GEOKON

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*Instruction Manual*

# Model 6300

## Vibrating Wire In-Place Inclinometer


(Doc Rev P, 11/11)

## Warranty Statement

Geokon, Inc. 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 which wear or which are damaged by misuse are not warranted. This includes fuses and batteries.

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## 1. INTRODUCTION

The Geokon Model 6300 Vibrating Wire 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.
See Figure 1.

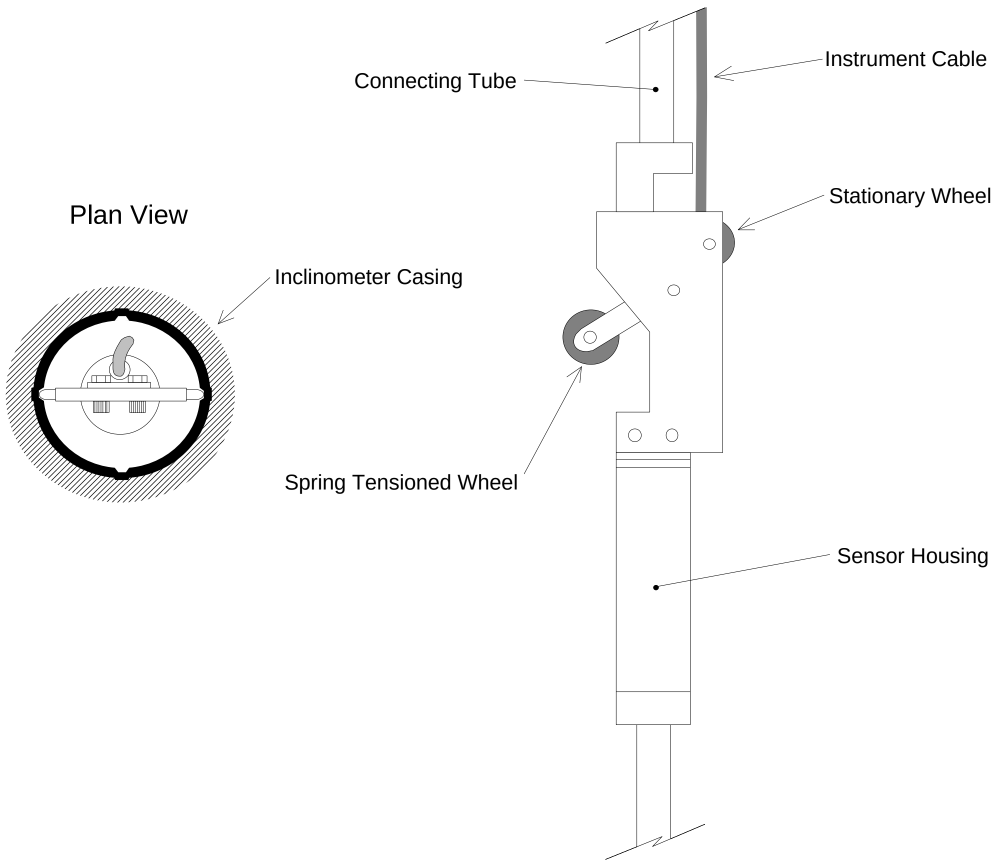



Figure 1 - Model 6300 Tilt Sensor Assembly

## 1.1. Tilt Sensor Construction

The sensor comprises a pendulous mass which is supported by a vibrating wire strain gage and an elastic hinge. See Figure 2. The strain gage senses the changes in force caused by rotation of the center of gravity of the mass. The mass and sensor are enclosed in a waterproof housing which includes components for connecting the sensor to wheel assemblies and/or other sensors. The wheel assemblies centralize the sensors and allow the assembly to be lowered into the casing. Swivel joints are included to prevent the wheel assemblies from running out of the casing grooves due to spiral problems. Stainless steel tubing is used to connect the transducer and wheel assemblies together, and the whole string is normally supported from the top of the casing. Biaxial systems use two transducers mounted at 90° to each other.

