INSTRUCTION MANUAL

AquiStar® T1

Temperature Sensor

AquiStar™
Data Collection Systems

INW™

True data, measure by measure

Table of Contents

Introduction

T1 Temperature Sensor

The T1 Temperature Sensor represents the latest state-of-the-art technology and has been designed to provide trouble-free submersible operation in liquid environments, when properly installed and operated. This sensor communicates via SDI-12 (v1.3) or Modbus® protocol.

Please take the time to read through this manual if you are not familiar with this product.

Initial Inspection and Handling

Upon receipt of your sensor, inspect the shipping package for damage. If any damage is apparent, note the signs of damage on the appropriate shipping form. After opening the carton, look for concealed damage such as a cut cable. If concealed damage is found, immediately file a claim with the carrier.

Check the etched label on the sensor to be sure that the proper range and type were provided. Also check the label attached to the cable at the connector end for the proper cable length.

Do's and Don'ts

Do handle the device with care.
Do store the device in a dry, inside area when not in use.

Don't install the device so that the connector end is submerged.
Don't support the device with the connector or with the connectors of an extension cable. Use a strain relief device to take the tension off the connectors.
Don't allow the device to free-fall down a well at high velocities as impact damage can occur.
Don't bang or drop the device on hard objects.
Don't disassemble the device. (The warranty is void if sensor is disassembled.)

Installation & Operation

The T1 measures temperature and supply voltage. A typical application is measuring temperature in wells and tanks.

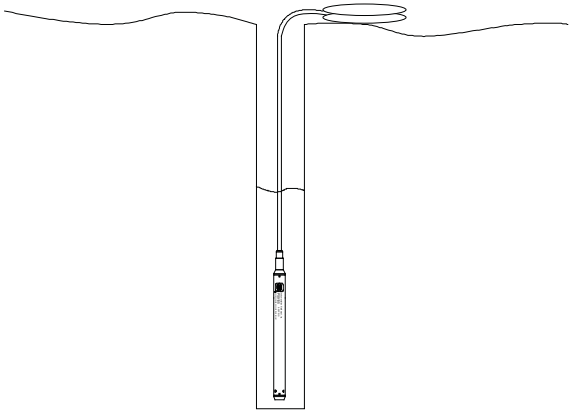
Using with an SDI-12 Datalogger

The T1 submersible temperature sensor represents the latest in state-of-the-art level measurement technology. This sensor was designed for use with SDI-12 dataloggers and provides a temperature and supply voltage output. (See Appendix A for wiring information.)

Temperature values are returned in degrees Celsius, and supply voltage values are returned in volts. Every sensor is individually calibrated at the factory, using an environmental test chamber. Sensor specific calibration values are stored in the sensor.

Well Installation

Lower the sensor to the desired depth. Fasten the cable to the well head using tie wraps or a weather proof strain-relief system. It is recommended that several readings be taken to insure proper operation after installation.



Installation

Notes:

- **Proper grounding is very important!** INW recommends the following: (1) the sensor cable shield (the wrapped shield inside the cable) be attached to the power ground on the datalogger and (2) the grounding lug be connected via a 12 AWG or larger wire, to a grounding rod driven into the earth. It is also recommended that your power supply be tied to the same earth ground. (See also: Grounding Issues in the Trouble Shooting section of this manual.)

Other Installations

The sensor can be installed in any position. Strapping the sensor body with tie wraps or tape will not hurt it. If the sensor is being installed in a fluid environment other than water, be sure to check the compatibility of the fluid with the wetted parts of the sensor. INW can provide a variety of seal materials if you are planning to install the sensor in an environment other than water.

Maintenance

Sensor: There are no user-serviceable parts. If problems develop with sensor stability or accuracy, contact INW. If the sensor has been exposed to hazardous materials, do not return it without notification and authorization.

