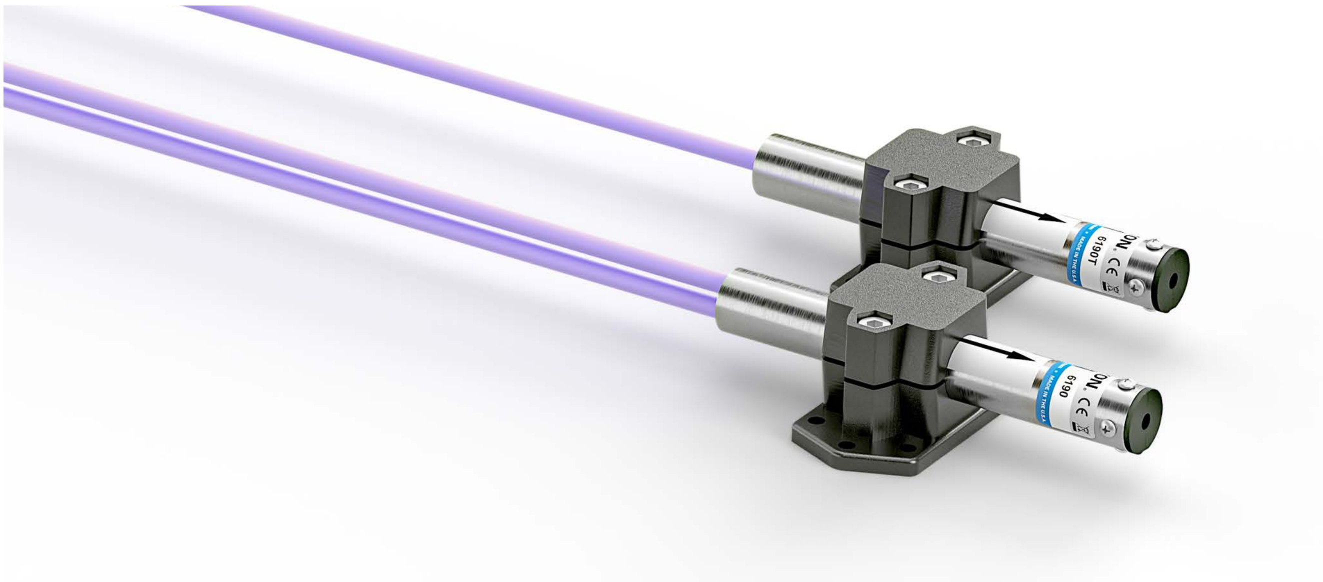
Model 6190

Tilt Sensor

Instruction Manual



GEOKON®

Document Revision: B.1 | Release date: 08/28/24

WARRANTY STATEMENT

GEOKON warrants its products to be free of defects in materials and workmanship, under normal use and service for a period of 13 months from date of purchase. If the unit should malfunction, it must be returned to the factory for evaluation, freight prepaid. Upon examination by GEOKON, if the unit is found to be defective, it will be repaired or replaced at no charge. However, the WARRANTY IS VOID if the unit shows evidence of having been tampered with or shows evidence of being damaged as a result of excessive corrosion or current, heat, moisture or vibration, improper specification, misapplication, misuse or other operating conditions outside of GEOKON's control. Components that wear or are damaged by misuse are not warranted. This includes fuses and batteries.

GEOKON manufactures scientific instruments whose misuse is potentially dangerous. The instruments are intended to be installed and used only by qualified personnel. There are no warranties except as stated herein. There are no other warranties, expressed or implied, including but not limited to the implied warranties of merchantability and of fitness for a particular purpose. GEOKON is not responsible for any damages or losses caused to other equipment, whether direct, indirect, incidental, special or consequential which the purchaser may experience as a result of the installation or use of the product. The buyer's sole remedy for any breach of this agreement by GEOKON or any breach of any warranty by GEOKON shall not exceed the purchase price paid by the purchaser to GEOKON for the unit or units, or equipment directly affected by such breach. Under no circumstances will GEOKON reimburse the claimant for loss incurred in removing and/or reinstalling equipment.

Every precaution for accuracy has been taken in the preparation of manuals and/or software, however, GEOKON neither assumes responsibility for any omissions or errors that may appear nor assumes liability for any damages or losses that result from the use of the products in accordance with the information contained in the manual or software.

TABLE OF CONTENTS

1. INTRODUCTION

The GEOKON Model 6190 Tilt Sensor is designed for permanent long-term monitoring of changes in tilt of structures such as dams, embankments, foundation walls, retaining walls, buildings, and similar applications. The basic principle of operation uses MEMS accelerometers to measure static tilt of the structure being studied. Monitoring by the instrument allows for very precise measurements of inclination to be collected.

Each sensor is comprised of an addressable, triaxial, Micro-Electro-Mechanical Systems (MEMS) device inside a sealed stainless steel housing. The device measures inclination along three axes, of which two will be of interest for any given installation. Each sensor also contains a digital temperature sensor for measuring temperature.

Sensors are coupled to the structure of interest using an adjustable mounting bracket and hardware. Sensors may be used individually or in combination with others. Electrically, sensors are connected to each other with four-wire bus cable and molded waterproof connectors.

Standalone sensors, available in standard and corrosion resistant options, can be purchased with variable length cable.

Each sensor is individually serialized and calibrated. A calibration sheet for each sensor is provided, showing the relationship between sensor output and inclination.

The Model 6190 uses industry standard Modbus® Remote Terminal Unit (RTU) protocol to communicate. It employs an RS-485 (half duplex) electrical interface, recognized for its prevalence, simplicity, and success as a robust, industrial physical layer.

Data can be collected using GeoNet Addressable Loggers, the Model 8020-38 Addressable Bus Converter, Model 8600 Series Dataloggers, Campbell Scientific Dataloggers, or any other device capable of operating as a Modbus RTU client and having an RS-485 port.

2. INSTALLATION

2.1 CABLE CONNECTIONS

When making cable connections, line up the orientation dot on the outside of the male connector with the two orientation dots on the outside of the female connector (Figure 1). This will ensure the pins and receptacles of the connectors align correctly. To prevent water entry, be sure to push the connectors together until they are fully mated (Figure 2). For additional security, GEOKON recommends taping the connectors together with electrical or black mastic tape.

Note: To facilitate mating, the male connectors have dielectric grease applied. Do not remove this grease.

Caution! Care should be taken to avoid cutting or damaging the cable jacket, which could introduce moisture into the interior of the string, thereby causing irreparable damage to the sensors.

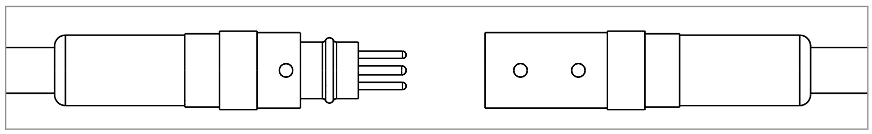


FIGURE 1: *Cable Connection Detail*

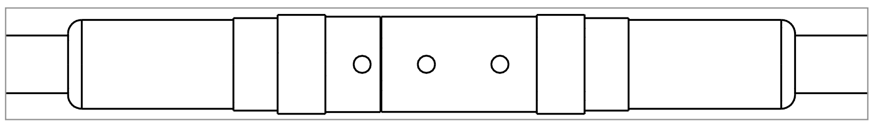


FIGURE 2: *Connected Cables*

2.2 PRELIMINARY TESTS

Prior to installation, check the sensors for proper operation by completing the steps below.

