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Instruction Manual

Model 6150B

Standard Analog Addressable
MEMS In-Place Inclinometer

(REV B 2/16)

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LIST of FIGURES, TABLES and EQUATIONS

1. INTRODUCTION

The Geokon Model 6150B Standard Analog Addressable MEMS In-Place Inclinometer system is designed for long-term monitoring of deformations in structures such as dams, embankments, foundation walls and the like. The basic principle is the utilization of tilt sensors to make accurate measurement of inclination, over segments, in boreholes drilled into the structure being studied. The continuous nature of the instrument allows for very precise measurement of changes in the borehole profile to be measured. The instrument is installed in standard grooved inclinometer casing.

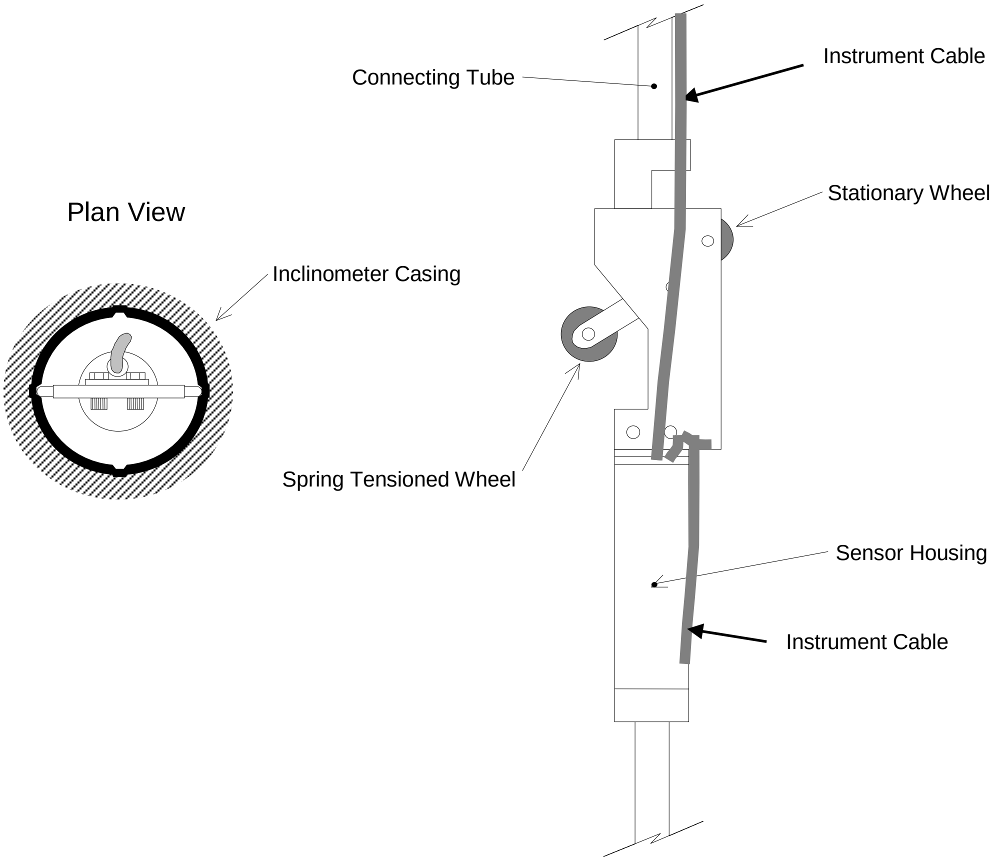


Figure 1 - Model 6150B MEMS Standard Analog addressable Tilt Sensor Assembly

1.1. Tilt Sensor Construction

The tilt sensor comprises one or two micro-electrical-mechanical-systems, (MEMS), sensors mounted inside a sealed housing. The Housing has a mounting bracket on its upper end for connecting the sensor to a wheel assembly that centralizes the sensor and orients the sensor when lowered into the casing grooves. A lug on the lower end connects to a universal coupling, which allows unimpeded relative movement between the spacing rods, and a swivel joint which prevents the wheel assemblies from running out of the casing grooves. Stainless steel tubing is used to connect and space apart the transducer and wheel assemblies. The whole string is normally suspended from the top of the casing. Biaxial systems use two transducers mounted at 90° to each other. Each housing contains a thermistor for reading temperatures.

The sensors are connected together by a single 6-pair cable that is permanently attached to each sensor as part of a string with the cable going in and out of the top of the sensor, one to the sensor above and one to the sensor below. Each string is custom made according to customer specifics The maximum number of sensors is 16 and the maximum cable length is 305 meters. The assembly is read using the Micro-1000 or Micro-800 Datalogger.

Note. The use of a safety cable, attached to the bottom wheel assembly, is strongly recommended. Not only can it be used to retrieve the assembly in the event that one of the joints breaks loose, but it is also very useful in lowering the assembly into the casing.

2. INSTALLATION

2.1. Preliminary Tests

Standard system

Prior to installation, the sensors can be checked for proper operation. Dataloggers are used to read Addressable IP as described in Appendix D, page 15.

Each tilt sensor is supplied with a calibration sheet,(a typical one is shown in Figure 6), which shows the relationship between output voltage and inclination. The addressable tilt sensor electrical wiring diagram is shown in Appendix C Page 14. Carefully hold each sensor being addressed in an approximately vertical position and observe the reading. The sensor must be held in a steady position. The readings should be close to the factory vertical reading.

