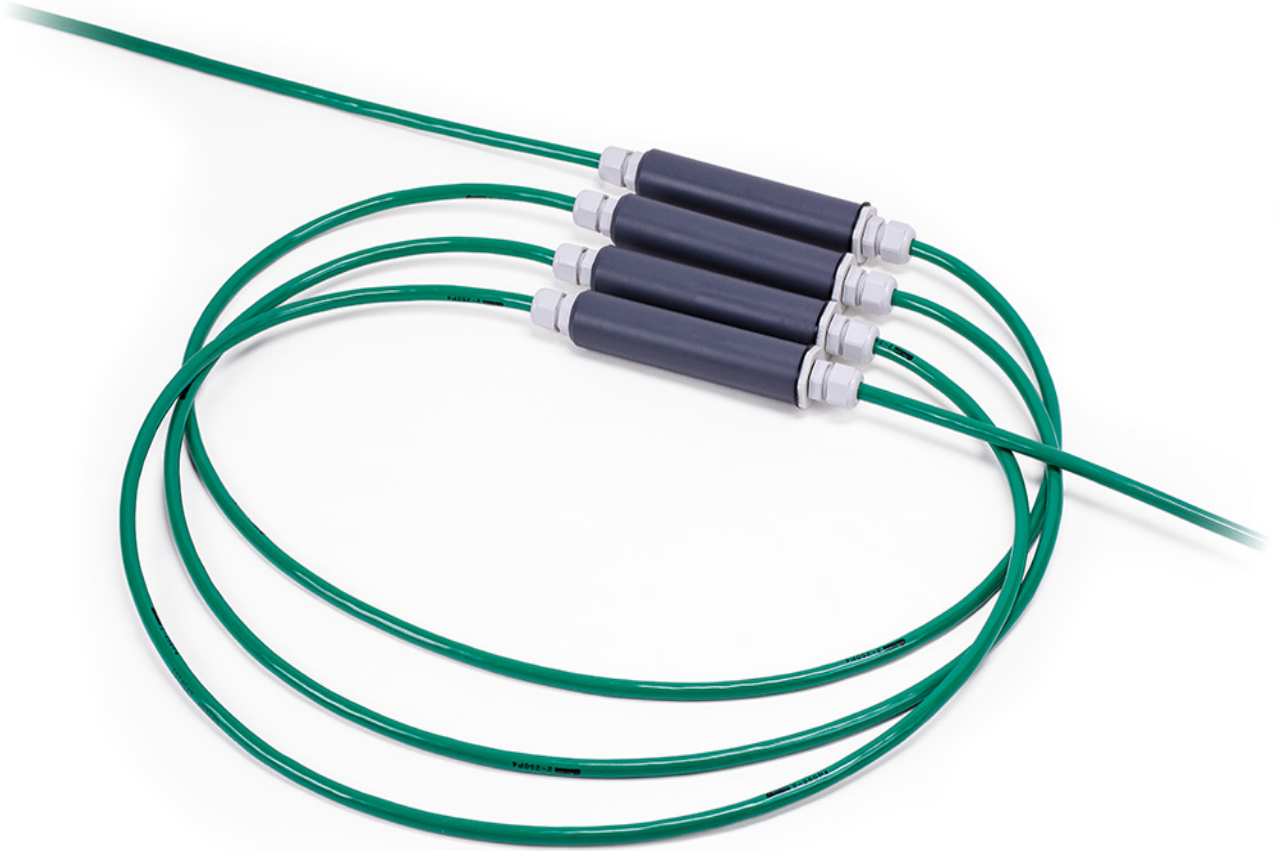


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# **Model 3810A**

## **Addressable Thermistor String**

### Instruction Manual





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# 1. INTRODUCTION

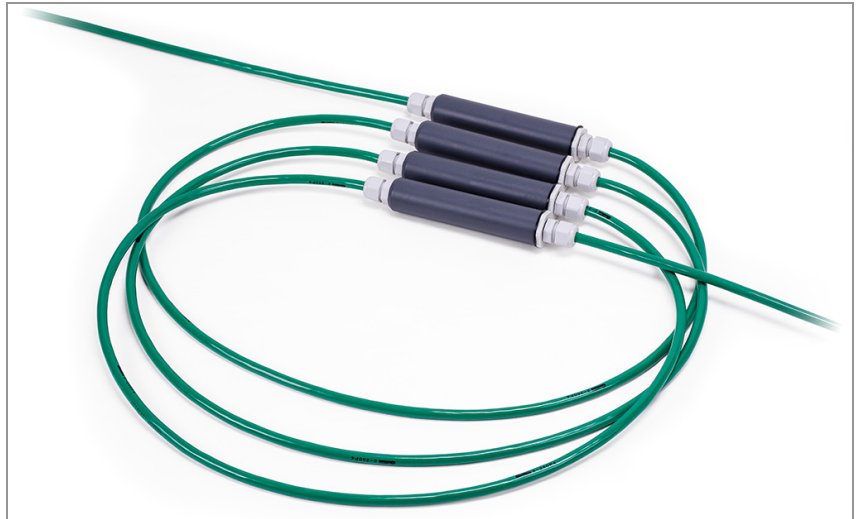
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GEOKON's Model 3810A thermistor strings are temperature sensors that combine NTC thermistors with digital Modbus RTU communication for ease of setup and use. Each thermistor sensor contains a small printed circuit board assembly (PCBA) with a thermistor and circuitry for communication and analog to digital conversion. These sensors are assembled with cable using customer-specified spacing. Then each sensor is encapsulated in a protective housing, creating a finished thermistor string.

Thermistors are semiconductors that behave as resistors with a high (usually negative) temperature coefficient of resistance: they are thermal resistors. The thermistor beads are made from a mixture of metal oxides encased in epoxy or glass. The beads are small in size and extremely robust, with a high degree of stability over a long life span. The accuracy and interchangeability of the thermistor bead used on the 3810A is  $\pm 0.07$  °C, within the temperature range of 0 °C to 50 °C.