1. Place the sensors in the correct order by referring to the labels on the sensors and the provided paperwork.
2. Starting with the first sensor, connect the sensors by plugging the male cable connector from the second sensor into the female connector from the first sensor. (See Section 2.1 for cable connection details.)
3. Repeat this process until the entire string is connected.

Note: The male termination sensor (6190T) must be used as the last sensor for each string.

4. Connect the string to a datalogger or PC (Refer to Section 2.5 for details.)
5. Hold the first sensor in a vertical position, the sensor must be held steady while taking the reading. The observed reading should be close to the factory vertical reading listed on the calibration report. The temperature indicated on the readout should be close to ambient. Tilting the sensor in one direction should cause the readings to increase. Tilting the sensor in the opposite direction should cause the readings to decrease. Repeat this process with the remaining sensors.

Once the preliminary tests are complete, disconnect the string from the readout device and disconnect the sensors from each other.

If any of these preliminary tests fail, refer to Section 5 for troubleshooting.

2.3 SENSOR ORIENTATION

As triaxial capable devices, Model 6190 Tilt Sensors measure inclination along three axes, and may be used in both vertical and horizontal installations.

For vertical installations, orient the sensor with the indicator arrow pointing up or down. For horizontal installations, orient the sensor with the arrow pointing right or left. Detailed sensor orientation descriptions are provided in Appendix E.

2.4 SENSOR INSTALLATION

1. Place the mounting bracket on the mounting surface and position it so the tilt sensor is in the intended orientation, as described above.
2. Using the center-hole on one side of the mounting bracket and the curved slot on the other side, mark where to drill.
3. Using a hammer drill, drill two 9.5mm (3/8 inch) diameter holes approximately 32 mm (1.25 inch) deep.
4. Clean out the holes thoroughly, blowing them out with compressed air if possible.
5. Insert the two 1/4 inch drop-in anchors into the holes. The threaded end should be closest to the opening of the hole.
6. Insert the setting tool, small end first, into the first anchor. Expand the anchor by hitting the large end of the setting tool with several sharp hammer blows.
7. Repeat Step 6 for the second hole.
8. Align the mounting bracket with the anchors. Secure the bracket by threading two 1/4 – 20 socket head cap screws (provided) through the center-hole and curved slot of the mounting bracket, and into the drop-in anchors.
9. Remove the cover of the mounting bracket by loosening the two cap screws holding it in place.
10. Place the tilt sensor into the bracket and reinstall the bracket cover. Make sure to properly orient the tilt sensor per Appendix E.
11. One axis of the sensor may be adjusted by loosening the 1/4–20 socket head cap screw positioned in the curved slot, and rotating the sensor and bracket together until the desired position is reached. Re-tighten the cap screw to secure the sensor in place.
12. A second axis may be adjusted by loosening the bracket cover slightly so the sensor may be rotated within the bracket. Re-tighten the bracket cover cap screws to secure the sensor in place.
13. Step 11 and 12 may be made easier by connecting a 8020-38 addressable bus converter and PC to the sensor while adjustments are being made so the readings may be observed.
14. Repeat Step 1 through 13 for each subsequent sensor.
15. Plug the female connector of the first sensor into the male connector of the second sensor. If using an extension cable, connect the first and second sensors together using the extension cable. (See Section 2.1 for cable connection details.

2.5 READOUT

If your datalogger has built-in RS-485 communications, connect the cable using the wiring diagram below. (The datalogger must have the appropriate port available.)

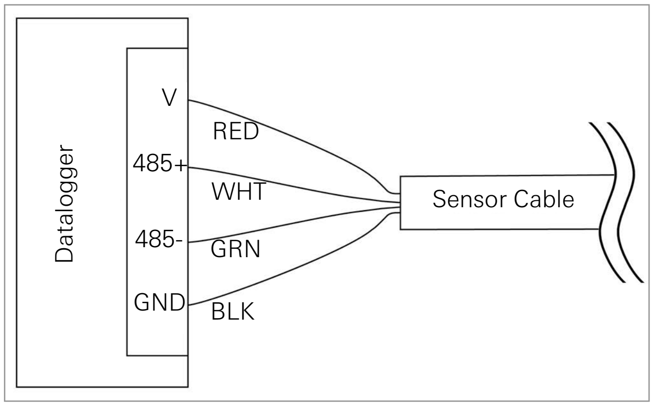


FIGURE 3: *Wiring of Datalogger with built-in RS-485 Conversion*

If your datalogger does not have built-in RS-485 communications, a Model 8020-38 Addressable Bus Converter (Figure 4) can be utilized. The Model 8020-38 allows addressable strings to be connected 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.

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

If utilizing a Model 8020-38 to connect the tilt sensor to a readout, wire the connections as shown. (The dataloggers must have the appropriate port available.)

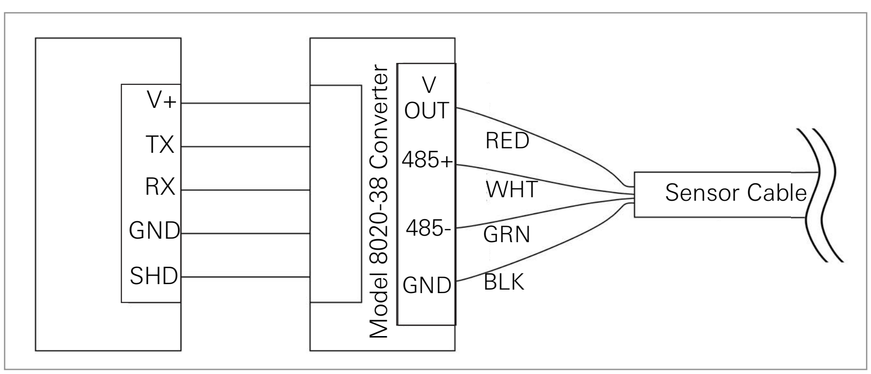


FIGURE 5: *Wiring of Datalogger without built-in RS-485 Conversion*

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

2.6 FOUR-PIN WATERPROOF CONNECTOR

The pinouts for the four-pin male and female connectors are shown below; the function of each wire is detailed in Table 1 below.

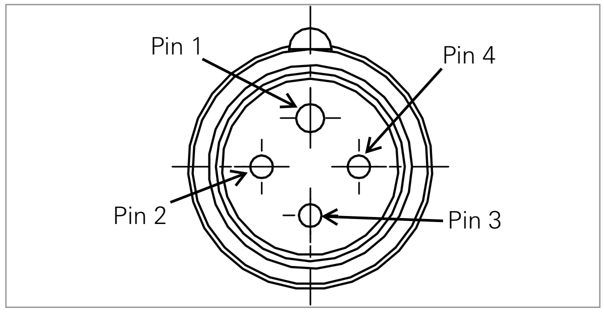


FIGURE 6: *Male Waterproof Connector*

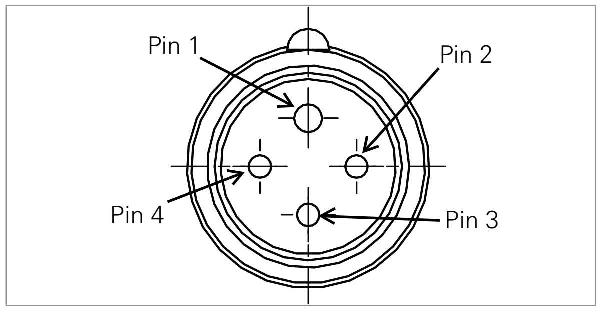


FIGURE 7: *Female Waterproof Connector*

Pin	Wire Color	Function
1	Red	Power
2	Black	Ground
3	White	RS-485+ Data High
4	Green	RS-485- Data Low

TABLE 1: *Four-Pin Wiring Chart*

3. MODBUS RTU PROTOCOL

3.1 INTRODUCTION TO MODBUS

Model 6190 Tilt Sensors use the industry standard Modbus Remote Terminal Unit (RTU) protocol to communicate with the chosen readout method. As the name suggests, 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. Model 6190 Tilt Sensors use the RS-485 electrical interface because of its prevalence, simplicity, and success as a robust, industrial physical layer.