It would be helpful if all the sensors and cables could be laid out on a flat surface next to the top of the casing.

2.2. Model 6150B Assembly and Installation

1. **Connect the safety cable to the bottom wheel assembly**.

   (See Figure 2) This is strongly recommended. Not only can it be used to retrieve the assembly in the event that one of the joints breaks loose, but it is also very useful in lowering the assembly into the casing. The alternative is to hold the tube sections with vice-grips at the top of the casing.

   The bottom wheel assembly is labeled, it has no universal joint, just the swivel. The safety cable has a loop at its bottom end which fits over the long bolt used to hold the bottom wheel assembly to the first tube section. This is shown in Figure 3. The cable eyebolt is trapped between two nuts.

2 **Connect the first length of gage tubing to the bottom wheel assembly.**

   The lengths of tubing making up the IPI string are shown in a table supplied separately along with the calibration sheets. [Where the inter-anchor spacing is large, two tubes are joined together by a special union]. Use the 10-32 screws and nuts, and use Loctite222 on all threads to make this and all the other joints.

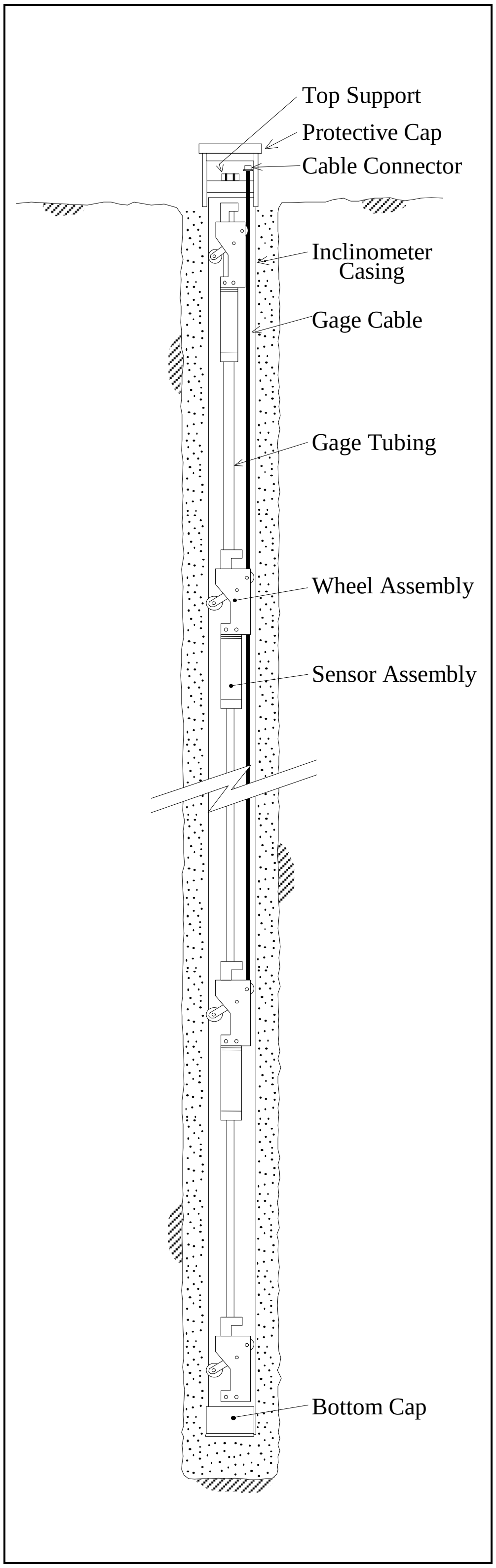


Figure 2 Model 6150B Installation

It is customary (and recommended) to point the A+ direction in the same direction as the anticipated movement, i.e., towards the excavation being monitored or down-slope in the case of slope stability applications.

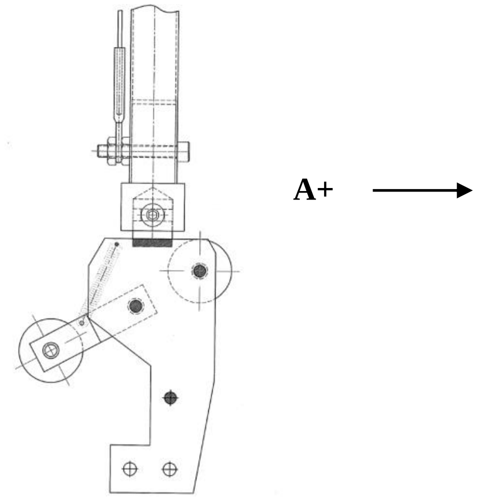


Figure 3 Bottom Wheel Assembly

2.2.3 The next step is to attach the bottom sensor assembly.

The sensors are delivered pre-attached to the wheel assemblies. The tongue of the sensor fits inside the slot of the wheel assembly with the orientation set such that the A+ direction marked on the sensor is aligned on the same side as the fixed wheel on the wheel assembly. Tilts in the positive direction yield increasing readings.
Lower the bottom wheel assembly into the casing until the connecting rod is at the top of the casing. Grip the rod with vice grips then attach the sensor assembly using a single long 10-32 capscrew. (Use Loctite222 on all threads)

[With a biaxial system the second MEMS sensor is included in the housing and is oriented with its positive direction 90° clockwise from the upper sensor (looking downwards in plan). This is the B+ direction. See Figure 4.]