The cable consists of two twisted pairs, each wrapped with aluminized Mylar foil and a single drain wire. There are four conductors: power, ground, and the two differential RS-485 lines for communication. A short-circuit between any of the four conductors will render all sensors in the string inoperable. Likewise, a break in the cable would render inoperable all sensors below the break. However, because the 3810A uses a bus topology, failure of any single thermistor sensor does not affect any of the other sensors.

The sensors are polled individually via industry standard Modbus RTU (Remote Terminal Unit) commands.



**FIGURE 1:** Model 3810A Addressable Thermistor String

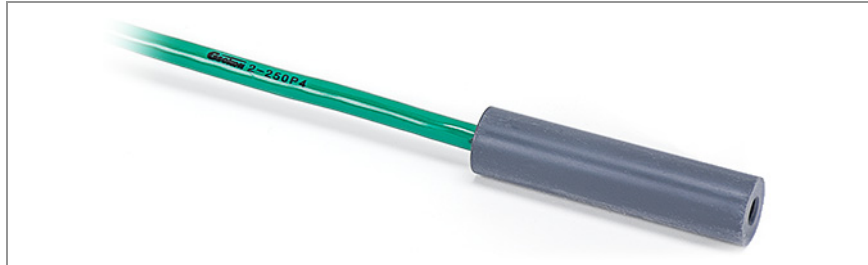


**FIGURE 2:** Model 3810A Addressable Thermistor

## 2. INSTALLATION

### 2.1 THERMISTOR STRING

Uncoil the thermistor string and place it in the installation medium. For installations in which the string will be in contact with soil, rock, etc., take care to prevent damage to the cable and sensor. The termination assembly at the end of the string is made with a 1/4-20 x 1/2" deep threaded hole in it. This allows for a weight or cord/rope to be attached for assisting with the installation. The maximum pulling force that can safely be applied to the string is 20 lb.