More information about Modbus can be found at the following website:

http://www.modbus.org/specs.php

3.2 MODBUS RTU OVERVIEW

The Modbus RTU protocol uses packets (messages made up of multiple sections) 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 server device.
3. Data (multi-byte) – The payload of the function code being sent.
4. Cyclic Redundancy Check or CRC (two bytes): A 16-bit data integrity check calculated over the other bytes in the packet.

3.3 MODBUS TABLES

The most recent sensor readings are stored in memory registers, read using a Modbus command. Angle and temperature readings are available in processed or precursor formats. Register addresses and formats are described in Table 2.

Note: GEOKON stores the gauge factor and offsets in the sensor during the factory calibration process. Therefore, the outputs of the A, B, and C axes are corrected values.

Table 3 shows device control addresses. Any non-zero value written to the trigger address initiates a measurement cycle, updating the angle and temperature measurement registers. Any anomalies detected during the most recent measurement cycle produce a non-zero error code. Refer to Appendix C for an explanation of these codes.

The flash password prevents unintended writes to the nonvolatile memory in Table 4 and the preprogrammed device information in Table 5. Contact GEOKON for instructions.

Register Address	Byte	Word	Parameter	Units	Type	Access
0x100	0	LSW	A-Axis	degrees	float	RO
	1					
0x101	2	MSW				
	3					
0x102	4	LSW	B-Axis	degrees	float	
	5					
0x103	6	MSW				
	7					
0x104	8	LSW	C-Axis	degrees	float	
	9					
0x105	10	MSW				
	11					
0x106	12	LSW	Temperature	°C	float	
	13					
0x107	14	MSW				
	15					
0x108	16	LSW	Uncorrected A-Axis	degrees	float	
	17					
0x109	18	MSW				
	19					
0x10A	20	LSW	Uncorrected B-Axis	degrees	float	
	21					
0x10B	22	MSW				
	23					
0x10C	24	LSW	Uncorrected C-Axis	degrees	float	
	25					
0x10D	26	MSW				
	27					

TABLE 2: *Register Addresses and Formats*

Register Address	Byte	Word	Parameter	Units	Type	Access
0x118	48		Trigger	N/A	uint16	RW
	49					
0x119	50	LSW	Password	N/A	uint32	
	51					
0x11A	52	MSW				
	53					
0x11B	54		Measure Cycle	N/A	uint16	
	55					

TABLE 3: *Device Control Addresses*

Register Address	Byte	Word	Parameter	Units	Type	Access
0x200	0		Drop Address	N/A	uint16	RO
	1					
0x201	2		Sensor Type	N/A	string	
	3					
0x202	4					
	5					
0x203	6					
	7					
0x204	8					
	9					
0x205	10					
	11					
0x206	12					
	13					
0x207	14					
	15					
0x208	16					
	17					
0x209	18	LSW	Serial Number	N/A	uint32	
	19					
0x20A	20	MSW				
	21					
0x20B	22		Software Version	N/A	uint16	
	23					
0x20C	24		Hardware Version	N/A	uint16	
	25					

TABLE 4: *Non-Volatile Memory*

Register Address	Byte	Word	Parameter	Units	Type	Access
0x20D	26	LSW	A Offset	degrees	float	RO
	27					
0x20E	28	MSW				
	29					
0x20F	30	LSW	B Offset	degrees	float	
	31					
0x210	32	MSW				
	33					
0x213	38	LSW	A Gauge Factor	degrees	float	
	39					
0x214	40	MSW				
	41					
0x215	42	LSW	B Gauge Factor	degrees	float	
	43					
0x216	44	MSW				
	45					

TABLE 5: *Preprogrammed Device Information*

4. DATA REDUCTION

4.1 INCLINATION CALCULATION

The output of the 6190 Tilt Sensor is a corrected angle of inclination. The standard sensor has a full range of ±90° and a calibrated range of ±30°. Register values for the Gauge Factor and Offset are factory-written to the Modbus registers for each sensor. Calibration data populates these registers.

Each sensor is provided with a unique Gauge Factor (G) and the Offset that are used to calculate the corrected inclination angle (θ) of the sensor.

4.2 ENVIRONMENTAL FACTORS

Since the purpose of the tilt sensor is to monitor site conditions, factors that may affect these conditions should be observed and recorded. Seemingly minor effects may have real influence on the behavior of the structure being monitored and may give an early indication of potential problems. Some of these factors include, but are not limited to, blasting, rainfall, tidal or reservoir levels, excavation and fill levels and sequences, traffic, temperature and barometric changes, changes in personnel, nearby construction activities, seasonal changes, etc.

5. TROUBLESHOOTING

Maintenance and troubleshooting of Model 6190 Tilt Sensor is confined to periodic checks of the cable connections. The sensors are sealed and there are no user serviceable parts.

Should difficulties arise, consult the list of possible solutions shown below. Refer to Appendix C for Modbus error codes. Consult the factory for additional troubleshooting help.

SYMPTOM: TILT SENSOR READINGS ARE UNSTABLE OR FAIL TO READ

- ☐ Is there a source of electrical noise nearby? Most probable sources of electrical noise are motors, generators, and antennas.
- ☐ Check all cable connections, terminals, and plugs.
- ☐ Water may have penetrated the interior of the tilt sensor or connectors. Contact GEOKON.

APPENDIX A. SPECIFICATIONS

A.1 MODEL 6190 TILT SENSOR

Range[1]	±90°
Resolution[2]	0.00025° (0.004 mm/m)
Precision[3]	±0.0075° (±0.13 mm/m)
Nonlinearity	±0.005° across ±30° range (±0.09 mm/m)
Temperature Dependent Uncertainty	±0.001°/°C across ±5° angular range (±0.016 mm/m) ±0.0016°/°C across ±15° angular range (±0.026 mm/m) ±0.0026°/°C across ±30° angular range (±0.042 mm/m)
Power Supply Voltage	12 VDC ±20%
Operating Current[4]	12 mA ±1 mA
Standby Current[4]	2 mA ±0.1 mA
Maximum Supply Current[5]	500 mA
Sensor Diameter	25.4 mm (1 inch)
Sensor Length	180.3 mm (7.1 inches)
Sensor Weight	0.29 kg (0.64 lb)
Materials	6190, 6190S, and 6190-T: 316 Stainless Steel, Engineered Polymer 6190S-CR: Titanium
Mounting Bracket Dimensions (L x W x D)	97 x 56 x 53 mm (3.8 x 2.2 x 2.1 inch)
Mounting Bracket Weight	0.54 kg (1.18 lb)
Mounting Bracket Materials	Brackets for 6190, 6190S, and 6190-T: Black Powder Coated Aluminum Brackets for 6190S-CR: Titanium
Electrical Cable	Four Conductor, Foil shield, Polyurethane jacket, nominal OD = 7.9 mm
Interface	RS-485
Protocol	MODBUS
Baud Rate	115,200 bps
Temperature Accuracy	±0.5 °C
Ingress Protection	IP68 to 3 MPa (300 m head water)
Operating Temperature	-40 to 65°C (-40 to 149°F)

TABLE 6: *Model 6190 Tilt Sensor Specifications*

[1] Calibrated Range: ±30°

[2] 99% confidence interval (i.e. 99 out of 100 individual readings fall within this tolerance).