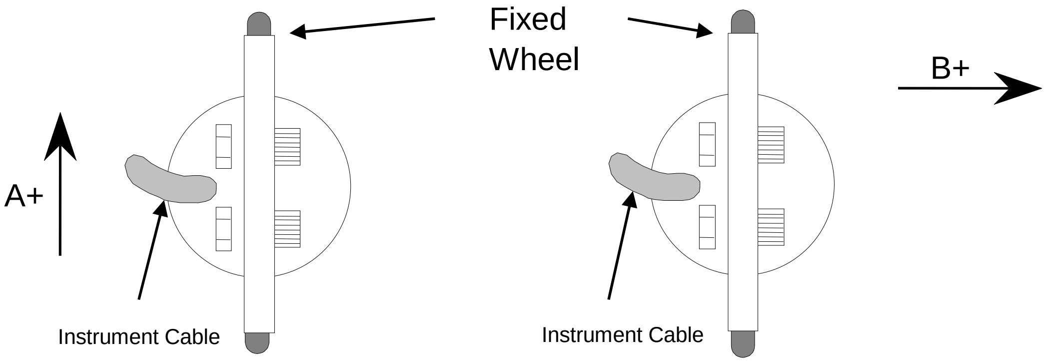


Figure 4- Biaxial Sensor Orientation

4. Assembling the IPI string

This first gage assembly is now lowered into the borehole, (using the safety cable if one is used), with the fixed-wheel aligned in the so-called A+ direction. It is customary (and recommended) to point the A+ direction in the same direction as the anticipated movement, i.e., towards the excavation being monitored or down-slope in the case of slope stability applications.

While holding the bottom sensor assembly at the top of the casing, the next rod segment with sensors, wheel assembly, universal joint and swivel are attached to the top of the first rod segment using a single long 10-32 capscrew. (Use Loctite222 on all threads), and lowered in the same orientation. The system can become quite heavy and a clamp of some sort (two vice grips) should be used to hold the rods in place while being assembled. The use of a winch to hold the safety cable can be of help.

Continue to add gage tubing, sensors and wheel assemblies until the last sensor has been installed. At this point, the top suspension must be attached to the upper wheel assembly (or the gage tube). The assembly is bolted to the wheel assembly (or tube) as before, and then lowered into position on the casing.

After the sensor string is lowered into position, the safety cable can be tied off around the top of the casing and the signal cables can be run to the readout location and terminated at the datalogger or otherwise fixed. Readings can be taken immediately after installation, but it is recommended that the system be allowed to stabilize for a few hours before recording zero conditions.

3. TAKING READINGS

3.1 Dataloggers

The 6150B MEMS Standard Analog Addressable In-place Inclinometer will be monitored continuously and automatically using a Datalogger. Connections to the Geokon Model 8021 Micro-1000 Datalogger, which uses a Campbell Scientific CR1000 MCU, are shown in Appendix C Page 14. The CR1000MCU datalogger supplied with the 6150B has been programmed to read the MEMS tiltmeter 100 times at each sample and calculate the average. If the user programs their own datalogger t is recommended that averaging be used to achieve better accuracies and more stable readings.

3.2 Measuring Temperature

Although the temperature dependence of the MEMS tilt meter is close to zero, and usually does not require compensation, it sometimes happens that temperature effects can cause real changes of tilt; therefore each MEMS tilt sensor is equipped with a thermistor for reading temperature. This enables temperature-induced changes in tilt to be distinguished from tilts due to other sources.

The datalogger automatically measures the thermistor resistance and converts it into a temperature using the equation B-1 shown in Appendix B .

The above remarks apply mainly to structures exposed to sunlight: in these situations it is not uncommon for the structure to expand and contract differentially during to course of the day. For land-slide applications where the MEMS sensors are buried in the ground, temperature variations are very small or non-existent and ground movements are unaffected by temperatures. In these situations it is not necessary to measure temperatures.

4. DATA REDUCTION

4.1. Tilt Calculation

The output of the MEMS Sensor is proportional to the sine of the angle of inclination from the vertical. For the +/- 15 degree sensor the FS output is approximately 4 volts.
The relationship between the reading, **R**, and the angle of inclination, **θ,** is given by the equation:

$$\theta = \mathrm{Sin}^{-1}(RG) \qquad \text{or} \qquad \mathrm{Sin}\theta = RG$$

Equation 1 Inclination versus voltage.

Where **R** is the reading in Volts and **G** is the Gage Factor (sinθ/volt) shown on the calibration sheet. Note that the small voltage reading at zero inclination can be ignored since it is only the tilting, i.e. change of inclination that is of interest. Note also that for small angles $\sin\theta = \theta$ radians.

So the amount of tilt, in degrees, is given by the equation

$$\text{Tilt} = \mathrm{Sin}^{-1}(R_1 - R_0)G \text{ degrees}$$

Equation 2 Tilt degrees versus voltage.

Positive values are tilts in the direction of the arrows A+ and B+

4.2. Temperature Correction

The Model 6150B Standard Analog Addressable MEMS Tiltmeter has very small temperature sensitivity equal to +1 arc second per degree centigrade rise. The tilt corrected for temperature is:

$$\text{Tilt} = \mathrm{Sin}^{-1}(R_{1corr} - R_0)G \text{ degrees}$$

$$\text{Where } R_{1corr} = R_1 - 0.0003\,(T_1 - T_0)$$

Equation 3 Tilt versus voltage corrected for Temperature.