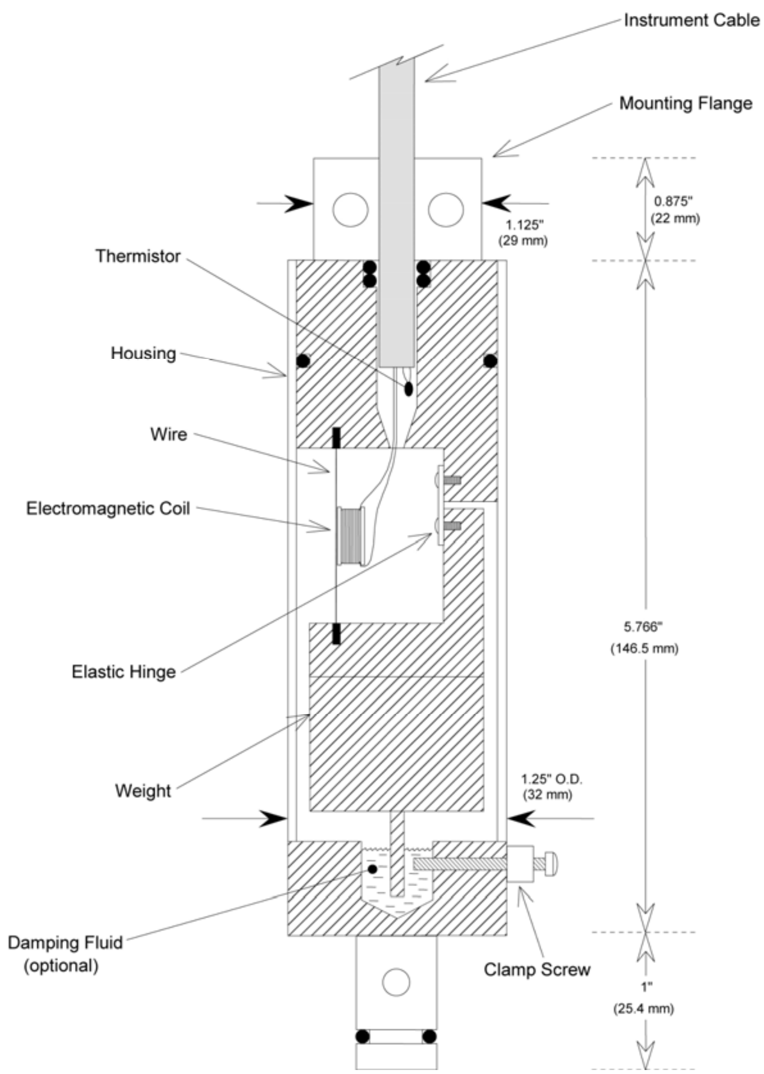



Figure 2 - Model 6300 Tilt Sensor

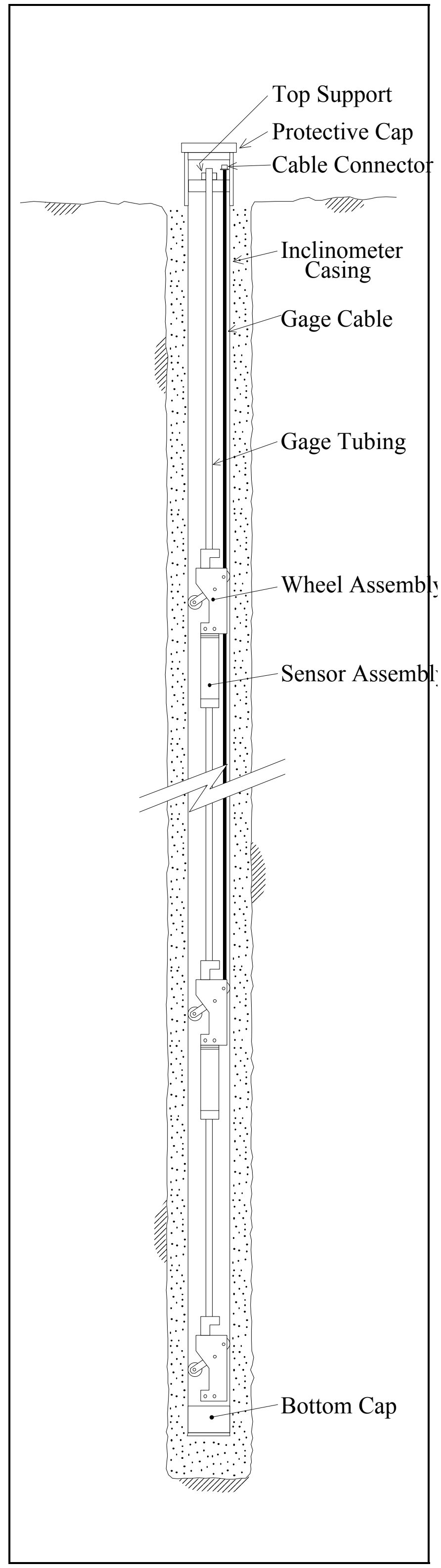
**To prevent damage during shipment the tilt sensors are locked in place by means of a locking clamp screw. This slotted-head clamp screw must be removed and replaced by a Phillips-head seal screw, (provided in the zip-lock bag), to render the tiltmeter operative.**