[3] Includes random walk (changes between consecutive readings that have no discernible cause) and seismic noise during testing.

[4] Operating and standby current are for each individual sensor drop in a string.

[5] Per entire string.

A.2 PARTS LIST

6180-3-1	Readout Cable, <15 m length bare leads
6180-3-2	Readout Cable, 16 to 30 m length, bare leads
6180-3V	Readout Cable, >30 m length, bare leads
6190	MEMS Digital Tilt Sensor, Triaxial
6190S	Standalone MEMS Digital Tilt Sensor, Triaxial
6190S-CR	Standalone MEMS Digital Tilt Sensor, Triaxial, Corrosion Resistant
6190-T	MEMS Digital Tilt Sensor
6190-1	Mounting Hardware Kit
6195-1-10FT	Extension Cable, 10 ft. length
6195-1-25FT	Extension Cable, 25 ft. length
6195-1-50FT	Extension Cable, 50 ft. length
6195-1-100FT	Extension Cable, 100 ft. length
6195-1-150FT	Extension Cable, 150 ft. length
6195-1-200FT	Extension Cable, 200 ft. length
TLS-208	Rawl Setting Tool, 1/4”

TABLE 7: *Model 6190 Tilt Sensor Parts List*

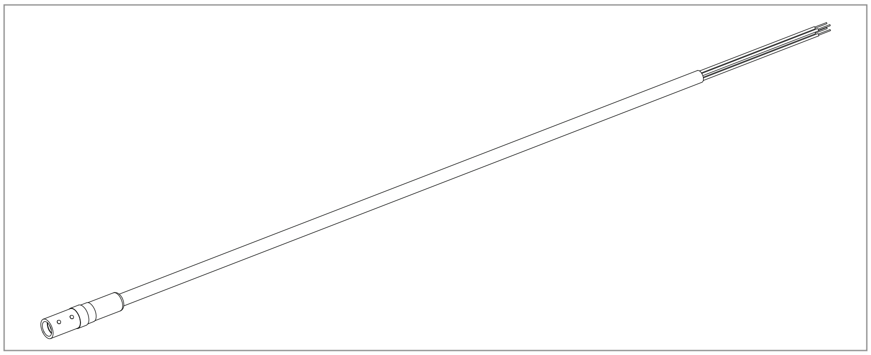


FIGURE 8: *Model 6180-3-1, -3-2 Topside Readout Cable/Bare Leads, < 50FT*

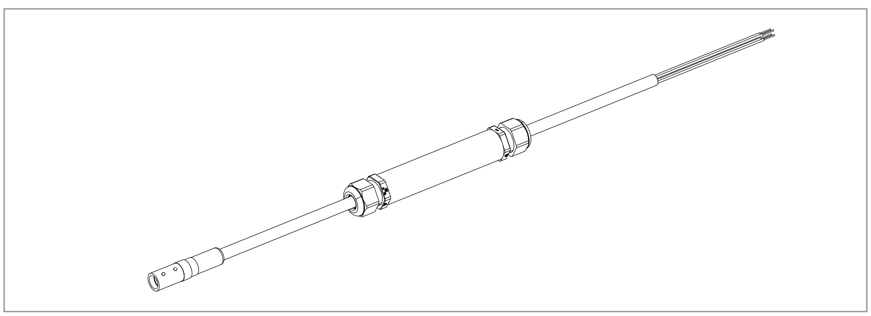


FIGURE 9: *Model 6180-3V Topside Readout Cable/Bare Leads, > 100FT*

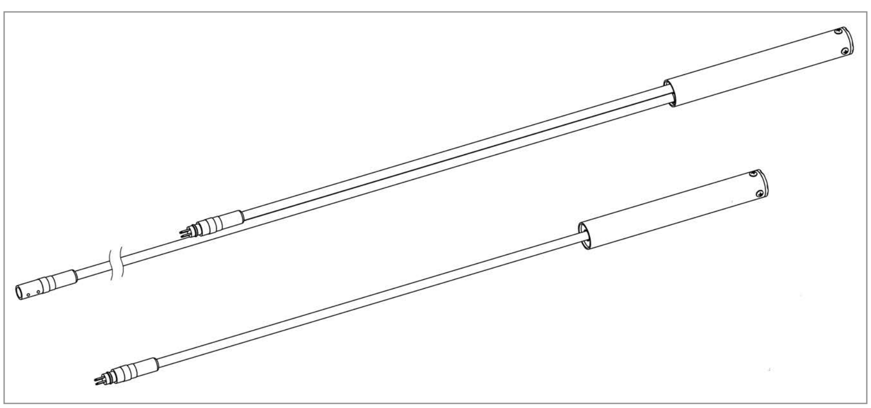


FIGURE 10: *Model 6190 Tilt Sensor (Top), Model 6190T Terminal Sensor (Bottom)*

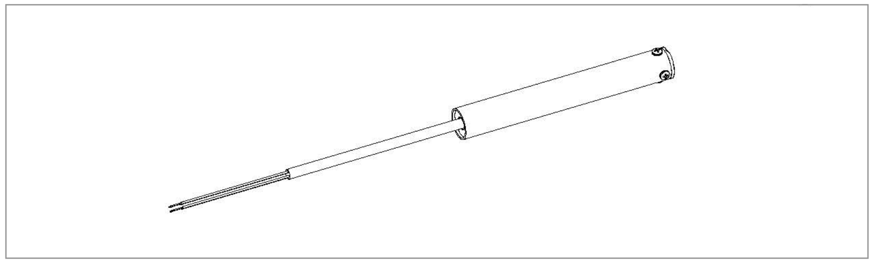


FIGURE 11: *Model 6190S and 6190S-CR Standalone Tilt Sensors*

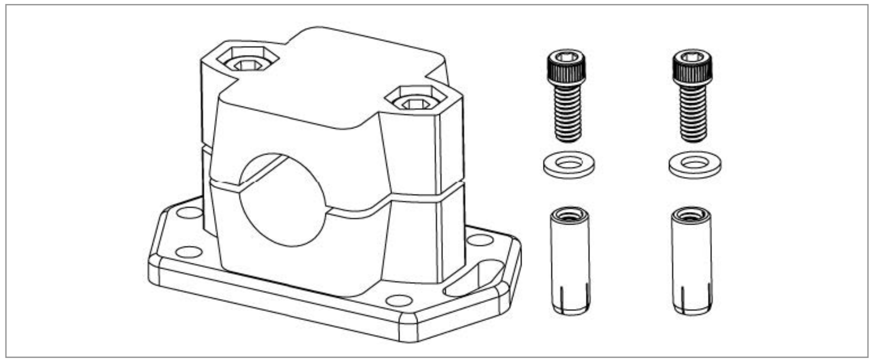


FIGURE 12: *6190-1 Mounting Kit (Includes hex key, not shown)*

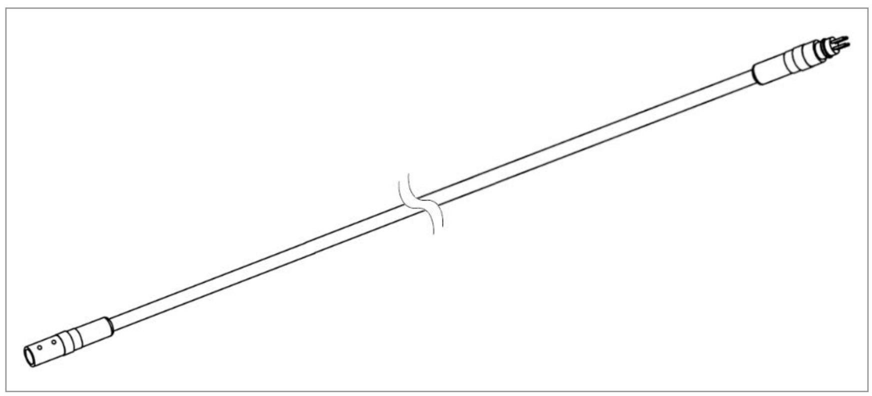


FIGURE 13: *Model 6195-1 Extension Cable*

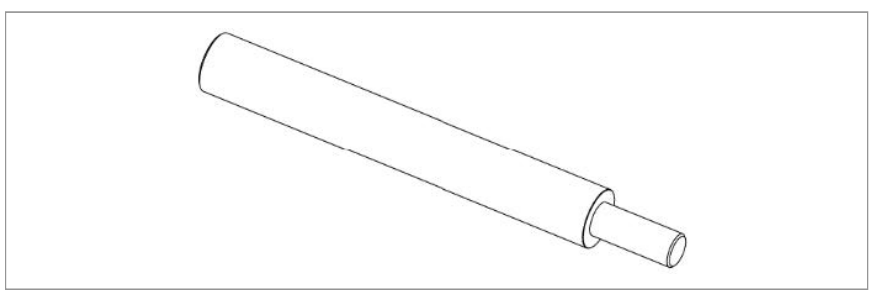


FIGURE 14: *TLS-208 Rawl Setting Tool, 1/4"*

GEOKON®

Calibration Report

Model Number: 6190

Calibration Date: December 20, 2023

Serial Number: 2330066 AAxisAngular

Temperature: 22.1 °C

Calibration Instruction: CI-MEMS PCBA (IPI_TILT, Triaxial)

Technician: R Judd