Normally, temperature corrections are not required. An important point to note is that sudden changes in temperature will cause both the structure and the Tiltmeter to undergo transitory physical changes, which will show up in the readings. The gage temperature should always be recorded, and efforts should be made to obtain readings when the instrument and structure are at thermal equilibrium. The best time for this tends to be in the late evening or early morning hours.

4.3. Deflection Calculation

The lateral offset, **D**, of the top of any segment relative to the vertical line running through the bottom of the segment is equal to **L**$\mathbf{\sin\theta}$**,** where L is the length of the segment, between pivot points, and θ is the inclination of the segment to the vertical.

The length L_1, L_2, L_3,…. etc., can be calculated by adding **336mm**,(both uniaxial and biaxial systems) to the individual lengths of tubing. This will give the correct distance between pivot points.

The profile of the borehole is constructed by using the cumulative sum of these lateral offsets starting with the bottom segment, $\mathbf{L_1}$. For instance, referring to figure 5, the total lateral offset of the top of the upper segment, (which is usually at the surface), from the vertical line drawn through the bottom of the lower segment, (located at the bottom of the borehole), is

$$D_5 = L_1\sin\theta_1 + L_2\sin\theta_2 + L_3\sin\theta_3 + L_4\sin\theta_4 + L_5\sin\theta_5$$

Equation 4 - Offset Calculation

Therefore, ignoring temperature corrections,

$$D_5 = G_1L_1R_1 + G_2L_2R_2 + G_3L_3R_3 + G_4L_4R_4 + G_5L_5R_5$$

And the deflection, **ΔD,** i.e. the change in offset is

$$\Delta D_n = \sum_1^n G_nL_n\,\Delta R_n$$

Equation 5 - Deflection Calculation

Where $\mathbf{\Delta R_1 = (R_1\text{-}R_0)}$ i.e. the present reading on Tiltmeter 1 minus the initial reading on Tiltmeter 1; and $\mathbf{\Delta R_2 = (R_2\text{-}R_0)}$ i.e. the present reading on Tiltmeter 2 minus the initial reading on Tiltmeter 2; and similarly for all the other Tiltmeters.

Although the system is designed for use in continuous segments with pivots, the sensors can be installed without interconnecting tubing in standard, round tubing or pipe using special friction anchors. In those systems, the assumption is made that the measured deflection occurs over the segment length, the mid-point of which is at the sensor location, and that L is the distance between adjacent midpoints.

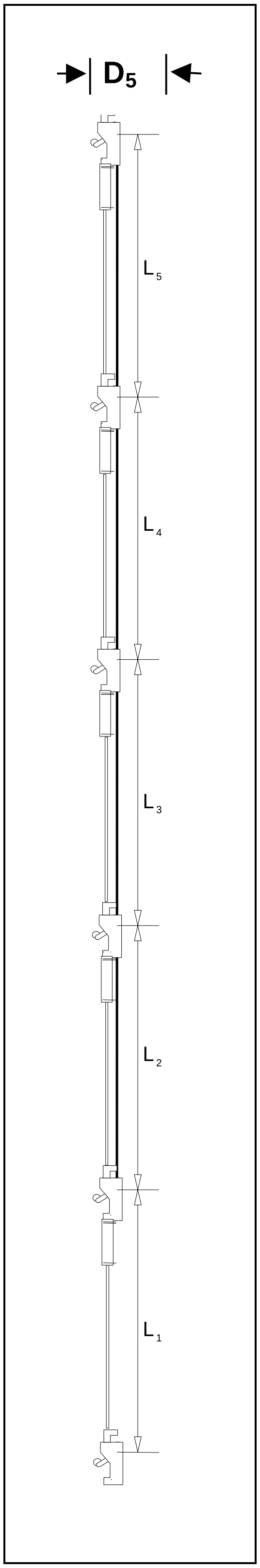
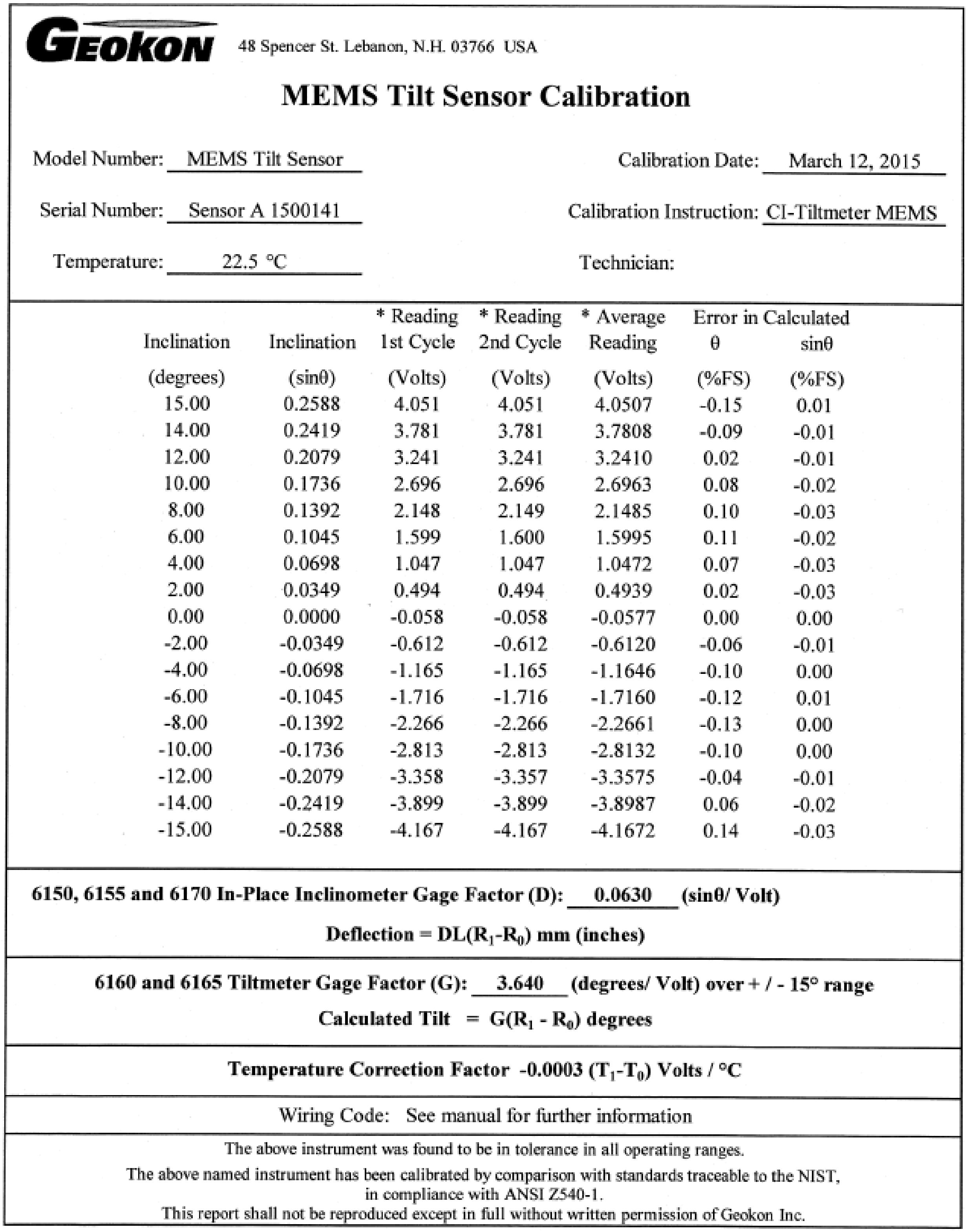


