Model 6185

Horizontal In-Place Inclinometer System

Instruction Manual

GEOKON®

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1. INTRODUCTION

The GEOKON Model 6185 Horizontal In-Place Inclinometer (IPI) System enables long-term monitoring of deformations beneath structures such as dams, landfills, embankments, etc. The basic principle of operation uses MEMS accelerometers to measure static tilt at specified positions in a casing installed in the structure being studied. The instrument is designed to be installed in standard grooved inclinometer casing, which is installed in the borehole. Monitoring by the instrument allows for very precise measurement of changes in the borehole profile.

Each sensor is comprised of an addressable Micro-Electro-Mechanical Systems (MEMS) device inside a sealed stainless steel housing. The device measures the "A" and "B" axes of the borehole. Each sensor also contains a digital temperature sensor for reading temperatures.

The sensors are mechanically joined with quick-connect ball joints, which allow for unimpeded relative movement between sensors and accommodate any spiraling of the casing. Electrically, sensors are connected to each other with four-wire bus cable and molded waterproof connectors.

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

Data is collected by connecting the IPI string to a readout device (PC, datalogger, SCADA system, etc.) via a customer-specified readout cable.

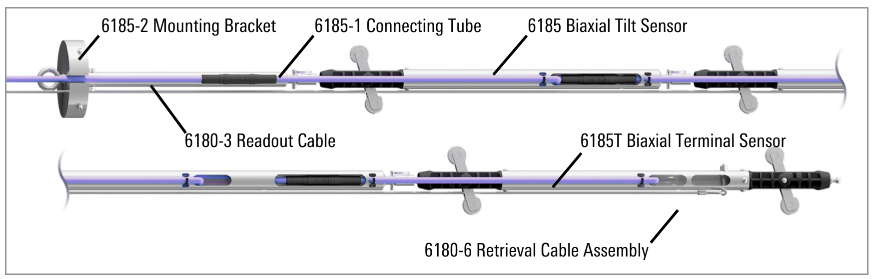

FIGURE 1: *Model 6185 Parts Identification*

2. INSTALLATION

2.1 PRELIMINARY TESTS

Prior to installation, check the sensors for proper operation. Complete the following steps:

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 connector from the second sensor into the female connector from the first sensor. Proceed in this manner until the full string is connected.

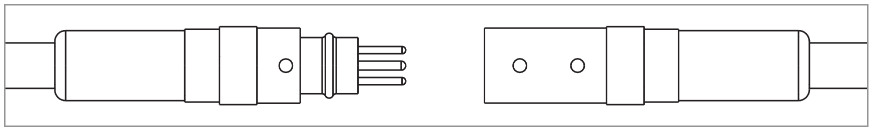

FIGURE 2: *Cable Connection Detail*

> **Caution!** When connecting the sensors, make sure to line up the orientation dot on the outside of the male connector with the two orientation dots on the outside of the female connector. This will ensure the pins and receptacles on the interior of the connectors align correctly. Push the connectors together until they are completely mated.
>
> **NOTE:** To facilitate mating, the male connectors have dielectric grease applied. Do not clean or remove the grease.

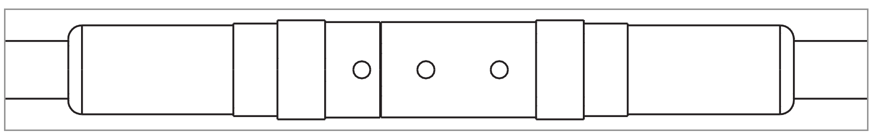

FIGURE 3: *Connected Cables*

3. Connect the completed string to a Model 8020-38 converter, PC, or datalogger (refer to Section 2.6).
4. Hold the first sensor in a horizontal position and observe the reading. The tilt sensor must be held steady while taking the reading. The observed reading should be close to the factory horizontal reading. Tilting the sensor in a positive direction (A+ or B+, as marked on the sensor) should yield increasing readings. Tilting the sensor in a negative direction (A- or B-) should yield decreasing readings. The temperature indicated on the readout should be close to ambient. Repeat this process with the remaining sensors.
5. Once the preliminary tests are complete, disconnect the string from the readout device and disconnect the sensors from each other.

Should any of these preliminary tests fail, see Section 5 for troubleshooting.

2.2 RETRIEVAL CABLE

GEOKON strongly recommends attaching a retrieval cable to the inner-most (terminal) sensor, Model 6185T. This can be used to retrieve the assembly in the event of an accident, and it also can be helpful when installing the assembly into the casing.

Model 6180-6 Retrieval Cable Assembly purchased from GEOKON consists of a customer-specified length of aircraft cable (07-125SS316-E/M) with eye bolt and hex nuts pre-attached for ease of installation, along with all hardware required to anchor the string.

To connect the retrieval cable to the terminal sensor, complete the following steps:

1. Remove the two hex nuts from the eye bolt.
2. Insert the eye bolt through both connection holes on the terminal sensor.
3. Thread the two nuts back onto the bolt and tighten against one another using two 5/16" crescent wrenches; this will retrieval the retrieval cable to the terminal sensor.

The figure below shows a properly connected retrieval cable.