**FIGURE 3:** Model 3810A-3 End Terminator

### 2.2 HARDWARE REQUIREMENTS

**Communications:** RS-485, half-duplex

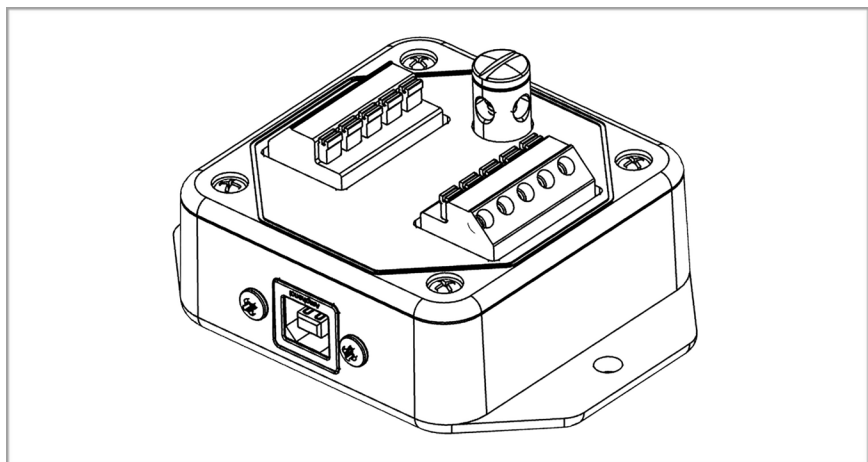
**Baud Rate:** 115200

**Power:** 12.0V  $\pm$  20% @ 1.2mA/sensor

### 2.3 MODEL 8020-38 RS-485 TO TTL/USB CONVERTER

GEOKON makes the Model 8020-38 Addressable Bus Converter for connecting addressable strings to personal computers, readouts, dataloggers, and programmable logic controllers. The converter acts as a bridge using the TTL or USB protocols between readers and the GEOKON RS-485-enabled sensor strings.

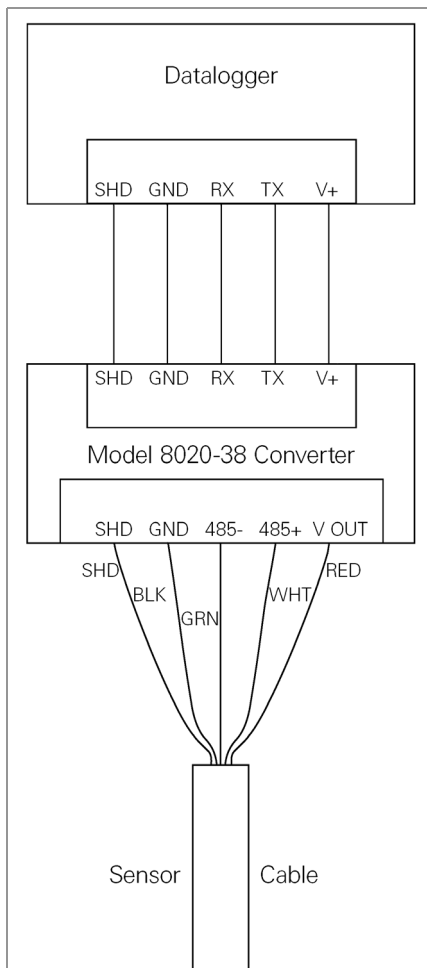
For more information, please refer to the Model 8020-38 instruction manual.



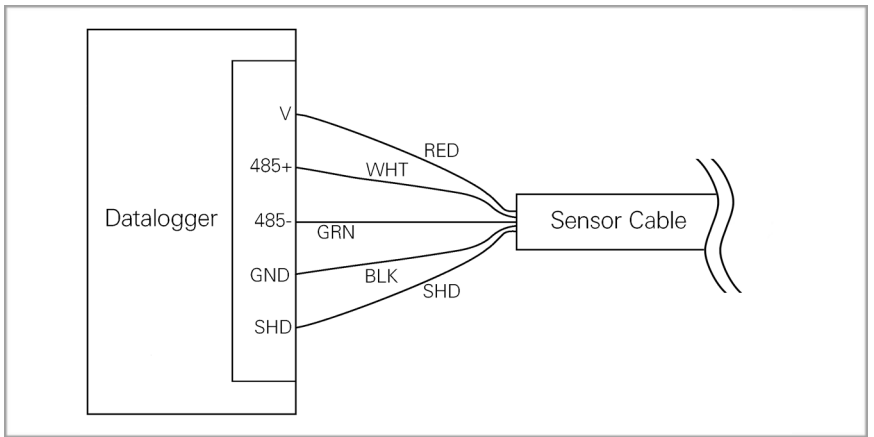
**FIGURE 4:** Model 8020-38 RS-485 to TTL/USB Converter

**Note:** The datalogger you use must have the appropriate port available.

- If your datalogger does not have built-in RS-485 communications, connect the wiring using the diagram in Figure 5.
- If your datalogger has built-in RS-485 communications, connect the wiring using the diagram in Figure 6.