Cable: Cable can be damaged by abrasion, sharp objects, twisting, crimping or crushing and pulling. Take care during installation and use to avoid cable damage. If a section of cable is damaged, it is recommended that you send your sensor back to replace the cable harness assembly.

Connectors (if used): The contact areas (pins & sockets) of the connectors will wear out with extensive use. If your application requires repeated connections, other types of connectors can be provided. The connectors used by INW are not submersible, but are designed to be splash-resistant.

Trouble Shooting

Erratic Readings

Erratic readings can be caused by a damaged sensor, damaged cable, poor connections or improper operation of readout equipment. In most cases, erratic readings are due to moisture getting into the system. Assuming that the readout equipment is working correctly, the first thing to check is the connection. Look for moisture between contacts or a loose or broken wire.

Erratic and erroneous readings can also occur due to improper grounding.
See Grounding Issues.

Zero Readings

Continuous zero readings are caused by an open circuit which usually indicates broken cable, a bad connection, or possibly a damaged sensor. Check the connector to see if a wire has become loose, or if the cable has been cut. If neither of these appears to cause the problem, the sensor needs factory repair.

Grounding Issues

It is commonly known that when using electronic equipment, both personnel and equipment need to be protected from high power spikes that may be caused by lightning, power line surges, or faulty equipment. Without a proper grounding system, a power spike will find the path of least resistance to earth ground – whether that path is through sensitive electronic equipment or the person operating the equipment. In order to ensure safety and prevent equipment damage, a grounding system must be used to provide a low resistance path to ground.

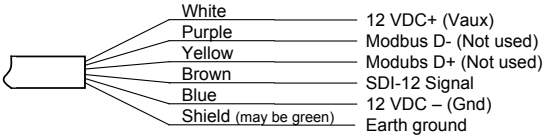
When using several pieces of interconnected equipment, each of which may have its own ground, problems with noise, signal interference, and erroneous readings may be noted. This is caused by a condition known as a Ground Loop. Because of natural resistance in the earth between the grounding points, current can flow between the points, creating an unexpected voltage difference and resulting erroneous readings.

The single most important step in minimizing a ground loop is to tie all equipment (sensors, dataloggers, external power sources and any other associated equipment) to a single common grounding point. INW recommends the following: (1) the sensor cable shield (the wrapped shield inside the cable) be attached to the power ground on the datalogger and (2) the grounding lug be connected via a 12 AWG or larger wire, to a grounding rod driven into the earth. It is also recommended that if you are using an external power supply to power the datalogger that it be tied to the same earth ground.

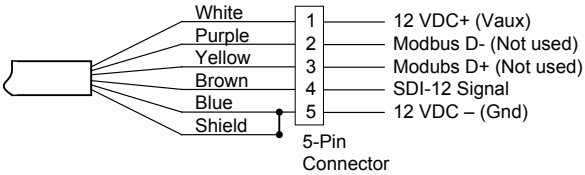
Appendix A: Technical Specifications

Wiring Information

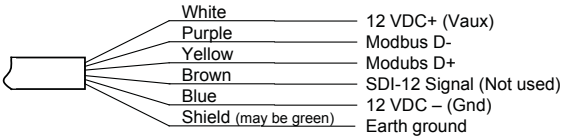
For SDI-12
— without connector



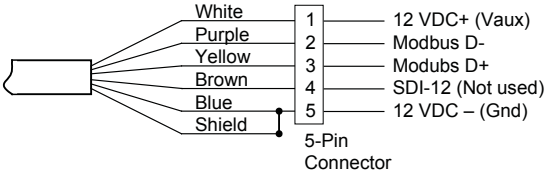
For SDI-12
— with 5-pin connector



For Modbus®
— without connector



For Modbus® with
— with 5-pin connector



Connections

Dimensions and Specifications

GENERAL

Length	6.7” (17 cm)
Diameter	0.75” (1.9 cm)
Weight	0.8 lb (0.4 kg)
Body Material	316 stainless steel or titanium
Wire Seal Material	Viton® and Teflon®
Submersible Cable	Polyurethane, polyethylene, FEP, *or* Tefzel® available
Terminating Connector	Available
Communication	RS485 Modbus® RTU SDI-12 (ver. 1.3)
Direct Modbus Read Output	32-bit IEEE floating point
SDI-12 Output	ASCII
Internal Math	32-bit floating point
Operating Temperature Range[1]	-5° C to 70° C
Storage Temperature Range	-40° C to 80° C