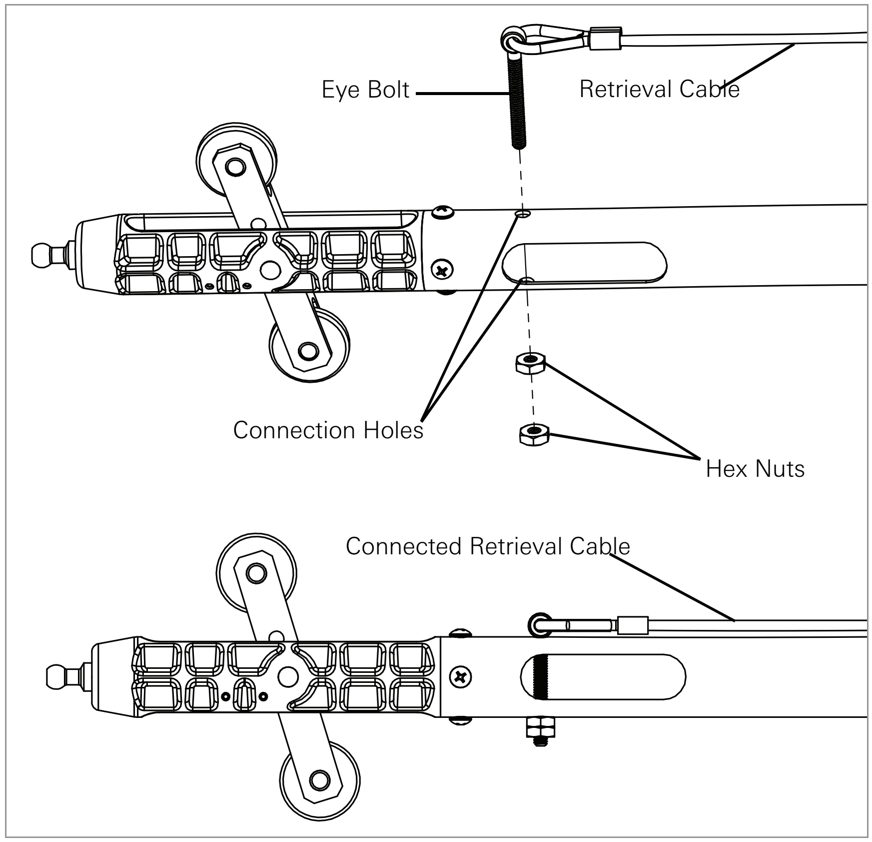

FIGURE 4: *Connecting a Retrieval Cable*

4. Tie off the outer end of the retrieval cable by attaching it to an appropriate anchor point. Begin by hooking the supplied thimble onto the anchor point, if possible.
5. Loop the bare end of the retrieval cable assembly around the anchor point.
6. Fold the "dead end" of the cable back onto the "live end", then secure one of the supplied cable clamps onto the cable at a distance of approximately 3.5 inches from the anchor point. (Install the cable clamp nuts firmly, but don’t tighten them down yet).
7. Orient the cable clamp with the two ends of the U-bolt facing toward the "live end" of the cable as shown below.

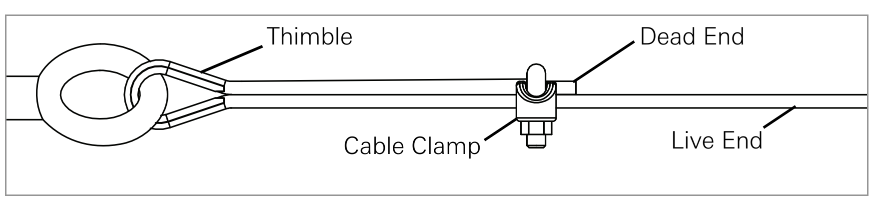

FIGURE 5: *Attach the First Cable Clamp*

8. Seat the loop formed by the cable into the channel of the thimble.
9. Install a second cable clamp onto the cable at the base of the thimble (see image below).

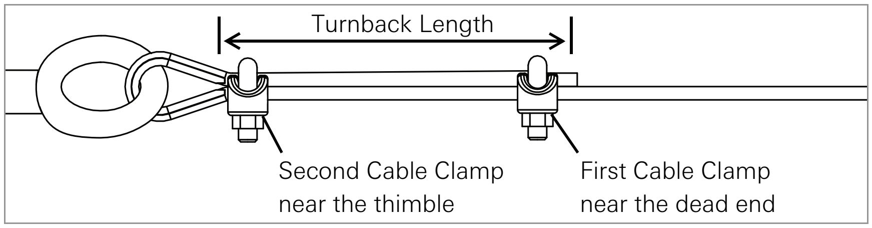

FIGURE 6: *Attach the Second Cable Clamp*

10. Adjust the first cable clamp so the "turnback length" measures approximately 3.25 inches.
11. Apply light tension to the cable to remove all slack. Tighten all four cable clamp nuts to a torque specification of approximately 4.5 ft-lbs.
12. If desired, the third supplied cable clamp may be installed in between the first and second cable clamps (make sure to tighten nuts to the previously mentioned torque specification).
13. Trim the excess cable from the "dead end", leaving at least 3/8 inch of length from the first cable clamp. Alternatively, wrap the end of the cable with tape and then tape it to the main length of the retrieval cable.