**FIGURE 5:** Wiring of Datalogger without built-in RS-485 Conversion



**FIGURE 6:** *Wiring of Datalogger with built-in RS-485 Conversion*

### 3. MODBUS RTU PROTOCOL

---

#### 3.1 INTRODUCTION TO MODBUS

Model 3810A Addressable In-Place Inclinometers use the industry standard Modbus Remote Terminal Unit (RTU) protocol to communicate with the chosen readout method. Modbus was designed to work on what is known as a **bus network**, meaning that every device receives every message that passes across the network. The Modbus standard does not specify a physical layer (connection type), but it will work with any interface that can communicate asynchronously with multiple devices (e.g., RS-485, RS-422, optical, radio, etc.). Model 3810A strings use RS-485 as the electrical interface because of its prevalence, simplicity, and success as a robust, industrial physical layer.

#### 3.2 MODBUS RTU OVERVIEW

The Modbus RTU protocol uses packets (multiple sections that together compose a message) to communicate and transfer data between devices on the network. The general format of these packets is as follows:

1. Modbus Address (one byte) – the address of the specific device on the bus. (Labeled on the sensors as #1, #2, #3, etc.)
2. Function Code (one byte) – the action to be carried out by the slave device.
3. Data (multi-byte) – the payload of the function code being sent.
4. CRC (two bytes) – cyclic redundancy check; a 16-bit data integrity check calculated over the other bytes in the packet.

#### 3.3 MODBUS TABLES

The most recent sensor reading is stored in a table. The reading is presented in different formats in different sections of the table. The register location and size of these variables are described in the table below.

Variable	Type (Modbus Message)	HEX	Decimal	Description
ADC	uint16	0x0100	256	Raw 16-bit thermistor reading
IC Temp.	int16	0x0101	257	Low-quality 10-bit temperature reading
Resistance	float32	0x0102	258	Decimal thermistor reading (Ohms)
		0x0103	259	
Trigger	uint16	0x0118	280	Write nonzero value to initiate measurement

**TABLE 1:** RAM Storage

#### 3.4 READING 3810A SENSORS

While Modbus RTU supports roughly 20 different function codes, the simple functionality of a bused temperature sensor, such as the GEOKON 3810A, eliminates the need for all but two of them. Only the Write Holding Register (0x06) function code and Read Holding Registers (0x03) are needed to read the sensors.

First, use the Write Holding Register function to refresh the temperature measurement. The command initiates multiple analog-to-digital (ADC) conversions that are averaged to optimize precision and resolution. The updated measurements will be ready approximately 0.25 seconds after the request. An example request is shown in the table below.

	Device Address	Function Code	Data Address	Register Value	CRC
HEX <sub>16</sub>	02	06	0118	0001	C9C2
DEC <sub>10</sub>	2	6	280	1	51,650

**TABLE 2:** Example Query - Trigger Measurement

Use device address 0 to “broadcast” the trigger command to all drops simultaneously. Measurements between successive address are staggered by 50 milliseconds to prevent excess current draw from simultaneous activation.

The Read Holding Registers function can be used to read one or more 16-bit registers (two bytes each), starting at the Data Address that was sent in the command packet. Temperatures can be retrieved in two alternate formats; one as a raw 16-bit ADC value, the other as a 32-bit floating point (decimal) number that is the computed resistance of the on-board thermistor. For ease of use and program simplicity, the 32-bit floating-point reading is recommended. An example of this query and response is shown in the tables below.

	Device Address	Function Code	Data Address	Number of Registers	CRC
HEX <sub>16</sub>	02	03	0102	0002	6404
DEC <sub>10</sub>	2	3	258	2	25,604

**TABLE 3:** Example Query - Floating Point Resistance Reading

	Device Address	Function Code	Byte Count	Lower 16-bits	Upper 16-bits	CRC
HEX <sub>16</sub>	02	03	04	C87C	4628	04F5
DEC <sub>10</sub>	2	3	4	floating point result		1,269

**TABLE 4:** Example Response - Floating Point Resistance Reading

```

14:46:39.705 [TX] - 02 03 01 02 00 02 64 04
14:46:39.762 [RX] - 02 03 04 C8 7C 46 28 04 F5

```

**FIGURE 7:** PC Terminal Program Screen Capture

The above shows the IEEE-754 floating-point response as two parts—each one is composed of two bytes. Because of how this information is stored in memory, the two parts are received in reverse order; the complete floating-point number in HEX is 0x4628C87C (10,802.12 ohms).