Figure 5
Deflection Intervals



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MEMS Tilt Sensor Calibration

Model Number: MEMS Tilt Sensor

Calibration Date: March 12, 2015

Serial Number: Sensor A 1500141

Calibration Instruction: CI-Tiltmeter MEMS

Temperature: 22.5 °C

Technician:

Inclination	Inclination	* Reading 1st Cycle	* Reading 2nd Cycle	* Average Reading	Error in Calculated θ	sinθ
(degrees)	(sinθ)	(Volts)	(Volts)	(Volts)	(%FS)	(%FS)
15.00	0.2588	4.051	4.051	4.0507	-0.15	0.01
14.00	0.2419	3.781	3.781	3.7808	-0.09	-0.01
12.00	0.2079	3.241	3.241	3.2410	0.02	-0.01
10.00	0.1736	2.696	2.696	2.6963	0.08	-0.02
8.00	0.1392	2.148	2.149	2.1485	0.10	-0.03
6.00	0.1045	1.599	1.600	1.5995	0.11	-0.02
4.00	0.0698	1.047	1.047	1.0472	0.07	-0.03
2.00	0.0349	0.494	0.494	0.4939	0.02	-0.03
0.00	0.0000	-0.058	-0.058	-0.0577	0.00	0.00
-2.00	-0.0349	-0.612	-0.612	-0.6120	-0.06	-0.01
-4.00	-0.0698	-1.165	-1.165	-1.1646	-0.10	0.00
-6.00	-0.1045	-1.716	-1.716	-1.7160	-0.12	0.01
-8.00	-0.1392	-2.266	-2.266	-2.2661	-0.13	0.00
-10.00	-0.1736	-2.813	-2.813	-2.8132	-0.10	0.00
-12.00	-0.2079	-3.358	-3.357	-3.3575	-0.04	-0.01
-14.00	-0.2419	-3.899	-3.899	-3.8987	0.06	-0.02
-15.00	-0.2588	-4.167	-4.167	-4.1672	0.14	-0.03

6150, 6155 and 6170 In-Place Inclinometer Gage Factor (D): 0.0630 (sinθ/ Volt)

Deflection = $DL(R_1-R_0)$ mm (inches)

6160 and 6165 Tiltmeter Gage Factor (G): 3.640 (degrees/ Volt) over + / - 15° range

Calculated Tilt = $G(R_1 - R_0)$ degrees

Temperature Correction Factor -0.0003 (T_1-T_0) Volts / °C

Wiring Code: See manual for further information

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.