2.3 SENSOR ORIENTATION

All wheel assemblies should be oriented in the same direction when installed in the casing. The wheel assemblies are attached at the factory so the leading wheel is facing the A+ direction of the sensor (as shown in the figure to the left). Axis directions are also physically labeled on each sensor.

Point the A+ direction so that it faces downwards and the leading wheel intersects with the bottom groove of the casing.

The MEMS device monitors both A and B directions. The B+ direction is 90 degrees clockwise from the A+ direction, as viewed from above. The A direction corresponds to pitch of the casing, while the B direction corresponds to the roll of the casing.

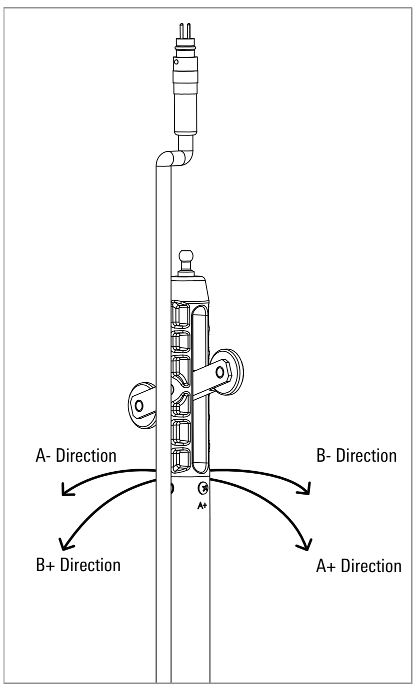

FIGURE 7: *A & B Directions*

2.4 SENSOR INSTALLATION

The first sensor to install is the Model 6185T terminal sensor, which includes two sets of wheels.

2.4.1 INSTALL THE FIRST SENSOR

1. Insert the 6185T sensor into the casing, making sure to orient the wheels correctly for proper axis orientation (see Section 2.3), and with the male cable connector facing out toward the opening of the casing.

2.4.2 CONNECT THE SECOND SENSOR TO THE FIRST SENSOR

1. Each 6185 segment is supplied with a barbed locking pin pre-installed.

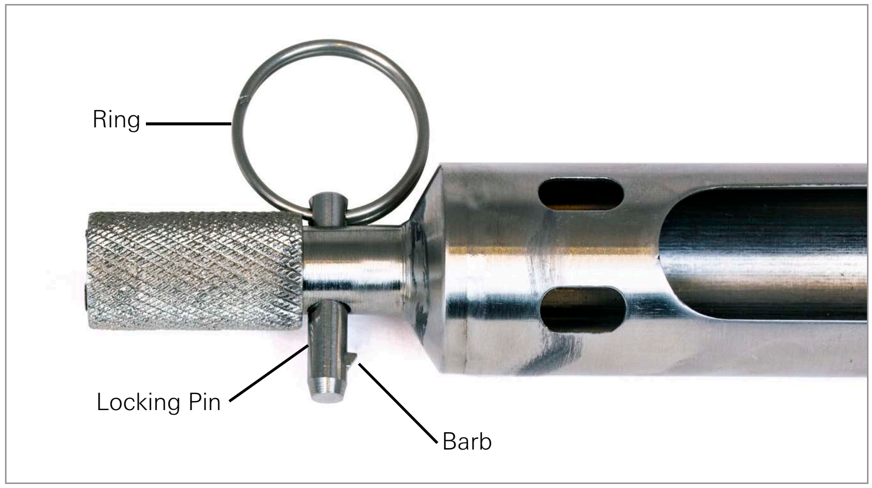

FIGURE 8: *Pre-inserted Locking Pin*

2. Remove the locking pin by depressing the barb and pulling the ring at the same time.

FIGURE 9: *Remove the Locking Pin*

3. Retract the spring sleeve on the second sensor and mate the ball stud of the first sensor to the receiver of the second sensor by connecting them together using a lateral motion.