POWER

Operating Voltage	9 - 16 VDC
Over Voltage Protection	24 VDC
Power Supply Current	Active 3mA avg./10mA peak Sleep 150 µA
Electomagnetic & Transient Protection	IEC-61000 — 4-3, 4-4, 4-5, 4-6

TEMPERATURE

Element Type	Digital IC on board
Accuracy	± 0.2° C
Resolution	0.06° C
Units	Celsius, Fahrenheit, Kelvin

Contact factory for extended temperature ranges.

[1] *Requires freeze protection kit if in water below freezing.*

Appendix B: SDI-12 Commands and Register Definitions

SDI-12 Command Nomenclature

a = Sensor address
{crc} = SDI-12 compatible 3-character CRC
<cr> = ASCII carriage return character
<lf> = ASCII line feed character

Following commands are shown in the format of:
cmd response // comments

SDI-12 Commands

Query and Setup Commands

```
//*** Sensor Identification
aI!        a13  INWUSA  PT120.7sssssssss<cr><lf>  //   note: 0.7 will change to reflect
                                                        current firmware revision
                                                        sssssssss = device serial #
//*** Acknowledge Active
a!         a<cr><lf>

//*** Address Query
?!         a<cr><lf>

//*** Change Address
aAb!        b<cr><lf>                              //   change address from a to b
```

Request measurement

```
aM!        a0023<cr><lf>                          //   request temperature/voltage
                                                        measurement
aD0!       a+0+25.0000+12.0512<cr><lf>            //   read null, temperature (°C), voltage (V)

aM2!       a0021<cr><lf>                          //   request temperature measurement
aD0!       a+25.0000<cr><lf>                      //   read temperature (°C)

aM3!       a0021<cr><lf>                          //   request power supply voltage
                                                        measurement
aD0!       a+12.0512<cr><lf>                      //   read power supply voltage (V)

aM4!       a0ttt4<cr><lf>                         //   request averaged data. ttt depends upon
                                                        programmed average duration
aD0!       a+0+0+0+25.0000<cr><lf>                //   read null, null, null, average temperature
```

Request measurement with CRC

```
aMC!       a0023<cr><lf>                          //   request temperature/voltage measurement
aD0!       a+0+25.0000+12.0512{crc}<cr><lf>       //   read null, temperature (°C), voltage (V)

aMC2!      a0021<cr><lf>                          //   request temperature measurement
aD0!       a+25.0000{crc}<cr><lf>                 //   read temperature (°C)
```

aMC3!	a0021<cr><lf>	//	request power supply voltage measurement
aD0!	a+12.0512{crc}<cr><lf>	//	read power supply voltage (V)
aMC4!	a0ttt4<cr><lf>	//	request averaged data. ttt depends upon programmed average duration
aD0!	a+0+0+0+25.0000{crc}<cr><lf>	//	read null, null, null, average temperature

Concurrent measurement

aC!	a00203<cr><lf>	//	request temperature/voltage measurement
aD0!	a+0+25.0000+12.0512<cr><lf>	//	read null, temperature (°C), voltage (V)
aC2!	a00201<cr><lf>	//	request temperature measurement
aD0!	a+25.0000<cr><lf>	//	read temperature (°C)
aC3!	a00201<cr><lf>	//	request power supply voltage measurement
aD0!	a+12.0512<cr><lf>	//	read power supply voltage (V)
aC4!	a0ttt04<cr><lf>	//	request averaged data. ttt depends upon programmed average duration
aD0!	a+0+0+0+25.0000<cr><lf>	//	read null, null, null, average temperature