## 4. MODBUS & CAMPBELL SCIENTIFIC DATALOGGERS

### 4.1 DESCRIPTION

Model 3810A sensor strings can be easily read using Campbell dataloggers that support ModBus RTU commands. Campbell dataloggers such as the CR6 and CR1000X can read half-duplex RS-485 on select RS-485 digital I/O pairs. This allows the 3810A string to be connected directly at the datalogger.

The Model 8020-38 Addressable Bus Converter enables Model 3810A sensor strings to work with Campbell dataloggers that do not support direct RS-485 communications, such as the CR800 and CR1000. The Model 8020-38 is a RS-485 to TTL converter, used with select TTL digital I/O pairs.

CRBasic is the programming language used with Campbell Scientific CRBasic dataloggers. Campbell Scientific's LoggerNet software is typically used when programming in CRBasic.

### 4.2 SAMPLE CR6 PROGRAM

The following sample program reads one 3810A string with five addressable thermistors. The string in this example communicates with the CR6 through the control ports C1 (green) and C2 (white), which are set up as ComC1:

```
'Constants used in Steinhart-Hart equation to calculate sensor temperature for
'10k thermistor

Const A = 1.128706256E-3
Const B = 2.342327483E-4
Const C = 0.8707279757E-7

Public ErrorCode           'Result of ModBusMaster communications attempt
Public Res As Float        'Resistance of thermistor must be stored as Type Float
Public Celsius(5)         'Calculated Celsius for 5 sensors in string
Public Count               'Counter to increment through temperature sensors

'Define Data Tables
DataTable (Test, 1,-1)
  Sample (5,Celsius()),IEEE4) 'Sample Celsius for 5 sensors in string
EndTable

'Main Program
BeginProg
'Open COM port with RS-485 communications at 115200 baud rate
SerialOpen (ComC1,115200,16,0,50,3)
'Read all 5 sensors in string every 4 seconds
Scan (4,Sec,0,0)
  'Loop to read each thermistor
  For Count = 1 To 5
    'Reset temporary storage for next reading
    Res = 0
    'Flush Serial between readings
    SerialFlush (ComC1)
    'Write to register 0x118 to trigger thermistor string
    'NOTE: ModbusMaster won't send 0x118 unless "&H119" is entered
    ModbusMaster (ErrorCode,ComC1,115200,Count,6,1,&H119,1,1,50,0)
    'Delay after triggering the measurement
    Delay (1,1,Sec)
    'Use Modbus command to retrieve resistance from thermistor string
    ModbusMaster (ErrorCode,ComC1,115200,Count,3,Res,&H103,1,1,50,0)
    'Calculate thermistor temperature from ohms to Celsius using Steinhart-hart
    equation
    Celsius(Count) = 1/(A+B* LN(Res) + C * LN(Res)^3)-273.15
  Next
  'Call Table to store Data
  CallTable Test
NextScan
EndProg
```

### 4.3 SAMPLE CR1000 PROGRAM WITH REQUIRED MODEL 8020-38 ADDRESSABLE BUS CONVERTER

The following sample program reads one 3810A string with five addressable thermistor sensors. The string in this example is connected to a RS-485 to TTL converter and communicates with the CR1000 through the control ports C1 and C2, which are setup as COM1:

```
'Constants used in Steinhart-Hart equation to calculate sensor temperature for
'10k thermistor

Const A = 1.128706256E-3
Const B = 2.342327483E-4
Const C = 0.8707279757E-7

Public ErrorCode           'Result of ModbusMaster communications attempt
Public Resistance As Float 'Resistance of thermistor must be stored as Type Float
Public Celsius(5)         'Calculated Celsius for 5 sensors in string
Public Count               'Counter to increment through temperature sensors

'Define Data Tables

DataTable(Test,1,-1)
  Sample (5,Celsius()),IEEE4) 'Sample Celsius for 5 sensors in string
EndTable

'Main Program

BeginProg
'Open COM port with TTL communications at 115200 baud rate
SerialOpen (Com1,115200,16,0,50)
'Read all 5 sensors in string every 4 seconds
Scan (4,Sec,0,0)
'Loop to read each thermistor
For Count = 1 To 5
'Reset temporary storage for next reading
Resistance = 0
'Flush Serial between readings
SerialFlush (Com1)
'Write to register 0x118 to trigger thermistor string
'NOTE: ModbusMaster won't send 0x118 unless "&H119" is entered
ModbusMaster (ErrorCode,Com1,115200,Count,6,1,&H119,1,1,50,0)
'Delay after triggering the measurement
Delay (1,1,Sec)
'Use Modbus command to retrieve resistance from thermistor string
ModbusMaster (ErrorCode,Com1,115200,Count,3,Resistance,&H103,1,1,50,0)
'Calculate thermistor temperature from ohms to Celsius using Steinhart-hart equation
Celsius(Count) = 1/(A+B* LN(Resistance) + C * LN(Resistance)^3)-273.15
Next
'Call Table to store data
CallTable Test
NextScan
EndProg
```

## 5. TEMPERATURE CALCULATION

---

Thermistors can be read using a GEOKON Micro 1000, Micro 800, or 8600 Datalogger, or any PC that has a USB port and GEOKON's free 3810A Utility program.