Reference Average (Angular Degrees)	Sensor Output (Angular Degrees)	Error (Angular Degrees)
-30.0010	-30.0014	-0.0003
-20.0004	-19.9986	0.0018
-14.9999	-15.0019	-0.0020
-10.0001	-9.9986	0.0015
-4.9996	-5.0011	-0.0016
0.0002	-0.0011	-0.0014
5.0000	5.0020	0.0020
9.9998	10.0015	0.0017
15.0003	14.9989	-0.0015
20.0005	20.0000	-0.0005
30.0005	30.0007	0.0002

The above instrument was found to be in tolerance in all operating ranges.
The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1.

This report shall not be reproduced except in full without written permission of Geokon.

FIGURE 15: *A Axis Angular Calibration Report*

GEOKON

Calibration Report

Model Number: 6190

Serial Number: 2330066 AAxisTemperature

Calibration Instruction: CI-MEMS PCBA (IPI_TILT, Triaxial)

Calibration Date: December 20, 2023

Temperature: 21.2 °C

Technician:

SetPoint (Degrees Celsius)	Sensor Output (Angular Degrees)	Error (Angular Degrees/Degree Celsius)
-35	0.1596	0.0000
-20	0.1586	0.0000
-5	0.1611	-0.0001
10	0.1588	0.0000
25	0.1594	0.0000
40	0.1632	0.0003
55	0.1565	-0.0001
70	0.1605	0.0000

The above instrument was found to be in tolerance in all operating ranges.
The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1.

FIGURE 16: *A Axis Temperature Calibration Report*

GEOKON®

Calibration Report

Model Number: 6190

Calibration Date: December 20, 2023

Serial Number: 2330066 BAxisAngular

Temperature: 22.0 °C

Calibration Instruction: CI-MEMS PCBA (IPI_TILT, Triaxial)

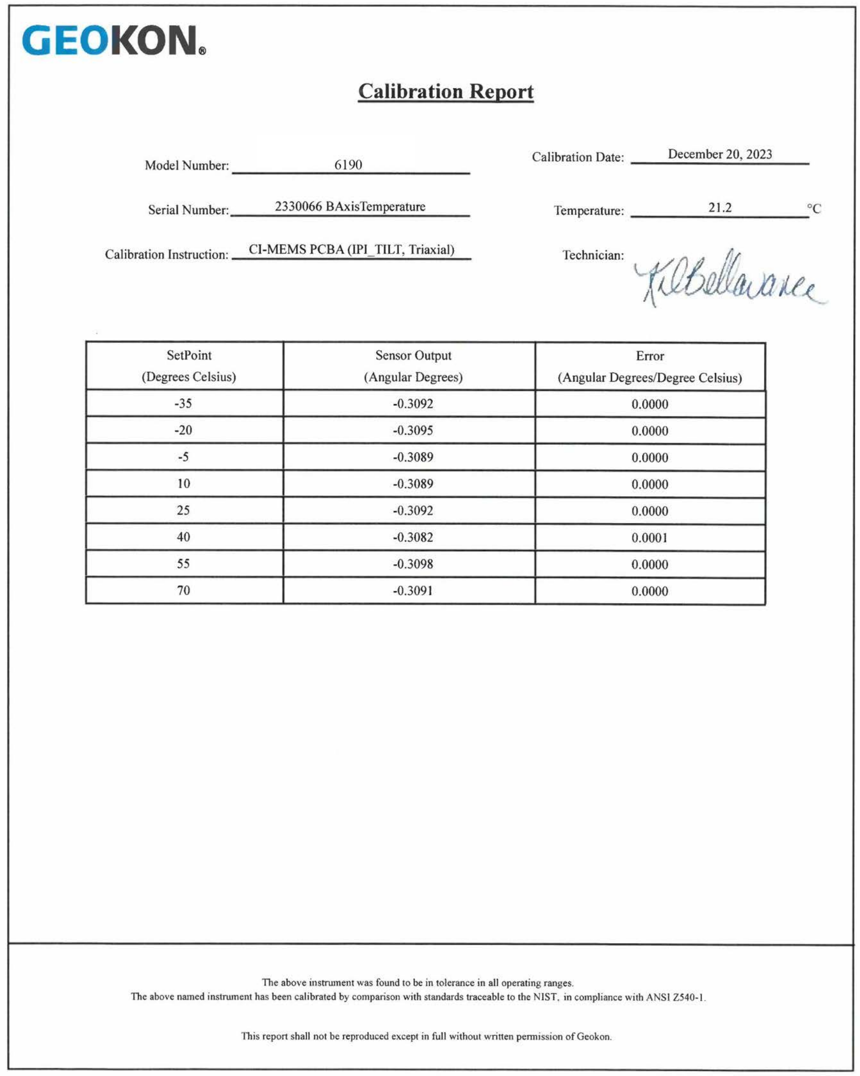
Technician: RJudd

Reference Average (Angular Degrees)	Sensor Output (Angular Degrees)	Error (Angular Degrees)
-30.0010	-30.0008	0.0002
-20.0004	-20.0011	-0.0007
-14.9999	-15.0001	-0.0003
-10.0001	-9.9993	0.0007
-4.9996	-4.9984	0.0012
0.0002	-0.0004	-0.0006
5.0000	4.9996	-0.0004
9.9998	9.9987	-0.0012
15.0003	15.0012	0.0009
20.0005	20.0009	0.0004
30.0005	30.0003	-0.0002

The above instrument was found to be in tolerance in all operating ranges.
The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1.