# 2. INSTALLATION

## 2.1. Preliminary Tests

Prior to installation, the sensors need to be checked for proper operation. Each tilt sensor is supplied with a calibration sheet that shows the relationship between readout digits and inclination. The tilt sensor electrical leads (usually the red and black leads) are connected to a readout box (see section 3) and the current reading compared to the calibration readings. After backing-off the clamp screw 3 full turns, carefully position the sensor against a vertical surface and observe the reading. It will take a few seconds to come to equilibrium and the sensor must be held in a steady position. The readings should be within +/- 200 digits of the factory reading, re-tighten the clamp screw 3 turns.

**Note: Vibrating wire tilt sensors are shock sensitive and severe shocks can cause a permanent offset or even break the suspension. (The unit will not survive a 2 ft. (.5 m) drop onto a hard surface). When transporting the tiltmeter tighten the locking clamp screw.**




Checks of electrical continuity can also be made using an ohmmeter. Resistance between the gage leads should be approximately 180 Ω, ±10 ohms. Remember to add cable resistance when checking (22 AWG stranded copper leads are approximately 14.7Ω/1000' or 48.5Ω/km, multiply by 2 for both directions). Between the green and white should be approximately 3000 ohms at 25° (see Table B-1), and between any conductor and the shield should exceed 2 megohm.

## 2.2. Model 6300 Assembly and Installation

1. Connect the safety cable to the bottom wheel assembly. (See Figure 3) 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 anchor is labeled and 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 anchor to the first tube section. This is shown in Figure 3. The cable eyebolt is trapped between two nuts.

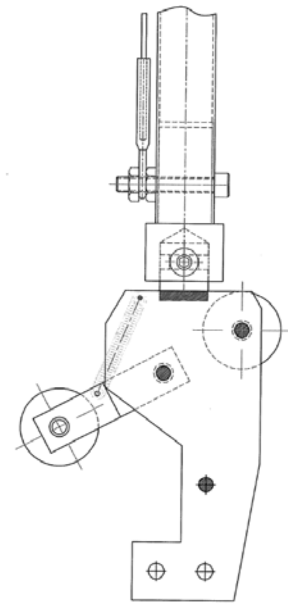


Figure 3. Bottom Wheel Assembly with Safety Cable

2. Connect the first length of gage tubing to the bottom wheel assembly. The length of tube is shown in the table supplied with this manual. (In some cases, two tubes are joined together by a special union.) Use the 10-32 screws and nuts, and a thread locking cement to make this joint.

3. The next step is to attach the uniaxial or biaxial sensor assembly.

### 2.2.1. Uniaxial System

The uniaxial sensor is delivered unattached to its wheel assembly and should be attached using the two 10-32 nuts and cap screws supplied. 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 in digits.

**Vibrating wire tilt sensors are shipped with a clamp screw holding the internal pendulum mechanism so that it is not damaged in shipment. A label is attached to each sensor emphasizing the importance of removing the slotted-head clamp screw completely and replacing it with the Phillips-head seal screw taped to the sensor. (Extra seal screws are provided in a zip-lock bag along with other accessories in case some become lost). This is very important for the sensor to be able to respond to tilting and remain waterproof.**

The sensor and wheel assembly is now attached to the first tube section using a single long 10-32 capscrew. (Use Loctite222 on all threads)

### 2.2.2. Biaxial System

The biaxial sensors are delivered unattached to the wheel assembly and to each other. The upper sensor should be attached to the wheel assembly using the two 10-32 nuts and cap screws supplied. 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 in digits).