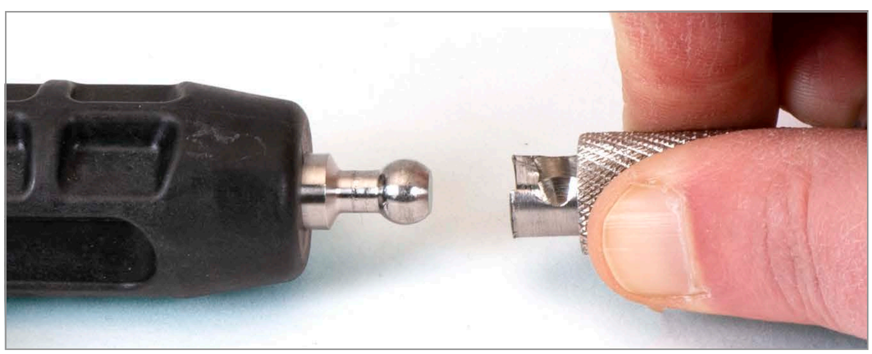

FIGURE 10: *Retract the Spring Sleeve*

4. Capture the ball stud by releasing the spring sleeve (make sure the sleeve returns to its initial position).

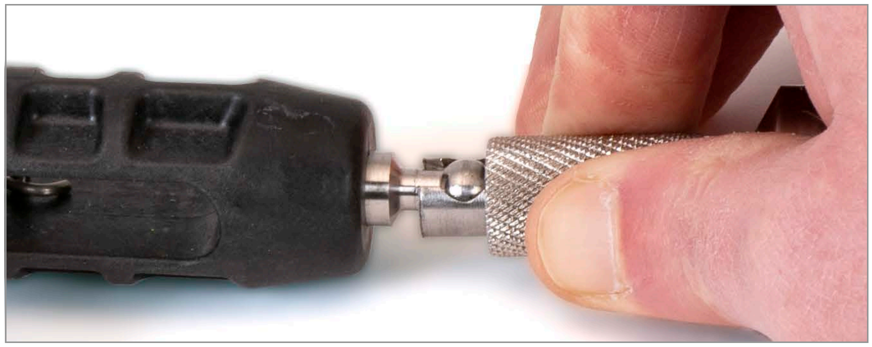

FIGURE 11: *Capture the Ball Stud*

5. Reinsert the locking pin to prevent the sleeve from retracting while in use.

FIGURE 12: *Completed Connection*

6. Plug the male connector of the first sensor's signal cable into the female connector of the second sensor's signal cable.

   Caution! When connecting the sensors, make sure to align the two orientation dots on the outside of the female connector with the orientation dot on the outside of the male connector. This will ensure the pins and receptacles on the interior of the connectors align correctly. Push the male and female connectors together until they are completely mated.

   NOTE: To facilitate mating, the male connectors have dielectric grease applied. Do not clean or remove the grease.

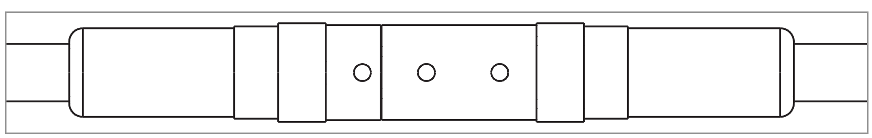

FIGURE 13: *Cable Connection Detail*

   Note: For additional security, tape the connectors together.

7. Using a provided tie wrap, secure the cable of the male connector to the tube of the second sensor by feeding the tie wrap through the parallel slots, around the cable, and back to itself; this will help provide strain relief for the connectors. Trim any length of excess tie wrap. See the figure below.

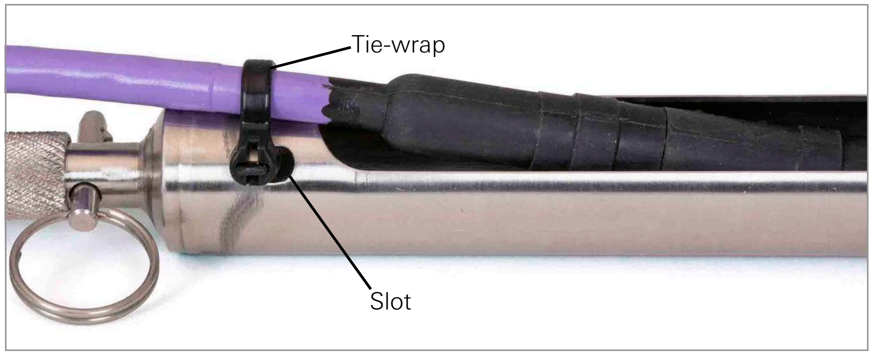

FIGURE 14: *Tie-Wrapped Cable*

8. Using the second sensor, push the IPI string into the casing until the wheels of the second sensor begin to engage the grooves of the casing.
9. Repeat steps 2 - 8 above for each subsequent sensor.
10. Plug the male connector of the outer-most sensor to the female connector of the readout cable (6180-3-1, 6180-3-2, or 6180-3V). Connect the other end of the readout cable to the readout device or data-logger.

2.5 CONNECTING THE MOUNTING BRACKET

To properly position the string relative to the end of the casing, order the desired length of connecting tube (6185-1-1 or 6185-1-2) with each string.

2.5.1 FASTEN THE CONNECTING TUBE TO THE BRACKET

1. Remove the two hex nuts from the cap screw using a ⅜" crescent wrench.
2. Remove the cap screw from the connecting tube.
3. Assemble the open end of the connecting tube onto the tube adapter on the mounting bracket (6185-2).
4. Align the two holes of the connecting tube with the cross-drilled hole of the tube adapter.
5. Reinsert the cap screw through the connecting tube and tube adapter.
6. Thread the two hex nuts back into the cap screw and tighten them against one another using two ⅜" crescent wrenches.