This report shall not be reproduced except in full without written permission of Geokon.

FIGURE 17: *B Axis Angular Calibration Report*



GEOKON

Calibration Report

Model Number: 6190

Calibration Date: December 20, 2023

Serial Number: 2330066 BAxisTemperature

Temperature: 21.2 °C

Calibration Instruction: CI-MEMS PCBA (IPI_TILT, Triaxial)

Technician: [signature]

SetPoint (Degrees Celsius)	Sensor Output (Angular Degrees)	Error (Angular Degrees/Degree Celsius)
-35	-0.3092	0.0000
-20	-0.3095	0.0000
-5	-0.3089	0.0000
10	-0.3089	0.0000
25	-0.3092	0.0000
40	-0.3082	0.0001
55	-0.3098	0.0000
70	-0.3091	0.0000

The above instrument was found to be in tolerance in all operating ranges.
The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1.

This report shall not be reproduced except in full without written permission of Geokon.

FIGURE 18: *B Axis Temperature Calibration Report*

GEOKON

Calibration Report

Model Number: 6190

Calibration Date: December 20, 2023

Serial Number: 2330066 CAxisAngular

Temperature: 22.0 °C

Calibration Instruction: CI-MEMS PCBA (IPI_TILT, Triaxial)

Technician: [signature]

Reference Average (Angular Degrees)	Sensor Output (Angular Degrees)	Error (Angular Degrees)
-30.0010	-30.0008	0.0002
-20.0004	-20.0011	-0.0007
-14.9999	-15.0001	-0.0003
-10.0001	-9.9993	0.0007
-4.9996	-4.9984	0.0012
0.0002	-0.0004	-0.0006
5.0000	4.9996	-0.0004
9.9998	9.9987	-0.0012
15.0003	15.0012	0.0009
20.0005	20.0009	0.0004
30.0005	30.0003	-0.0002

The above instrument was found to be in tolerance in all operating ranges.
The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1.

This report shall not be reproduced except in full without written permission of Geokon.

FIGURE 19: *C Axis Angular Calibration Report*

GEOKON®

Calibration Report

Model Number: 6190

Serial Number: 2330066 CAxisTemperature

Calibration Instruction: CI-MEMS PCBA (IPI_TILT, Triaxial)

Calibration Date: December 20, 2023

Temperature: 21.2 °C

Technician: [signature]

SetPoint (Degrees Celsius)	Sensor Output (Angular Degrees)	Error (Angular Degrees/Degree Celsius)
-35	-0.3092	0.0000
-20	-0.3095	0.0000
-5	-0.3089	0.0000
10	-0.3089	0.0000
25	-0.3092	0.0000
40	-0.3082	0.0001
55	-0.3098	0.0000
70	-0.3091	0.0000

The above instrument was found to be in tolerance in all operating ranges.
The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1.

FIGURE 21: *C Axis Temperature Calibration Report*

APPENDIX C. MODBUS ADDRESSABLE SYSTEM

C.1 MODBUS COMMUNICATIONS PARAMETERS

Port Setting	Required Value
Bits per Second	115,200
Data bits	8
Parity	None
Stop bits	1
Flow Control	None

TABLE 8: *Modbus Communications Parameters*

C.2 ERROR CODES

Number	Name	Cause	Remedy
2	Temperature Sensor Range	Measured temperature out of range. Thermistor may be too hot, too cold, or damaged.	Use adjacent sensors to validate or estimate temperature.
4	Temperature Sensor Verify	Secondary temperature sensor differed too much from high accuracy primary sensor.	Use adjacent sensors to validate or estimate temperature.
8	System Reset	Unexpected interruption in prior measurement cycle.	Ensure supply voltage is sufficient.

TABLE 9: *Error Codes*

Note: The sensor stores and transmits errors in binary code to compact the information. Though unlikely, two errors could occur in one measurement cycle. The resulting code will be the sum of the error numbers, e.g., error 4 plus error 8 appears as number 12.

APPENDIX D. CRBASIC PROGRAMMING

D.1 SAMPLE CR1000 PROGRAM

The following sample program reads one sensor string with three biaxial sensors. The string in this example communicates with the CR1000 through the control ports C1 and C2, which are setup as COM1. A RS-485 to TTL converter required.

```
Public ErrorCode              'Error Code sent back from ModBus Command
Public A_Axis_Degrees(3)      'A Axis Degree Output
Public B_Axis_Degrees(3)      'B Axis Degree Output
Public Celsius(3)             'Temperature Celsius
Public Count                  'Counter to increment through sensors
```

'Define Data Tables

```
DataTable(Test,1,-1)
   Sample (3,A_Axis_Degrees(),IEEE4)      'Store Degree Reading for A Axis
   Sample (3,B_Axis_Degrees(),IEEE4)      'Store Degree Reading for B Axis
   Sample (3,Celsius(),IEEE4)             'Store Thermistor C Reading
EndTable
```

'Main Program

```
BeginProg
    'Open COMport with TTL communications at 115200 baud rate
    SerialOpen (Com1,115200,16,0,50)
        'Read 3 sensors in MEMS String every 10 seconds
        Scan (10,Sec,0,0)
            'Loop through addresses of connected String
            For Count = 1 To 3
                'Reset temporary storage for both Degrees and Temp so not to retain
                'previous reading
                A_Axis_Degrees(Count) = 0
                B_Axis_Degrees(Count) = 0
                Celsius(Count) = 0

                'Flush Serial between readings
                SerialFlush (Com1)

                'Write to register to begin reading MEMS 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 write register
                Delay (1,1,Sec)

                'Use Modbus command to retrieve A Axis and B Axis Degree Readings
                ModbusMaster (ErrorCode,Com1,115200,Count,3,A_Axis_Degrees(Count),&H101,1,1,50,0)
                ModbusMaster (ErrorCode,Com1,115200,Count,3,B_Axis_Degrees(Count),&H103,1,1,50,0)

                'Use Modbus command to retrieve Thermistor Celsius from string
                ModbusMaster (ErrorCode,Com1,115200,Count,3,Celsius(Count),&H107,1,1,550,0)

                'Delay before proceeding to next reading
                Delay (1,1,Sec)
            Next
        'Call Table to store Data
        CallTable Test
    NextScan
EndProg
```