Concurrent measurement with CRC

aCC!	a00203<cr><lf>	//	request temperature/voltage measurement
aD0!	a+0+25.0000+12.0512{crc}<cr><lf>	//	read null, temperature (°C), voltage (V)
aCC2!	a00201<cr><lf>	//	request temperature measurement
aD0!	a+25.0000{crc}<cr><lf>	//	read temperature (°C)
aCC3!	a00201<cr><lf>	//	request power supply voltage measurement
aD0!	a+12.0512{crc}<cr><lf>	//	read power supply voltage (V)
aCC4!	a0ttt04<cr><lf>	//	request averaged data. ttt depends upon programmed average duration
aD0!	a+0+0+0+25.0000{crc}<cr><lf>	//	readnull, null, null, average temperature

Extended Commands

//*** Set duration for averaging reading

aXAttt!	attt<cr><lf>	//	set duration of averaged data for M4 command
	//	ttt = 1..997 seconds	

//*** Read/Modify Calibration Values

aXCnn{=<value>}!	a<value><cr><lf>	//	read{modify} calibration value nn

examples:

aXC00!	a+1.591600e-5<CR><LF>	//	read value of calibration register 00
aXC00=1.704e-4!	a+1.704000e-4<CR><LF>	//	set value of calibration register 00

//*** Set number of significant digits

aXSt!	at<cr><lf>	//	set # of significant digits for SDI-12 report data
		//	t = 1..7

Calibration Register Definitions

All calibration registers contain floating point values.

SDI-12 REG ID	Mnemonic	Description	Default Value
11	mT	Field temperature cal-slope	1.000000E+00
12	bT	Field temperature cal-offset	0.000000E+00
13	T_Alpha	Factory Temperature Cal-Alpha	0.000000E+00
14	T_Offset	Factory Temperature Cal-Offset	0.000000E+00
15	T_ZeroSlope	Factory Temperature Cal-ZeroSlope	0.000000E+00
18	T_mUnits	Temperature units conversion slope	1.000000E+00
19	T_bUnits	Temperature units conversion offset	0.000000E+00

Factory calibration values are set at the factory.
Writing to Factory Calibration registers will void calibration!!

Field calibration values can be set by user. If set, these values will be applied to readings before values are returned.

Appendix C: Taking Modbus® Readings

Register Definitions

Modbus® Functions
Read the values in the registers using function 03-Read Holding Registers.

Parameter Data
32-bit ieee floating point values, read-only
These registers must be read as pairs

40003-4	Temperature (degrees C)
40005-6	Power supply voltage (volts)

Statistical Data Values

40013-14	Averaged temperature

Calibration and Conversion Constants
32-bit ieee floating point values, read/write

Register	*Mnemonic*	*Description*		
40223-24	mT	Field calibration	-	Temperature slope
40225-26	bT	Field calibration	-	Temperature offset
40227-28	T_Alpha	Factory calibration	-	Temperature alpha
40229-30	T_Offset	Factory calibration	-	Temperature offset
40231-32	T_ZeroSlope	Factory calibration	-	Temperature slope
40237-38	T_mUnits	Temperature Units	-	Conversion slope
40239-40	T_bUnits	Temperature Units	-	Conversion offset

Factory calibration values are set at the factory.
Writing to Factory Calibration registers will void calibration!!

Field calibration values can be set by user. If set, these values will be applied to readings before values are returned.

Sensor Configuration/Control

40301=n Set **averaging**: This enables sensor for n seconds (Read/Write). Each second, the statistical data registers will be update to contain new averages, max and min. At the completion of n seconds, the final statistical values will be left in the registers, and the sensor will be put to sleep. n = 0..10,800. If n = 0, the sensor is put to sleep, and the statistical data values are not updated.