The adaptor piece is now bolted to the bottom of the sensor using a single 10-32 cap screw and thread locking compound (Loctite 222)

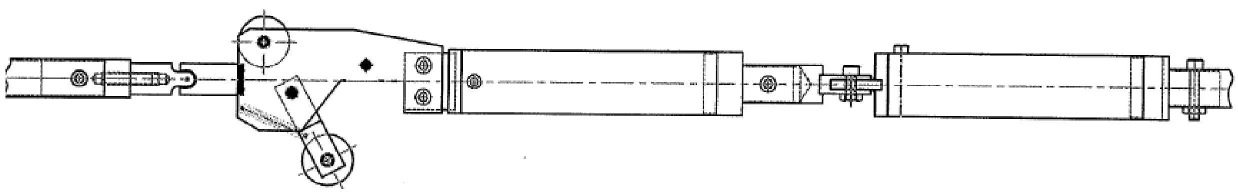


Figure 4. Biaxial sensor assembly

Two short cap screws are used to attach the lower sensor via this adaptor with its positive direction (Marked A+ on the sensor body) at 90° clockwise from the upper sensor (in plan looking down the casing). This will be the B+ direction. See Figure 5.

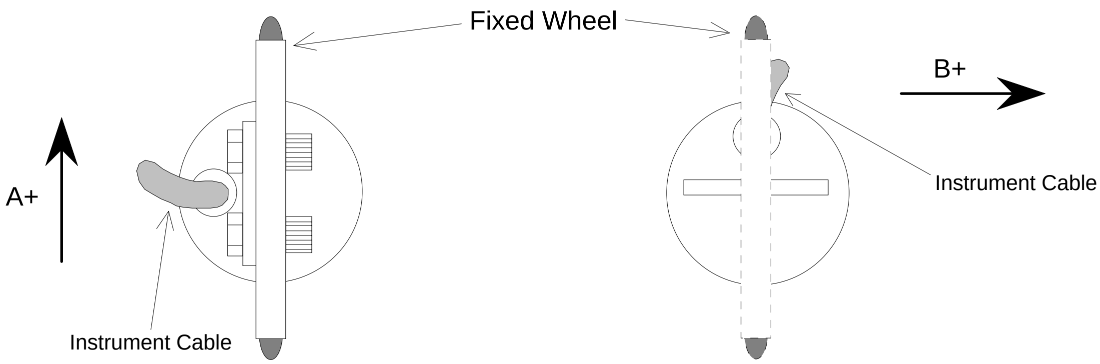



Figure 5 - Biaxial Sensor Orientation

Note that there is some clearance around the bolt holes which will allow for some manual alignment of the sensors (absolute alignment is not critical).

When the two sensors are connected, the lower one is joined to the previously prepared gage tube. **Vibrating wire tilt sensors are shipped with a clamp screw holding the internal pendulum mechanism so that it is not damaged in shipment. A label is attached to each sensor emphasizing the importance of removing the slotted-head clamp screw completely and replacing it with the Phillips-head seal screw taped to the sensor. (Extra seal screws are provided in a zip-lock bag along with other accessories in case some become lost). This is very important for the sensor to be able to respond to tilting and remain waterproof.**

This assembly is now lowered into the borehole, using the safety cable, with the upper assembly 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. Be sure that the lower wheel assembly and swivel are also aligned this way.

While holding the assembly at the top of the casing, using either the safety cable or vice grips on the tubing, the next segment with sensors, wheels and swivel are attached and lowered in the same orientation. The system can become quite heavy and a clamp of some sort may need to be used to hold the rods in place while being assembled. The use of a winch to hold the safety cable can be a help. Note that the longer cables are on reels to facilitate handling. Something like two little saw horses (or even folding chairs) with a broom stick across them to act as an axle will allow the cable to spool off as needed and provide a storage point for the rest of the cable.

The cables from the lower sensors should be taped or tie-wrapped to the assembly at intervals to support them as the system is built up and lowered down the borehole.

Continue to add gage tubing, sensors and wheel assemblies until the last sensor has been attached to the upper wheel assembly, which is pre-assembled to the top suspension. (See figure 6). The Top suspension can then lowered into position on the casing. It is important that the end of the casing be cut square to prevent any side pressure on the upper sensor wheel assembly.