D.2 SAMPLE CR6 PROGRAM

The following sample program reads one sensor string with three addressable sensors. The string in this example communicates with the CR6 through the control ports C1 and C2, which are setup as ComC1. The CR6 has built in RS 485 capability, so no RS-485 to TTL converter is required.

```
Public ErrorCode              'Error Code sent back from ModBus Command
Public A_Axis_Degrees(3)      'A Axis Degree Output
Public B_Axis_Degrees(3)      'B Axis Degree Output
Public Celsius(3)             'Temperature Celsius
Public Count                  'Counter to increment through sensors
```

'Define Data Tables

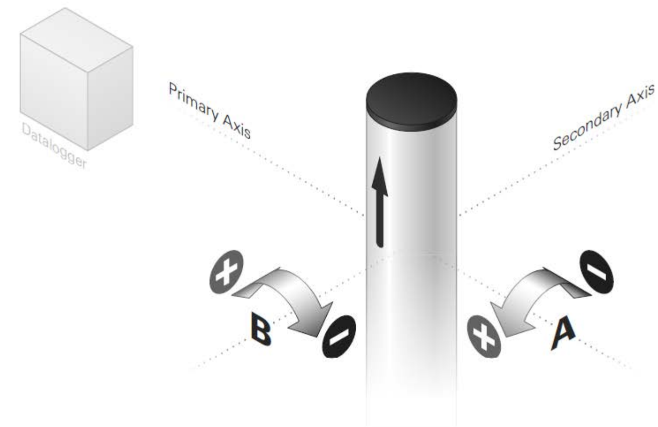
```
DataTable(Test,1,-1)
  Sample (3,A_Axis_Degrees(),IEEE4)     'Store Degree Reading for A Axis
  Sample (3,B_Axis_Degrees(),IEEE4)     'Store Degree Reading for B Axis
  Sample (3,Celsius(),IEEE4)            'Store Thermistor C Reading
EndTable
```

'Main Program

```
BeginProg
    'Open COMport with RS-485 communications at 115200 baud rate
    SerialOpen (ComC1,115200,16,0,50,3)
        'Read 3 sensors in MEMS String every 10 seconds
        Scan (10,Sec,0,0)
            'Loop through addresses of connected String
            For Count = 1 To 3
                'Reset temporary storage for both Degrees and Temp so not to retain
                'previous reading
                A_Axis_Degrees(Count) = 0
                B_Axis_Degrees(Count) = 0
                Celsius(Count) = 0

                'Flush Serial between readings
                SerialFlush (ComC1)

                'Write to register 0x118 to trigger string
                'NOTE: ModbusMaster won't send 0x118 unless "&H119" is entered

                ModbusMaster (ErrorCode,ComC1,115200,Count,6,1,&H119,1,1,10,0)
                'Delay after write register
                Delay (1,1,Sec)

                'Use Modbus command to retrieve A Axis and B Axis Degree Readings
                ModbusMaster (ErrorCode,ComC1,115200,Count,3,A_Axis_Degrees(Count),&H101,1,1,10,0)
                ModbusMaster (ErrorCode,ComC1,115200,Count,3,B_Axis_Degrees(Count),&H103,1,1,10,0)

                'Use Modbus command to retrieve Thermistor Celsius from string
                ModbusMaster (ErrorCode,ComC1,115200,Count,3,Celsius(Count),&H107,1,1,10,0)

                'Delay before proceeding to next reading
                Delay (1,1,Sec)
            Next
        'Call Table to store Data
        CallTable Test
    NextScan
EndProg
```

APPENDIX E.   TILT SENSOR ORIENTATION

WALL MOUNT: ARROW POINTED UP



SENSOR CONFIGURATION

- Mounted to **WALL**, **VERTICAL** installation
- **DATALOGGER** positioned **ABOVE**, relative to sensor

SENSOR ORIENTATION

- Sensor **ARROW** pointed **UP**, facing **FRONT**

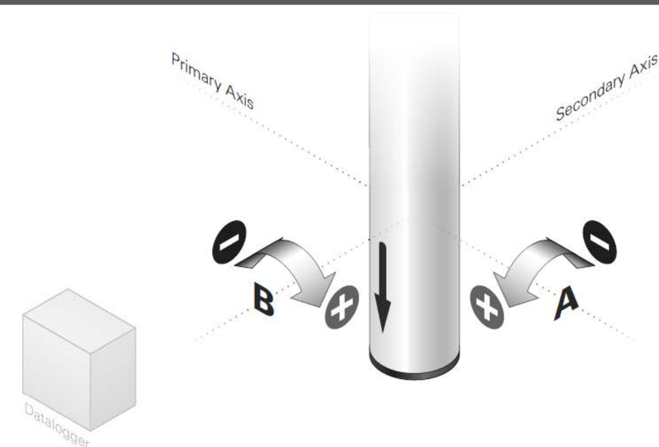
PRIMARY AXIS A

- **AXIS A POSITIVE/NEGATIVE ROTATION** readings:
  - ⊕ Top Toward
  - ⊖ Top Away

SECONDARY AXIS B

- **AXIS B POSITIVE/NEGATIVE ROTATION** readings:
  - ⊕ Counterclockwise
  - ⊖ Clockwise

WALL MOUNT: ARROW POINTED DOWN



SENSOR CONFIGURATION

- Mounted to **WALL**, **VERTICAL** installation
- **DATALOGGER** positioned **BELOW**, relative to sensor

SENSOR ORIENTATION

- Sensor **ARROW** pointed **DOWN**, facing **FRONT**

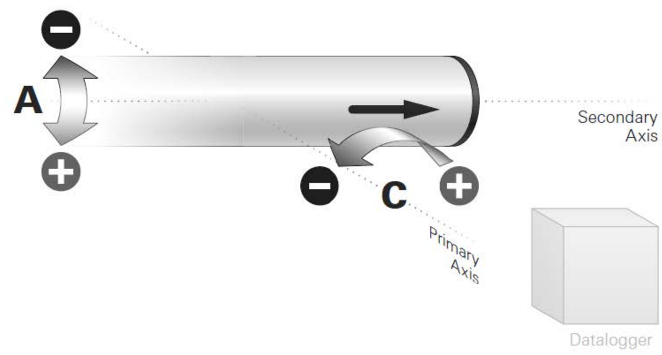
PRIMARY AXIS A

- **AXIS A POSITIVE/NEGATIVE ROTATION** readings:
  - ⊕ Top Toward
  - ⊖ Top Away

SECONDARY AXIS B

- **AXIS B POSITIVE/NEGATIVE ROTATION** readings:
  - ⊕ Clockwise
  - ⊖ Counterclockwise

WALL MOUNT: ARROW POINTED RIGHT



SENSOR CONFIGURATION

- Mounted to **WALL, HORIZONTAL** installation
- **DATALOGGER** positioned **RIGHT,** relative to sensor

SENSOR ORIENTATION

- Sensor **ARROW** pointed **RIGHT**, facing **FRONT**

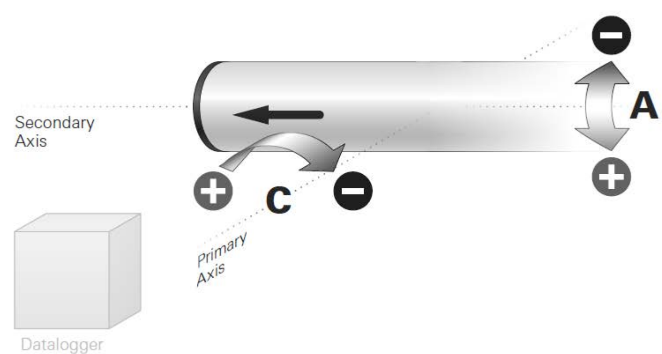
PRIMARY AXIS C

- **AXIS C POSITIVE/NEGATIVE ROTATION** readings:
  ⊕ Clockwise
  ⊖ Counterclockwise