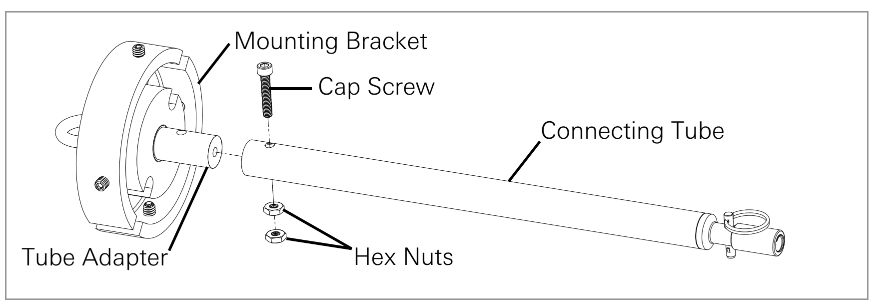

FIGURE 15: *Connecting Tube Fastened to Bracket*

2.5.2 CONNECT THE CONNECTING TUBE ASSEMBLY TO THE SENSOR STRING

The connecting tube assembly attaches to the sensor string similar to how the sensors attach to each other. For illustrated steps refer to Section 2.4.2.

1. Remove the locking pin from the connecting tube receiver by depressing the barb and pulling the ring at the same time.

2. Retract the spring sleeve on the connecting tube receiver and mate the ball stud of the top-most sensor to the receiver by connecting them together using a lateral motion.
3. Release the spring sleeve to secure the ball stud inside the sleeve.
4. Reinsert the locking pin to prevent the sleeve from retracting while in use.

2.5.3 POSITION THE OUTER-MOST SENSOR

1. Using the mounting bracket, push the string into the casing until the inner groove on the bracket is seated against the end of the casing.
   Note: Ensure the readout and retrieval cables are positioned within one of the two slots in the mounting bracket to avoid damage.
2. Using an Allen wrench, tighten the four mounting bracket set screws to secure the string to the end of the casing.

Important! Ensure the top rim of the casing is relatively square to properly seat the mounting bracket.

Readings may be taken immediately after installation, however, GEOKON recommends evaluating the data over a period of time to determine when the string has sufficiently stabilized and when the zero readings should be established.

2.6 READOUT

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

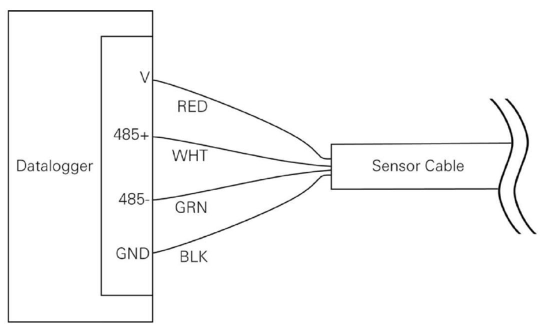

FIGURE 16: *Wiring of Datalogger with built-in RS-485 Conversion*

If your datalogger does not have built-in RS-485 communications, a Model 8020-38 Addressable Bus Converter (Figure 13) 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 17: *Model 8020-38 RS-485 to TTL/USB Converter*

If utilizing a Model 8020-38 to connect the inclinometer system to a readout, wire the connections as shown in Figure 18. (The dataloggers must have the appropriate port available.)

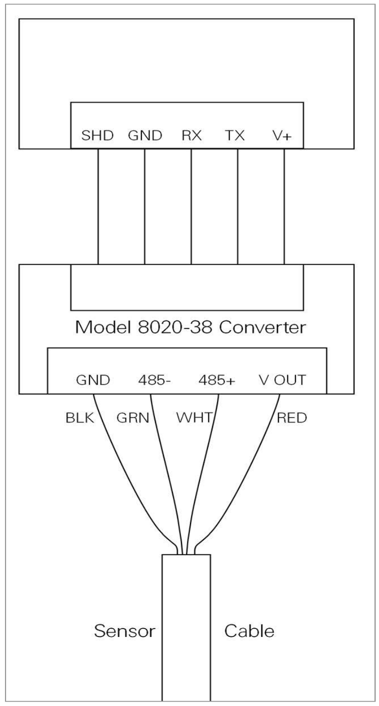

FIGURE 18: *Wiring of Datalogger without built-in RS-485 Conversion*

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

2.7 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.