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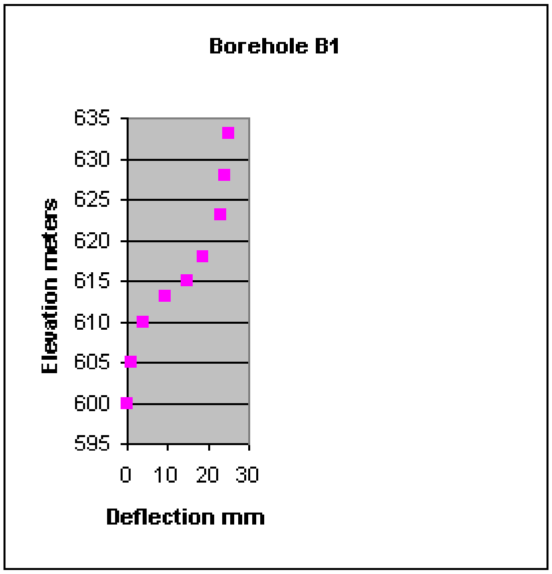
Figure 6 Sample Model 6150 MEMS Calibration Sheet

4.4 Sample Calculation

	MEMS		Borehole#1					
	DEFLECTION							
	CALCULATION							
SENSOR		L	Depth	Elevation	G	R0	T0	
		meters	meters	meters	Sinθ/V	Volts	° C	
Surface			0	633				
1		5	5	628	0.06271	0.582	20	
2		5	10	623	0.06303	0.5632	18	
3		5	15	618	0.06221	0.5495	18	
4		3	18	615	0.06295	0.532	17	
5		2	20	613	0.06284	0.5144	17	
6		3	23	610	0.06291	0.4883	17	
7		5	28	605	0.06273	0.4321	17	
8		5	33	600	0.06289	0.3962	17	

		R1	T1	$R1_{corr}$	$R1_{corr}$ -R0	GL(R1-R0)	Acc Defl	
		Volts	° C	Volts	Volts	mm	mm	
Surface								
1		0.5802	10	0.5832	0.0012	0.38	24.23	
2		0.5644	12	0.5662	0.003	0.95	23.85	
3		0.5632	17	0.5635	0.0140	4.35	22.90	
4		0.5514	17	0.5514	0.0194	3.66	18.55	
5		0.5602	17	0.5602	0.0458	5.76	14.89	
6		0.5169	17	0.5169	0.0286	5.40	9.13	
7		0.4404	17	0.4404	0.0083	2.60	3.74	
8		0.3998	17	0.3998	0.0036	1.13	1.13	



4.5. 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 the vibrating wire tilt sensors used in the Model 6150B Standard Analog Addressable In-Place Inclinometer are confined to periodic checks of cable connections. The sensors are sealed and there are no user-serviceable parts.

Consult the following list of problems and possible solutions should difficulties arise. Consult the factory for additional troubleshooting help.

Symptom: Tilt Sensor Readings are Unstable

✓ Is there a source of electrical noise nearby? Most probable sources of electrical noise are motors, generators and antennas. Make sure the shield drain wire is connected to ground.

Symptom: Tilt Sensor Fails to Read

✓ Is the cable cut or crushed? This can be checked with an ohmmeter. The nominal resistance of the thermistor is 3000 ohms at 25 degrees C. If the approximate temperature is known, the resistance of the thermistor leads can be estimated and used as a cable check. Remember to add cable resistance when checking (22 AWG stranded copper leads are approximately 16Ω/1000' or 52Ω/km, multiply by 2 for both directions). If the resistance reads infinite, or very high (megohms), a cut wire must be suspected. If the resistance reads very low (<20Ω) a short in the cable is likely.

✓ Does the Datalogger work with another tilt sensor? If not, the Datalogger may be malfunctioning.

Symptom: Thermistor resistance is too high.

✓ Is there an open circuit? Check all connections, terminals and plugs.

Symptom: Thermistor resistance is too low.

✓ Is there a short? Check all connections, terminals and plugs.

]✓ Water may have penetrated the interior of the tilt sensor. There is no remedial action.

APPENDIX A - SPECIFICATIONS

A.1. MEMS Tilt Sensor

Model:	**6150B**
Range	±15°
Resolution:[1]	+/-2 arc seconds, (+/- 0.01mm/m)
Accuracy[2]	+/-3 arc seconds
Linearity:[3]	+/- 0.07% FS
Cross axis sensitivity	4%
Thermal Zero Shift:	- 0.0003 volt/°C rise
Operating Temperature	-20 to +80° C -4 to 176° F
Power Requirements[4]:	6150B-1 (Uniaxial): +12V (nom) @ 30mA 6150B-2 (Biaxial): +12V (nom) @ 45mA
Sensor Output:	+/-4 Volts @ FS
Frequency Response:	-3db @ 8-28 Hz
Shock Resistance	2,000g
Thermistor Resistance:	3000Ω at 25ºC
Sensor Housing Dia:	32 mm, (1.250").
Length:	362mm,(14.25").
Weight:	0.7 kg. (1.5 lbs.).
Materials:	304 Stainless Steel
Electrical Cable:	6 twisted pair (12 conductor) 24 AWG Foil shield, Polyurethane jacket, nominal OD = 7.9 mm

Table A-1 Model 6150B Standard Analog Addressable MEMS Tilt Sensor Specifications

Notes:

[1] For best results requires a 4 ½ digit digital voltmeter.
Averaging 100 readings will yield resolution on the order of 2 arc seconds
[2] Based upon the use of a second order polynomial
[3] The output of the MEMS sensor is proportional to the sine of the angle of tilt
[4] **Voltages in excess of 18V will damage the circuitry and are to be avoided**