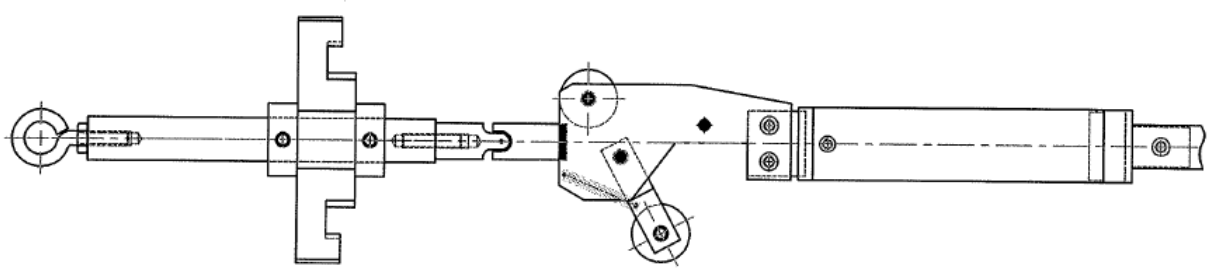


Figure 6 Top Suspension

After the sensor string has been 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 or otherwise fixed. Readings should be taken immediately after installation, but it is recommended that the system be allowed to stabilise for a few hours before recording zero conditions.

For IPI strings that are going to measure only across a subsurface zone of interest and will not reach the surface, the cross-piece of the top suspension is omitted and the IPI string is suspended at the proper depth by a length of aircraft cable, attached to the eyebolt, and tied off at the top of the casing.

## 2.3. Fluid Damping

The vibrating wire tilt sensor acts as a self-damping system when used in vibration free environments. When external ground or structural vibrations exceed a certain threshold, the pendulous mass will continue to "dither" and stable readings may not be possible. In such cases, additional damping can be achieved by adding a viscous damping fluid to a small reservoir contained in the sensor. A thin, wide "paddle" is connected to the mass and when the fluid is added the pendulum is damped by the action of the paddle in the damping fluid.

Most in-place installations will not require this fluid. However, if the instrument gives unstable outputs, or it is known that the structure is constantly vibrating, the fluid can be added. The fluid is a high-viscosity silicone oil which must be injected into the sensor with a syringe.

The sensor must be held upright during the injection of the fluid and at all times following the injection. This makes it necessary to perform this operation in the field. The following applies for a typical in-place installation.

1. After connecting the sensor to the gage tubing already in the casing, and after removal of the clamping screw, use the syringe applied, first pull the piston from the syringe and squeeze the silicone from the tube into the syringe. Replace the piston and start the silicone oil out of the "needle" end.
3. Now, inject 2.00cc into the hole in the sensor. Immediately following this operation, the seal screw should be replaced in the sensor.
4. The sensor may now be lowered into the casing.

## 2.4. Splicing and Junction Boxes

Because the vibrating wire output signal is a frequency rather than current or voltage, variations in cable resistance have little effect on gage readings and, therefore, splicing of cables has little effect and, in some case, may be beneficial. For example, if multiple sensors are installed in a borehole, and the distance from the borehole to the terminal box or datalogger is great, a splice could be made to connect the individual cables to a single multi-conductor cable. This multiconductor cable would then be run to the readout station. For such installations it is recommended that the transducer be supplied with enough cable to reach the top of the casing plus enough extra to make splicing possible.

The cable used for making splices should be a high quality twisted pair type with 100% shielding (with integral shield drain wire). When splicing, it is very important that the shield drain wires be spliced together! Splice kits recommended by Geokon (i.e. 3M Scotchcast™, model 82-A1) incorporate casts placed around the splice then filled with epoxy to waterproof the connections. When properly made, this type of splice is equal or superior to the cable itself in strength and electrical properties. Contact Geokon for splicing materials and additional cable splicing instructions.

Junction boxes and terminal boxes are available from Geokon for all types of applications. In addition, portable readout equipment and datalogging hardware are available. Contact Geokon for specific application information.

## 3. TAKING READINGS

### 3.1. Operation of the GK-403 Readout Box

The GK-403 can store gage readings and also apply calibration factors to convert readings to engineering units. Consult the GK-403 Instruction Manual for additional information on Mode "G" of the Readout. The following instructions will explain taking gage measurements using Mode "B".

Connect the Readout using the flying leads or in the case of a terminal station, with a connector. The red and black clips are for the vibrating wire gage, the white and green clips are for the thermistor and the blue for the shield drain wire.

