exit if the command is sent at the same time data is being sent from the H-3401SDI. Removing power from the H-3401SDI also causes it to exit this mode. Note: bucket tips less than 500mS apart are discarded (ignored) by the H-3401SDI.

Example of the XTEST test display:

```
+1.200+.013 (Time between tip is 1.2 Seconds, rainfall for this tip is 0.013 inches)
+60.00+.009
+4.400+.012
+2.2+.011
etc.
```

2.23

Extended "XHELP" Command

This command is used to give a full listing of the commands that can be used with the H-3401SDI. In response to this command a message that does not comply with the SDI-12 specification will be sent. This command should only be used when connected to a device, such as the H-4191, that can handle non-compliant messages.

Appendix A | Specifications

General

Output: SDI-12

Power Input

Voltage: 10.0 to 16.0 Volts DC

Current: (may be higher while charging the supercap)

Standby Mode: 180 μ A

Raining: 2.8 mA for 60 sec

Communicating: 6.0 mA

Timing

SDI-12: 0.1 second measurement sequence

SDI-12 Output

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

maximum cable length: 200 ft.

Environmental (electronics)

Operating Temperature: -40 to 60 EC

Storage Temperature: -50 to 70 EC

Mechanical

Operating Temperature: 0 to 50 EC

Connectors

SDI-12 Output: 4-position screw clamp terminal block (WAGO)

Mechanical

Bucket Tip Sensor: Magnetic reed switch.

Aperture: 8" diameter funnel

Housing: 8" diameter extruded aluminum tube. Cast aluminum base with drain tubes in the bottom. Anodized aluminum internal parts. Stainless steel screws and fasteners. Powder painted base, funnel and housing.

Mounting: 3 leveling screws with bolt down feet

Weight: 8 pounds

Calibration

Built in processor measures the time between bucket tips (rainfall rate) and uses this data to compute the bucket volume per tip at the current rainfall rate. A built-in polynomial provides corrected bucket volume for rainfall rates between 0 and 25 in/hour (for 0.01") or 0 to 500 mm/hour (for 0.2mm).

Warranty

The WaterLOG® H-3401SDI is warranted against defects in materials and workmanship for two years from date of shipment.

Appendix B | Ordering Guide

Rain Gauge		
Item Number	Description	
H-3401-00-00	Rain Gauge, Tipping Bucket, 8in Funnel, 0.01in/tip, 20ft cable, switch closure output	Precipitation Gauge with counter output 0.01in/tip
H-3401-00-01	Tipping Bucket Rain Gauge 8in Funnel SDI-12 output with external SDI cable, with 0.01in/tip output	Precipitation Gauge with SDI-12 0.01in/tip
H-3401-01-00	Tipping Bucket Rain Gauge 8in Funnel switch closure output with external SDI cable, with 0.1mm/tip output	Precipitation Gauge with counter output 0.1mm/tip
H-3401-01-01	Tipping Bucket Rain Gauge 8in Funnel SDI-12 output with external SDI cable, with 0.1mm/tip output	Precipitation Gauge with SDI-12 0.1mm/tip
H-3401-02-00	Tipping Bucket Rain Gauge 8in Funnel switch closure output with external SDI cable, with 0.2mm/tip output	Precipitation Gauge with counter output 0.2mm/tip
H-3401-02-01	Tipping Bucket Rain Gauge 8in Funnel SDI-12 output with external SDI cable, with 0.2mm/tip output	Precipitation Gauge with SDI-12 0.2mm/tip
H-3401-C	Funnel and Barrel Kit, 8in	Funnel and Barrel
H-3401-FSCREEN	Screen, Funnel Insert	Inner Funnel Fine Screen
H-3401-SCREEN	Screen, 8in Funnel	Debris Screen

Xylem |'zīləm|

- 1) The tissue in plants that brings water upward from the roots;
- 2) a leading global water technology company.

We're a global team unified in a common purpose: creating advanced technology solutions to the world's water challenges. Developing new technologies that will improve the way water is used, conserved, and re-used in the future is central to our work. Our products and services move, treat, analyze, monitor and return water to the environment, in public utility, industrial, residential and commercial building services settings. Xylem also provides a leading portfolio of smart metering, network technologies and advanced analytics solutions for water, electric and gas utilities. In more than 150 countries, we have strong, long-standing relationships with customers who know us for our powerful combination of leading product brands and applications expertise with a strong focus on developing comprehensive, sustainable solutions.

For more information on how Xylem can help you, go to www.xylem.com

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