SECONDARY AXIS A

- **AXIS A POSITIVE/NEGATIVE ROTATION** readings:
  ⊕ Top Toward
  ⊖ Top Away

WALL MOUNT: ARROW POINTED LEFT



SENSOR CONFIGURATION

- Mounted to **WALL, HORIZONTAL** installation
- **DATALOGGER** positioned **LEFT,** relative to sensor

SENSOR ORIENTATION

- Sensor **ARROW** pointed **LEFT**, facing **FRONT**

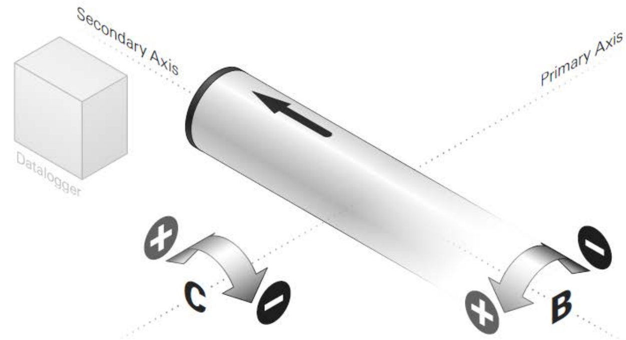
PRIMARY AXIS C

- **AXIS C POSITIVE/NEGATIVE ROTATION** readings:
  ⊕ Counterclockwise
  ⊖ Clockwise

SECONDARY AXIS A

- **AXIS A POSITIVE/NEGATIVE ROTATION** readings:
  ⊕ Top Toward
  ⊖ Top Away

FLOOR MOUNT: ARROW POINTED LEFT



SENSOR CONFIGURATION

- Mounted to **FLOOR, HORIZONTAL** installation
- **DATALOGGER** positioned **LEFT,** relative to sensor

SENSOR ORIENTATION

- Sensor **ARROW** pointed **LEFT**, facing **UP**

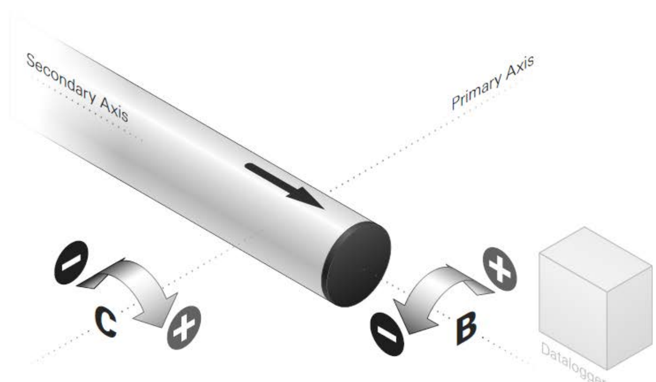
PRIMARY AXIS C

- **AXIS C POSITIVE/NEGATIVE ROTATION** readings:
  ⊕ Counterclockwise
  ⊖ Clockwise

SECONDARY AXIS B

- **AXIS B POSITIVE/NEGATIVE ROTATION** readings:
  ⊕ Top Toward
  ⊖ Top Away

FLOOR MOUNT: ARROW POINTED RIGHT



SENSOR CONFIGURATION

- Mounted to **FLOOR, HORIZONTAL** installation
- **DATALOGGER** positioned **RIGHT,** relative to sensor

SENSOR ORIENTATION

- Sensor **ARROW** pointed **RIGHT**, facing **UP**

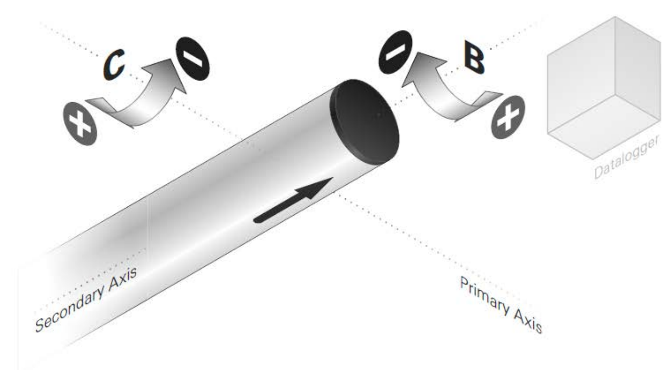
PRIMARY AXIS C

- **AXIS C POSITIVE/NEGATIVE ROTATION** readings:
  ⊕ Clockwise
  ⊖ Counterclockwise

SECONDARY AXIS B

- **AXIS B POSITIVE/NEGATIVE ROTATION** readings:
  ⊕ Top Away
  ⊖ Top Toward

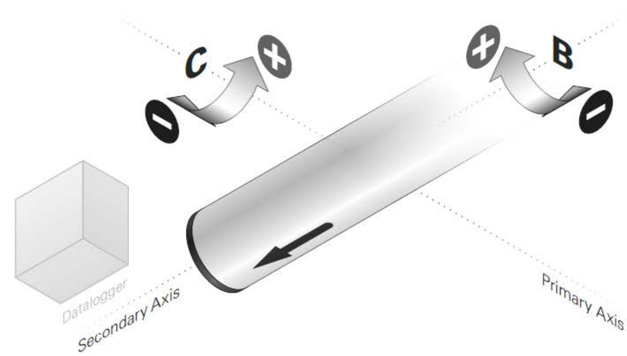
CEILING MOUNT: ARROW POINTED RIGHT



SENSOR CONFIGURATION	PRIMARY AXIS C
▪ Mounted to **CEILING, HORIZONTAL** installation ▪ **DATALOGGER** positioned **RIGHT,** relative to sensor	▪ **AXIS C POSITIVE/NEGATIVE ROTATION** readings: ⊕ Clockwise ⊖ Counterclockwise

SENSOR ORIENTATION	SECONDARY AXIS B
▪ Sensor **ARROW** pointed **RIGHT**, facing **DOWN**	▪ **AXIS B POSITIVE/NEGATIVE ROTATION** readings: ⊕ Top Toward ⊖ Top Away

CEILING MOUNT: ARROW POINTED LEFT



SENSOR CONFIGURATION	PRIMARY AXIS C
▪ Mounted to **CEILING, HORIZONTAL** installation ▪ **DATALOGGER** positioned **LEFT,** relative to sensor	▪ **AXIS C POSITIVE/NEGATIVE ROTATION** readings: ⊕ Counterclockwise ⊖ Clockwise

SENSOR ORIENTATION	SECONDARY AXIS B
▪ Sensor **ARROW** pointed **LEFT**, facing **DOWN**	▪ **AXIS B POSITIVE/NEGATIVE ROTATION** readings: ⊕ Top Away ⊖ Top Toward

GEOKON
48 Spencer Street
Lebanon, New Hampshire
03766, USA

Phone: +1 (603) 448-1562
Email: info@geokon.com
Website: www.geokon.com

GEOKON
is an **ISO 9001:2015**
registered company