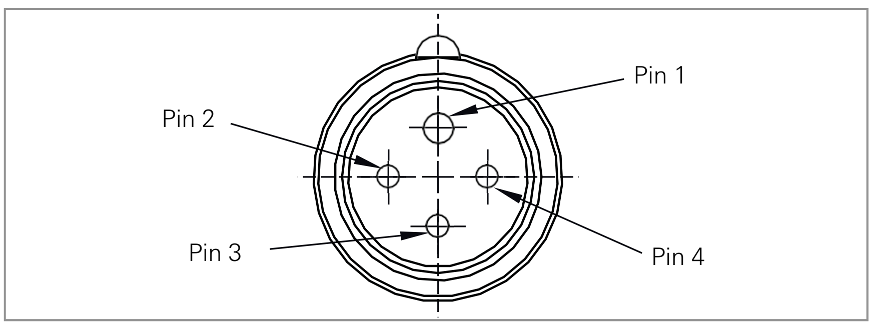

FIGURE 19: *Male Waterproof Connector*

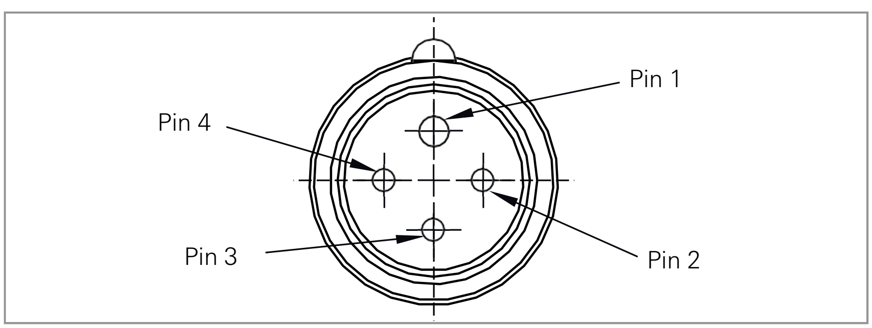

FIGURE 20: *Female Waterproof Connector*

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 6185 inclinometers 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 6185 inclinometers 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 slave 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 and B axes are both 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.2 for an explanation of these codes.

The flash password prevents unintended writes to the nonvolatile memory in Table 4. 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					
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					
0x10E	28	LSW	Thermistor ADC	N/A	uint16	
	29					
0x117	46		Error Code	N/A	uint16	
	47					

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*

4. DATA REDUCTION

4.1 INCLINATION CALCULATION

The output of the 6185 Inclinometer 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 using calibration data.

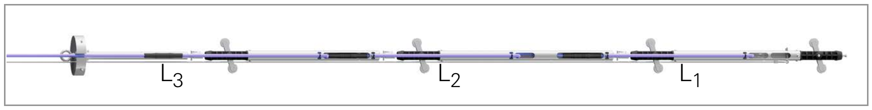

FIGURE 21: *Installation Example*

4.2 DEFLECTION CALCULATION

The displacement (D) of the wheel-end of any sensor relative to the horizontal line running through the receiver-end of the sensor is equal to:

$$D = L\sin\theta$$

EQUATION 1: *Sensor Displacement*

Where:
L = The length of the sensor
θ = Inclination angle of the sensor, as described above

The profile of the borehole is constructed by using the cumulative sum of these displacements starting with the terminal sensor.

The total displacement of the wheel-end of the outermost sensor from the horizontal line drawn through the end of the innermost sensor is:

$$D_{total} = L_1\sin\theta_1 + L_2\sin\theta_2 + L_3\sin\theta_3$$

EQUATION 2: *Total Displacement*

4.3 ENVIRONMENTAL FACTORS

Since the purpose of the inclinometer installation 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 6185 In-Place Inclinometers 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.2 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. There is no remedial action.

APPENDIX A. SPECIFICATIONS

A.1 INCLINOMETER SPECIFICATIONS

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)
Operating Temperature	-40 to 65 °C (-40 to 149 °F)
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")
Standard Sensor Length[6]	0.5 m, 1 m, 2 m, 3 m, 2 ft, 5 ft, 10 ft
Sensor Weight	0.5 m: 0.55 kg (1.22 lb), 1 m: 0.97 kg (2.14 lb), 2 m: 1.80 kg (3.98 lb), 3 m: 2.64 kg (5.82 lb), 2 ft: 0.64 kg (1.42 lb), 5 ft: 1.40 kg (3.10 lb), 10 ft: 2.67 kg (5.90 lb)
Materials	316 Stainless Steel, Engineered Polymer
Electrical Cable	Four Conductor, Foil shield, Polyurethane jacket, nominal OD = 7.9 mm
Minimum Sensor Spacing	0.5 m
Interface	RS-485
Protocol	Modbus
Baud Rate	115,200 bps
Temperature Accuracy	±0.5 °C
Ingress Protection	IP68 to 3 MPa (300 m/1000 ft of head)
Casing Diameter Range	58 mm to 90 mm

TABLE 5: *Model 6185 Inclinometer Specifications*

Notes:

[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
[6] Custom spacing available upon request

A.2 PARTS LIST

6185-0.5M	IPI MEMS Addressable Horizontal	Biaxial, Segment Length = 0.5 M
6185-1M	" " " "	Biaxial, Segment Length = 1M
6185-2M	" " " "	Biaxial, Segment Length = 2M
6185-3M	" " " "	Biaxial, Segment Length = 3M
6185-2FT	" " " "	Biaxial, Segment Length = 2FT
6185-5FT	" " " "	Biaxial, Segment Length = 5FT
6185-10FT	" " " "	Biaxial, Segment Length = 10FT
6185T-0.5M	IPI MEMS Addressable Horizontal, Terminal	Biaxial, Segment Length = 0.5M
6185T-1M	" " " " "	Biaxial, Segment Length = 1M
6185T-2M	" " " " "	Biaxial, Segment Length = 2M
6185T-3M	" " " " "	Biaxial, Segment Length = 3M
6185T-2FT	" " " " "	Biaxial, Segment Length = 2FT
6185T-5FT	" " " " "	Biaxial, Segment Length = 5FT
6185T-10FT	" " " " "	Biaxial, Segment Length = 10FT
6185-1-1	Connecting Tube, < 5 FT	Specify Length of Tube Required
6185-1-2	Connecting Tube, 5 FT - 10 FT	Specify Length of Tube Required
6185-2	Mounting Bracket	
6180-6	Retrieval Cable Assembly	Specify Length of 07-125SS316 Aircraft Cable Required
6180-3-1	Topside Readout Cable/Bare Leads, < 50 FT	Specify Length of 02-313P9LTD Signal Cable Required
6180-3-2	Topside Readout Cable/Bare Leads, 50 FT-100 FT	Specify Length of 02-313P9LTD Signal Cable Required
6180-3V	Topside Readout Cable/Bare Leads, > 100 FT	Specify Length of 02-313P9LTD Signal Cable Required
07-125SS316-E	Aircraft Cable, 1/8", English	
07-125SS316-M	Aircraft Cable, 1/8", Metric	
02-313P9LTD-M	Low Temp., Polyurethane Cable, 0.313", Violet	