### 5.1 STEINHART-HART COEFFICIENTS

$$A = 1.128706256 \times 10^{-3}$$

$$B = 2.342327483 \times 10^{-4}$$

$$C = 0.8707279757 \times 10^{-7}$$

### 5.2 FLOATING POINT RESISTANCE READINGS (PREFERRED METHOD)

R = Resistance reading (from register address 0x0102)

$$T = \frac{1}{A+B(\ln R)+C(\ln R)^3} - 273.15$$

### 5.3 RAW ADC (ANALOG TO DIGITAL CONVERTER) READINGS

Resistance can be found by:

R = ADC reading (from register address 0x0100)

$$R(\Omega) = 10,000 \times \left( \frac{65,535}{\text{Reading}} - 1 \right)$$

And temperature is:

$$T = \frac{1}{A+B(\ln R)+C(\ln R)^3} - 273.15$$

Using an example ADC reading from address 0x0100 of 0x7984 (31,108):

$$R(\Omega) = 10,000 \times \left( \frac{65,535}{31,108} - 1 \right) \cong 11,066.9\Omega$$

$$T = \frac{1}{A+B(\ln(11,066.9))+C(\ln(11,066.9))^3} - 273.15 \cong 22.70^\circ\text{C}$$



## 6. SOFTWARE

---


Model 3810A thermistor strings can be read by GEOKON's "Addressable String Reader" software. You can download this software from the GEOKON website:

**<http://www.geokon.com/Software>**

The Addressable String Reader application (ASR) is designed to help the user quickly connect to and read a GEOKON addressable string. The ASR will automatically detect the type of string connected and will configure the display accordingly. The three types of strings currently supported are the Addressable Thermistor (3810A) String, the Addressable VW (Vibrating Wire) (8020-30) Sensor String, and the Addressable MEMS (6150E and 6151E) String.

The ASR contains the following features:

- Communication via Windows COM Ports
- Selection of all drops, individual drops, or a combination of drops
- Recording of data in rows either by button click or cyclic, at selectable intervals
- Recorded data rows are viewable in list form
- Recorded data rows can be saved in CSV (comma-separated values) format

For more information, run the program and click the blue  button to display the software's Online Help.



## APPENDIX A. SPECIFICATIONS

---

### A.1 POWER

Power Supply:	5VDC to 15VDC
Current Per Sensor	
During reading:	8.7 mA (read)
Idle:	1.0 mA (idle)

### A.2 COMMUNICATION

Interface:	RS-485, half-duplex
Baud Rate:	115,200 bits/second
Query Response Time:	0.266 seconds (trigger write to values ready)

### A.3 MECHANICAL

Min Spacing:	200 mm / 8"
Housing:	Delrin / PVC
Length X Diameter:	140 x 22 mm / 5.5 x 7/8"
Working Load:	9.07 kg / 20 lbs
Breaking Strength:	22.68 kg / 50 lbs
Pressure Rating:	150 psig / 1 MPa
Sensors	
Wire:	248 maximum
Wireless:	30 maximum

### A.4 MEASUREMENTS

ADC Resolution:	16-bit
System Resolution (0 °C to 50 °C):	0.002 °C (nonlinear; largest step)
System Resolution (-20 °C to 80 °C):	0.005 °C (nonlinear; largest step)
System Repeatability (-20 °C to 80 °C):	0.002 °C (99% confidence interval)
Thermistor Type:	10KΩ NTC
Thermistor Interchangeability:	±0.07 °C
Range:	-20 °C to 80 °C
Accuracy:	±0.35 °C @ -20 to -10 °C
	±0.15 °C @ -10 to 0 °C
	±0.07 °C @ 0 to 50 °C
	±0.12 °C @ 50 to 65 °C
	±0.16 °C @ 65 to 80 °C









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