1. Turn the display selector to position "B". Readout is in digits (Equation 1).

2. Turn the unit on and a reading will appear in the front display window. The last digit may change one or two digits while reading. Press the "Store" button to record the value displayed. If the no reading displays or the reading is unstable see section 5 for troubleshooting suggestions. The thermistor will be read and output directly in degrees centigrade.

3. The unit will automatically turn itself off after approximately 2 minutes to conserve power.

### 3.2 Operation of the GK404 Readout Box

The GK404 is a palm sized readout box which displays the Vibrating wire value and the temperature in degrees centigrade.
The GK-404 Vibrating Wire Readout arrives with a patch cord for connecting to the vibrating wire gages. One end will consist of a 5-pin plug for connecting to the respective socket on the bottom of the GK-404 enclosure. The other end will consist of 5 leads terminated with alligator clips. Note the colors of the alligator clips are red, black, green, white and blue. The colors represent the positive vibrating wire gage lead (red), negative vibrating wire gage lead (black), positive thermistor lead (green), negative thermistor lead (white) and transducer cable drain wire (blue). The clips should be connected to their respectively colored leads from the vibrating wire gage cable.

Use the **POS** (Position) button to select position **B** and the MODE button to select **Dg** (digits). Other functions can be selected as described in the GK404 Manual.

The GK-404 will continue to take measurements and display the readings until the OFF button is pushed, or if enabled, when the automatic Power-Off timer shuts the GK-404 off.
The GK-404 continuously monitors the status of the (2) 1.5V AA cells, and when their combined voltage drops to 2V, the message **Batteries Low** is displayed on the screen. A fresh set of 1.5V AA batteries should be installed at this point

## 3.3. MICRO-10 Datalogger

The following parameters are recommended when using the Model 6350 with the MICRO-10 datalogger or any other CR10 based datalogger:

*Excitation* - The 2.5V excitation directly off the wiring panel is ideal for these sensors. The 5 volt supply from the AVW-1 and AVW-4 modules is also usable, but the 12V excitation should be avoided as it tends to overdrive the sensor. The default excitation voltage used in MICRO-10 systems is 5V.

*Excitation Frequency* - The starting and ending frequencies of the excitation sweep should be kept in a relatively narrow band for these sensors to maximize the stability and resolution of the output. The exact values can be calculated for a given sensor from the supplied calibration sheet. Ideally one could calculate settings by taking an initial reading and then setting the starting frequency to 200 Hz below and the ending frequency 200 Hz above. Alternately, the low end frequency sweep setting should be set to 14 (1400 Hz), the high end, 35 (3500 Hz).

## 3.4. Measuring Temperature

Each vibrating wire tilt sensor is equipped with a thermistor for reading temperature. The thermistor gives a varying resistance output as the temperature changes. Usually the white and green leads are connected to the internal thermistor.

1. If using an ohmmeter, connect an ohmmeter to the two thermistor leads coming from the tilt sensor. (Since the resistance changes with temperature are so large, the effect of cable resistance is usually insignificant.)

2. Look up the temperature for the measured resistance in Table B-1. Alternately the temperature could be calculated using Equation B-1.

Note: The GK-403 and the Gk 404 readout boxes will read the thermistor and display temperature in °C automatically.

## 4. DATA REDUCTION

### 4.1. Inclination Calculation

Inclinations are measured in digits on Position B on the GK-401, GK-403 or GK404 Readout Box. The output of the VW tilt sensor is proportional to the sine of the angle of tilt. For small angles θ and sinθ are the same, so the relationship between output digits and the amount of tilting, (change of the angle of inclination), **Δθ,** is given by the equation:

$$\Delta\theta = \Delta\sin\theta = (R_1 - R_0)\,G \quad \text{degrees tilt}$$

Equation 1 Calculation of Tilt (Linear).

Where: $R_1$ is the current reading in digits
$R_o$ is the initial reading in digits
and G is the Linear Gage Factor in degrees tilt/digit given on the Calibration Sheet supplied with the sensor.

The linear equation works very well for inclinations of less than four degrees. More than this and the linearity errors start to increase beyond 0.5%FS. The error incurred by using the linear equation is shown on the calibration chart.
For better accuracy at larger inclinations use the polynomial equation: This uses a second order curve to approximate the sine curve.

$$\theta = R^2A + RB + C \quad \text{degrees tilt}$$

Equation 2 Calculation of Tilt (Polynomial).