40401=a Set **sensor address** = a (Write Only)

40501=b	Set **baud rate** according to b (Write Only) b=0:38400 b=1:19200 b=2:9600 b=3:4800 b=4:2400 b=5:1200
40601=w	Set **auto-enable**. Causes sensor to be enabled automatically for w seconds after a read of any parameter data register. W=0 disables auto-enable. (This is normally set to 10 seconds at the factory.)

For lowest power usage, set this to zero. For fastest readings while still retaining as much power savings as possible, set slightly longer than your read frequency. See section on next page for information on how this setting affects your readings.

40701=L	Set **serial number**. L= unsigned longword value 0x0000000 .. 0xFFFFFFF (0 .. 4,294,967,295)
40801	Read sensor firmware revision. Word MSB = Major revision, LSB = minor revision. E.g., 0011 = revision 0.11

Readings and the Auto-Enable Setting

When a reading is requested, four things happen:

1. The sensor wakes up.
2. The current value in the register is returned.
3. The sensor turns on the analog portion, begins sampling, and begins putting the new values in the registers.

4a. If auto-enable is set to a positive value w, the sensor stays awake for w seconds, sampling and moving values into the registers all the while, and then goes to sleep.

4b. If auto-enable is set to zero, the sensor immediately goes to sleep after putting the reading in the register.

If your read frequency is less than the auto-enable value, the sensor will stay on continously, and your readigns will always be fresh, with the exception of the very first reading.

If your read frequency is greater than the auto-enable value, the following reading sequence is recommended:

1. Request a reading. This begins the wakeup process on the sensor and returns the value currently in the register, which will be old data. Throw this value away.
2. Wait one second, and then take another reading. This reading will have fresh data. Record this reading.

Note: This sequence applies only to Modbus® direct read. If reading the sensor via SDI-12, the warmup timing is automatically taken care of.

Reordering Information

For sales & service offices, please contact:

INW
www.inwusa.com
800-776-9355

LIMITED WARRANTY/DISCLAIMER - T1 SUBMERSIBLE TEMPERATURE SENSOR

A. Seller warrants that products manufactured by Seller when properly installed, used, and maintained, shall be free from defects in material and workmanship. Seller's obligation under this warranty shall be limited to replacing or repairing the part or parts or, at Seller's option, the products which prove defective in material or workmanship within ONE (1) year from the date of delivery, provided that Buyer gives Seller prompt notice of any defect or failure and satisfactory proof thereof. Any defective part or parts must be returned to Seller's factory or to an authorized service center for inspection. Buyer will prepay all freight charges to return any products to Seller's factory, or any other repair facility designated by Seller. Seller will deliver replacements for defective products to Buyer (ground freight prepaid) to the destination provided in the original order. Products returned to Seller for which Seller provides replacement under this warranty shall become the property of Seller.

This limited warranty does not apply to lack of performance caused by abrasive materials, corrosion due to aggressive fluids, mishandling or misapplication. Seller's obligations under this warranty shall not apply to any product which (a) is normally consumed in operation, or (b) has a normal life inherently shorter than the warranty period stated herein.

In the event that equipment is altered or repaired by the Buyer without prior written approval by the Seller, all warranties are void. Equipment and accessories not manufactured by the Seller are warranted only to the extent of and by the original manufacturer's warranty.

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B. With respect to products purchased by consumers in the United States for personal use, the implied warranties including but not limited to the warranties of merchantability and fitness for a particular purpose, are limited to twelve (12) months from the date of delivery.

Some states do not allow limitations on the duration of an implied warranty, so the above limitation may not apply to you. Similarly, some states do not allow the exclusion or limitation of consequential damages, so the above limitation or exclusion may not apply to you. This limited warranty gives you specific legal rights; however, you may also have other rights which may vary from state to state.

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