A.2. Thermistor (see Appendix B)

Range: -80 to +150° C
Accuracy: ±0.5° C

APPENDIX B - THERMISTOR TEMPERATURE DERIVATION

Thermistor Type: YSI 44005, Dale #1C3001-B3, Alpha #13A3001-B3

Resistance to Temperature Equation:

$$T = \frac{1}{A + B(\mathrm{LnR}) + C(\mathrm{LnR})^3} - 273.2$$

Equation B-1 Convert Thermistor Resistance to Temperature

Where; T = Temperature in °C.
LnR = Natural Log of Thermistor Resistance
$A = 1.4051 \times 10^{-3}$ (coefficients calculated over the −50 to +150° C. span)
$B = 2.369 \times 10^{-4}$
$C = 1.019 \times 10^{-7}$

Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp
201.1K	-50	16.60K	-10	2417	+30	525.4	+70	153.2	+110
187.3K	-49	15.72K	-9	2317	31	507.8	71	149.0	111
174.5K	-48	14.90K	-8	2221	32	490.9	72	145.0	112
162.7K	-47	14.12K	-7	2130	33	474.7	73	141.1	113
151.7K	-46	13.39K	-6	2042	34	459.0	74	137.2	114
141.6K	-45	12.70K	-5	1959	35	444.0	75	133.6	115
132.2K	-44	12.05K	-4	1880	36	429.5	76	130.0	116
123.5K	-43	11.44K	-3	1805	37	415.6	77	126.5	117
115.4K	-42	10.86K	-2	1733	38	402.2	78	123.2	118
107.9K	-41	10.31K	-1	1664	39	389.3	79	119.9	119
101.0K	-40	9796	0	1598	40	376.9	80	116.8	120
94.48K	-39	9310	+1	1535	41	364.9	81	113.8	121
88.46K	-38	8851	2	1475	42	353.4	82	110.8	122
82.87K	-37	8417	3	1418	43	342.2	83	107.9	123
77.66K	-36	8006	4	1363	44	331.5	84	105.2	124
72.81K	-35	7618	5	1310	45	321.2	85	102.5	125
68.30K	-34	7252	6	1260	46	311.3	86	99.9	126
64.09K	-33	6905	7	1212	47	301.7	87	97.3	127
60.17K	-32	6576	8	1167	48	292.4	88	94.9	128
56.51K	-31	6265	9	1123	49	283.5	89	92.5	129
53.10K	-30	5971	10	1081	50	274.9	90	90.2	130
49.91K	-29	5692	11	1040	51	266.6	91	87.9	131
46.94K	-28	5427	12	1002	52	258.6	92	85.7	132
44.16K	-27	5177	13	965.0	53	250.9	93	83.6	133
41.56K	-26	4939	14	929.6	54	243.4	94	81.6	134
39.13K	-25	4714	15	895.8	55	236.2	95	79.6	135
36.86K	-24	4500	16	863.3	56	229.3	96	77.6	136
34.73K	-23	4297	17	832.2	57	222.6	97	75.8	137
32.74K	-22	4105	18	802.3	58	216.1	98	73.9	138
30.87K	-21	3922	19	773.7	59	209.8	99	72.2	139
29.13K	-20	3748	20	746.3	60	203.8	100	70.4	140
27.49K	-19	3583	21	719.9	61	197.9	101	68.8	141
25.95K	-18	3426	22	694.7	62	192.2	102	67.1	142
24.51K	-17	3277	23	670.4	63	186.8	103	65.5	143
23.16K	-16	3135	24	647.1	64	181.5	104	64.0	144
21.89K	-15	**3000**	**25**	624.7	65	176.4	105	62.5	145
20.70K	-14	2872	26	603.3	66	171.4	106	61.1	146
19.58K	-13	2750	27	582.6	67	166.7	107	59.6	147
18.52K	-12	2633	28	562.8	68	162.0	108	58.3	148
17.53K	-11	2523	29	543.7	69	157.6	109	56.8	149
								55.6	150

Table B-1 Thermistor Resistance versus Temperature

APPENDIX C 6150B STANDARD ANALOG ADDRESSABLE SYSTEMS

Description:

The standard 6150B standard analog addressable system incorporates a Distributed Multiplexer Circuit Board that allows multiple MEMS type Tiltmeters, uniaxial or biaxial, to be connected as "drops" off of a single bus.

The Inclinometer "string" is addressed via ENABLE and CLOCK signals in the same manner as the Geokon Model 8032-16 Channel Multiplexer.

The addressable Inclinometer string is "enabled" by raising the appropriate Datalogger Control Port to 5V. After the string has been enabled, a delay of 125 mS is required before executing the 1st of the two clock pulses required to activate the 1st channel. Once the channel is selected, a delay of 100 mS is required for the sensor to warm-up. The sensor's A-axis is read 100 times and then the average of these readings is stored. The sensors B-axis is then read. Finally, the sensor's thermistor is read through a bridge completion circuit and the temperature is calculated using a polynomial formula. Examples of CRBASIC programming can be found in Appendix F.