Where A, B and C are the coefficients supplied on the calibration sheet. Calculate $\theta_1$ by substituting $R = R_1$ in the formula and then calculate $\theta_0$ by substituting $R = R_0$ then subtract to find the difference $\Delta\theta = (\theta_1 - \theta_0)$.

### 4.2. Temperature Correction

The Model 6350 Tiltmeter has a slight temperature sensitivity on the order of -0.5 digit per °C rise, i.e. the reading falls by 0.5 digits for every 1°C rise of temperature. The temperature correction is:

$$+0.5G(T_1 - T_0) \quad \text{degrees tilt}$$

Equation 3 Temperature Correction

Normally, corrections are not applied for this small effect because the structure being monitored usually is affected to a much greater degree. An important point to note, also, is that sudden changes in temperature will cause both the structure and the Tiltmeter to undergo transitory physical changes that will show up in the readings. The gage temperature should always be recorded for comparison, 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

Now, the change in reading must be converted to a lateral deflection. The lateral deflection is defined as $L\sin\Delta\theta$ where L is the gage length between pivot points and $\Delta\theta$ is the change in inclination determined from Equation 3. The length $L_1$, $L_2$, $L_3$,…. etc., can be calculated by adding **311mm**,(uniaxial systems) or **524mm**, (biaxial system), to the individual lengths of tubing. This will give the correct distance between pivot points.
The horizontal displacement profile can be constructed by using the cumulative sum of the displacement starting with the bottom segment. Subsequent readings over time will reveal changes in deflection, possible shear zones, etc. For example, referring to Figure 5 and Equation 4.

$$\mathbf{D_1 = L_1\,\Delta sin\theta_1}$$
$$\mathbf{D_2 = L_1\,\Delta sin\theta_1 + L_2\,\Delta sin\theta_2}$$
$$\mathbf{D_3 = L_1\,\Delta sin\theta_1 + L_2\,\Delta sin\theta_2 + L_3\,\Delta sin\theta_3}$$
$$\mathbf{D_4 = L_1\,\Delta sin\theta_1 + L_2\,\Delta sin\theta_2 + L_3\,\Delta sin\theta_3 + L_4\,\Delta sin\theta_4}$$
$$\mathbf{D_5 = L_1\,\Delta sin\theta_1 + L_2\,\Delta sin\theta_2 + L_3\,\Delta sin\theta_3 + L_4\,\Delta sin\theta_4 + L_5\,\Delta sin\theta_5}$$

Where, for small angles $\mathbf{\Delta sin\theta = (R_1 - R_0)\ G}$

Equation 4 – Horizontal Displacement Calculation

Although the system is designed for use with continuous segments and pivots, the sensors can be installed without interconnecting tubing in standard, round tubing or pipe using special friction anchoring. In those systems, the assumption is made that the measured deflection occurs over the segment length and that L is the distance between sensors.

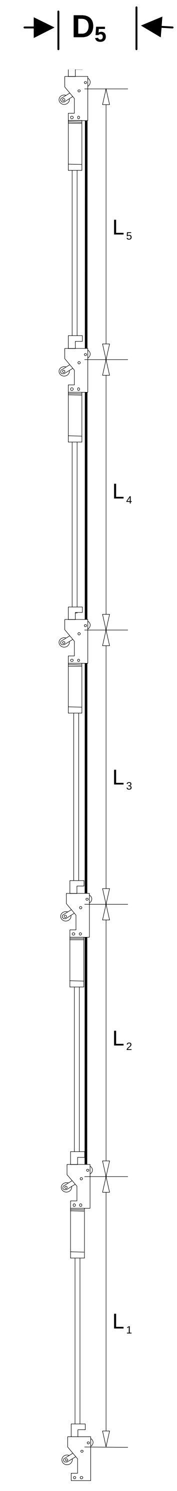


Figure 7 - Deflection Intervals

## 4.4. 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 a 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.

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## Vibrating Wire Tilt Sensor Calibration