TABLE 6: *Model 6185 Inclinometer Parts List*

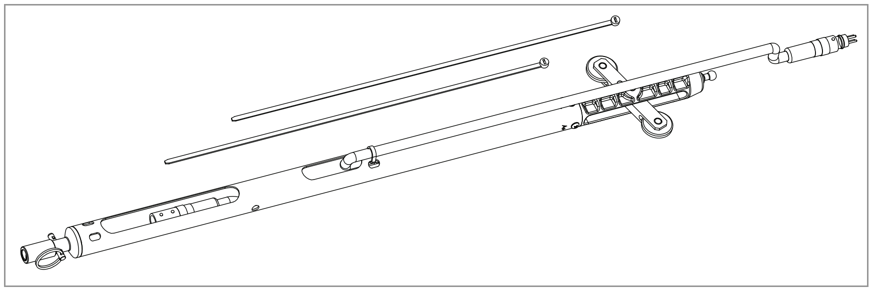

FIGURE 22: *Model 6185-0.5M, -1M, -2M, -3M, -2FT, -5FT, -10FT*

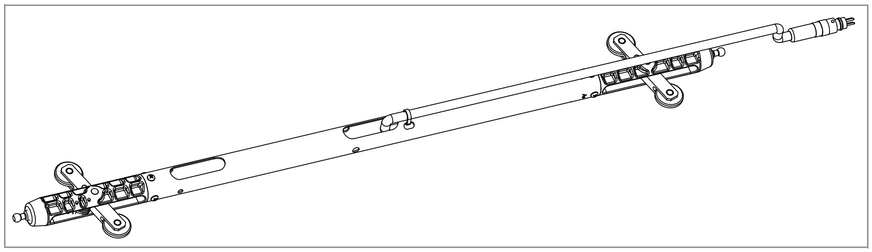

FIGURE 23: *Model 6185T-0.5M, -1M, -2M, -3M, -2FT, -5FT, -10FT*

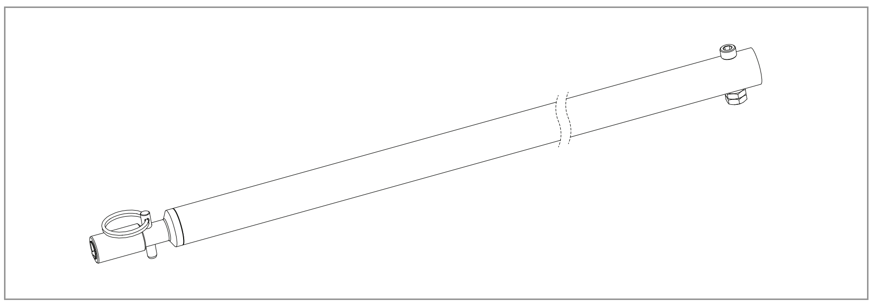

FIGURE 24: *Model 6185-1-1, 6185-1-2 Connecting Tube*

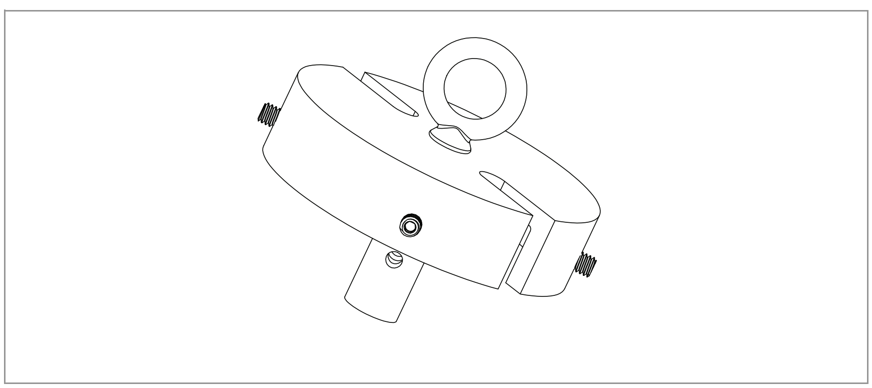

FIGURE 25: *Model 6185-2 Mounting Bracket*

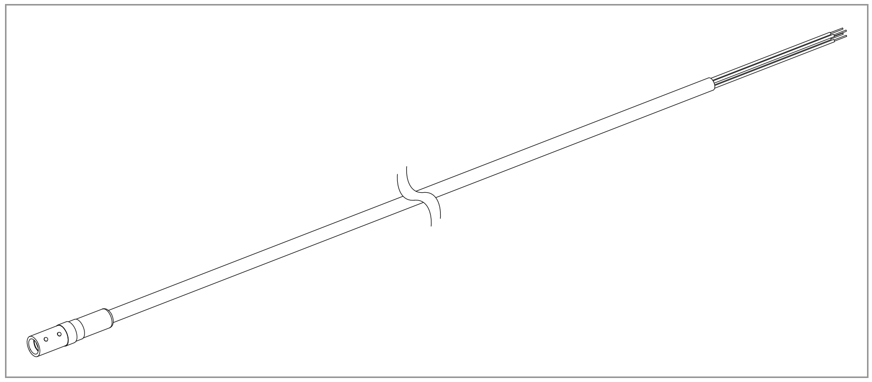

FIGURE 26: *Model 6180-3-1, -3-2 Topside Readout Cable/Bare Leads, < 100FT*

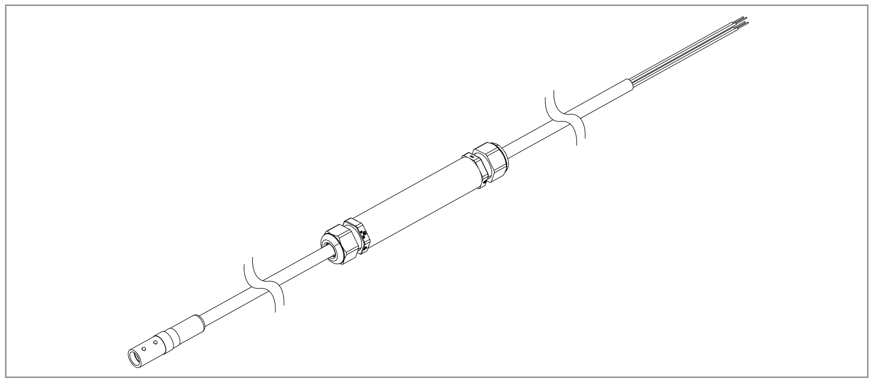

FIGURE 27: *Model 6180-3V Topside Readout Cable/Bare Leads, > 100FT*

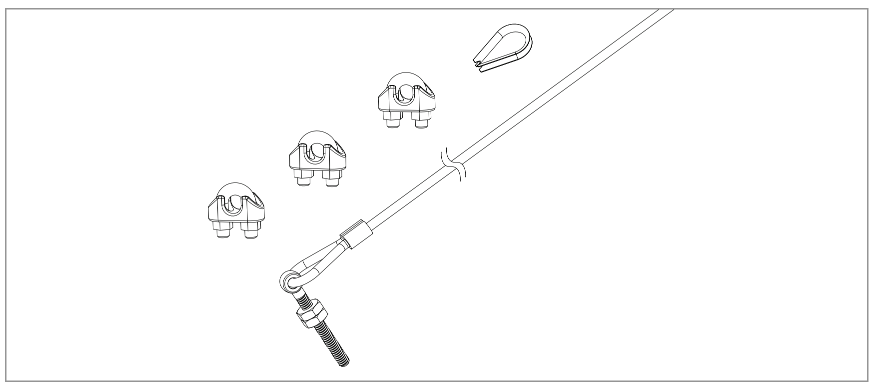

FIGURE 28: *Model 6180-6 Retrieval Cable Assembly*

GEOKON®

Calibration Report

Model Number: 6185-0.5M

Serial Number: 2330066 AAxisAngular

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

Calibration Date: December 20, 2023

Temperature: 22.1 °C

Technician:

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.

FIGURE 29: *Sample Model 6185 Calibration Sheet, A Axis Angular*

GEOKON

Calibration Report

Model Number: 6185-0.5M

Serial Number: 2330066 AAxisTemperature

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

Calibration Date: December 20, 2023

Temperature: 21.2 °C

Technician: Kilbellavance

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 30: *Sample Model 6185 Calibration Sheet, A Axis Temperature*

GEOKON®

Calibration Report

Model Number: 6185-0.5M

Calibration Date: December 20, 2023

Serial Number: 2330066 BAxisAngular

Temperature: 22.0 °C

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

Technician:

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.

FIGURE 31: *Sample Model 6185 Calibration Sheet, B Axis Angular*

GEOKON®

Calibration Report

Model Number: 6185-0.5M

Calibration Date: December 20, 2023

Serial Number: 2330066 BAxisTemperature

Temperature: 21.2 °C

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

Technician: KBellavance

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 32: *Sample Model 6185 Calibration Sheet, B Axis Temperature*

GEOKON®

Calibration Report

Model Number: 6185-0.5M

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.

FIGURE 33: *Sample Model 6185 Calibration Sheet, C Axis Angular*

GEOKON®

Calibration Report

Model Number: 6185-0.5M

Calibration Date: December 20, 2023

Serial Number: 2330066 CAxisTemperature

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.

FIGURE 34: *Sample Model 6185 Calibration Sheet, C Axis Temperature*

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 7: *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 or too cold, or it may be 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 8: *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 6185 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 6185 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
```

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