Wiring:

06-312V0 Cable Color	Connector Pin Designation	Addressable MEMS System (Logic Level Style)
Yellow	A	A-axis Output Differential +
Yellow's Black	B	A-axis Output Differential -
Brown	C	B-axis Output Differential +
Brown's Black	D	B-axis Output Differential -
Red	E	12VDC
Red's Black	F	Ground
White	G	Reset
White's Black	H	Ground
Green	J	Clock
Green's Black	K	Ground
Blue	L	Thermistor*
Blue's Black	M	Thermistor*
Bare	P	Shield

Table D-1 Addressable MEMS (Logic Level Style) Wiring

* 1K and 5K precision resistors are used to complete the thermistor bridge circuit:

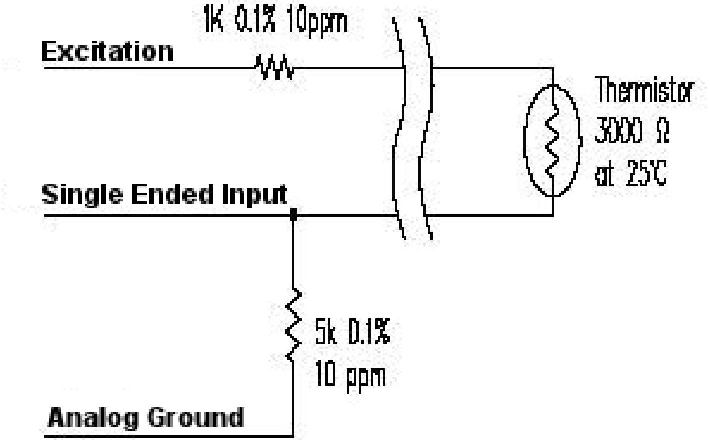


Figure D-1 Thermistor Bridge Circuit

Specifications for Addressable System (Logic Level Style) Circuit Board:

Board Dimensions:	4.5”(L) x 1.155”(W) x 0.4”(H)
Power Requirements:	+12V (+/- 3V) 35mA (max) when active 70uA (max) standby
Operating Temperature:	-20 to +70° C
Contact Resistance:	100 mΩ (typ)
Contact Breakdown Voltage:	1500 Vrms
Relay open/close time:	4mS (max)

APPENDIX D CRBASIC PROGRAMMING

Programming the 6150B Standard Analog Addressable MEMS IPI with CRBASIC

Description:

CRBASIC is the programming Language used with Campbell Scientific CRBASIC Dataloggers. Campbell's Loggernet Software is typically used when programming in CRBASIC. The MEMS sensor should be read with the VoltDiff instruction and the output averaged 100x.

Sample Program:

The following sample program reads 6 addressable uniaxial MEMS Gages and Thermistors. The A-Axis is read on Differential Channel 1, the Thermistors are read with Single Ended Channel 5 and the bridge excited with VX1. The string is enabled with Control Port 1 and clocked with control port 8. A bridge completion circuit must be used to read Thermistors.

```
'Reads 1 uniaxial MEMS string with 6 Gages and 6 Thermistors

'Declare Public Variables for all gages and calculations

Public MEMS_1
Public MEMS_2
Public MEMS_3
Public THERM_1
Public THERM_2
Public THERM_3
Public Reading_IPI_1(6)  'IPI String Reading for 6 Gages
Public Reading_THERM_1(6)  'Thermistor Readings for 6 Gages

'Declare Constants for Thermistor Readings
'Coefficients for Steinhart-Hart equation

Const A = .0014051
Const B = .0002369
Const C = .0000001019

'Counter

Dim i

'Store MEMS outputs and Thermistors every Scan

DataTable (MEMS_IPI,1,-1)

Sample (6,Reading_IPI_1(),IEEE4)
Sample (6,Reading_THERM_1(),IEEE4)

EndTable
```

```
BeginProg

'30 second scan interval

Scan (30,sec,0,0)

'Enable String using C1

PortSet(1,1)
'Delay
Delay(0,125,MSEC)

'Counter to loop 6 times

For i = 1 To 6

'1st clock using C8 (there is two clock pulses required for each gage)

PortSet(8,1)
Delay(0,10,MSEC)
PortSet(8,0)
Delay(0,10,MSEC)

'Read the A-axis
'Reset the temporary storage location for the 100 average readings

MEMS_3 = 0

'Counter to take 100 readings

For MEMS_1 = 1 To 100

'Differential voltage measurement on Differential Channel 1

VoltDiff (MEMS_2,1,mV5000,1,False,0,1000,0.001,0)

'Take the average
'Sum the readings

MEMS_3 = MEMS_3 + MEMS_2
Next




         'Calculate the Average reading value out of 100 readings
```

```
Reading_IPI_1(i) = MEMS_3 / 100

'Thermistor Reading

BrHalf(THERM_1,1,mV2500,5,VX1,1,2500,0,1000,250,2.5,0.0)

'Calculate the temperature

THERM_2 = THERM_1 / 5000
THERM_3 = (2.5 - (THERM_2*1000) - THERM_1)/THERM_2
Reading_THERM_1(i) = (1/(A+B*LN(THERM_3)+C*(LN(THERM_3))^3)-273.15)

'2nd clock using C8 to advance to next gage and thermistor

PortSet(8,1)
Delay(0,10,MSEC)
PortSet(8,0)
Delay(0,10,MSEC)

'Next channel counter

Next i

'Disable string

PortSet (1,0)

'Store Data for the IPI string

CallTable MEMS_IPI

NextScan
EndProg
```