Model Number: 6300 Series | Calibration Date: April 26, 2004

Serial Number: 04-4472 | Temperature: 22.9 °C

Cal. Std. Control #(s): 406, 213, 260, 189, 524, 529, 333 | Technician:

| Inclination | Inclination | * Reading 1st Cycle | * Reading 2nd Cycle | * Average Reading | Error (%FS) | |
|---|---|---|---|---|---|---|
| (sin) | (degrees) | (digits) | (digits) | (digits) | Linear | Polynomial |
| 0.0867 | 4.972 | 10469 | 10470 | 10470 | -0.31 | 0.01 |
| 0.0667 | 3.823 | 9910 | 9912 | 9911 | -0.20 | 0.01 |
| 0.0533 | 3.057 | 9540 | 9540 | 9540 | -0.10 | -0.02 |
| 0.0349 | 1.998 | 9023 | 9022 | 9023 | -0.05 | -0.01 |
| 0.0175 | 1.003 | 8535 | 8535 | 8535 | -0.03 | 0.00 |
| 0.0087 | 0.497 | 8285 | 8287 | 8286 | -0.04 | 0.02 |
| 0.0042 | 0.241 | 8161 | 8162 | 8162 | -0.01 | 0.00 |
| 0.0000 | 0.000 | 8044 | 8044 | 8044 | 0.00 | -0.01 |
| -0.0042 | -0.241 | 7926 | 7923 | 7925 | -0.03 | 0.01 |
| -0.0087 | -0.497 | 7800 | 7800 | 7800 | 0.00 | -0.01 |
| -0.0175 | -1.003 | 7551 | 7551 | 7551 | -0.01 | -0.01 |
| -0.0349 | -1.998 | 7059 | 7058 | 7059 | -0.09 | 0.03 |
| -0.0533 | -3.057 | 6537 | 6536 | 6537 | -0.14 | 0.00 |
| -0.0667 | -3.823 | 6159 | 6158 | 6159 | -0.18 | -0.02 |
| -0.0867 | -4.972 | 5587 | 5587 | 5587 | -0.33 | 0.00 |

*Readings displayed in GK-401 Position B.

**Linear Gage Factor (G): 0.002037 (degrees/ digit)**

**Polynomial Gage Factors: A: 5.084E-09 B: 1.955E-03 C: -16.053**

**Calculated Angle (degrees): Linear, $q = G(R_1 - R_0)+K(T_1-T_0)$**

**Polynomial, $q = AR^2 + BR + C$**

Wiring Code: Red and Black: Gage White and Green: Thermistor Bare: Shield

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 7 - Sample Model 6300 Calibration Sheet

## 5. TROUBLESHOOTING

Maintenance and troubleshooting of the vibrating wire tilt sensors used in the Model 6300 Inclinometer are is confined to periodic checks of cable connections. The sensors are sealed and there are no user-servicable 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 the readout box position set correctly? If using a datalogger to record readings automatically are the swept frequency excitation settings correct? Channel A of the GK-401 and GK-403 can be used to read the tilt sensor. To convert the Channel A period display to digits use Equation 1.
- ✓ 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 whether using a portable readout or datalogger. If using the GK-401 Readout connect the clip with the green boot to the bare shield drain wire of the tilt sensor cable. If using the GK-403 connect the clip with the blue boot to the shield drain wire.
- ✓ Does the readout work with another tilt sensor? If not, the readout may have a low battery or be malfunctioning.

***Symptom: Tilt Sensor Fails to Read***

- ✓ Is the cable cut or crushed? This can be checked with an ohmmeter. Nominal resistance between the two gage leads (usually red and black leads) is 180Ω, ±10Ω. Remember to add cable resistance when checking (22 AWG stranded copper leads are approximately 14.7Ω/1000' or 48.5Ω/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 readout or datalogger work with another tilt sensor? If not, the readout or datalogger may be malfunctioning.

***Symptom: Thermistor resistance is too high.***

- ✓ Is there an open circuit? Check all connections, terminals and plugs. If a cut is located in the cable, splice according to instructions in Section 2.3.

***Symptom: Thermistor resistance is too low.***

- ✓ Is there a short? Check all connections, terminals and plugs. If a short is located in the cable, splice according to instructions in Section 2.3.
- ✓ Water may have penetrated the interior of the tilt sensor. There is no remedial action.

APPENDIX A - SPECIFICATIONS

## A.1. Vibrating Wire Tilt Sensor

| Model: | 6300 |
|---|---|
| Range:[1] | ±10° |
| Resolution:[2] | 8 arc seconds |
| Accuracy:[3] | +/- 8 arc seconds |
| Linearity: [4] | +/- 0.3% FSR |
| Thermal Zero Shift: | ± 4 arc seconds/°C |
| Operating Temperature | -40 to +80° C<br>-40 to 175° F |
| Operating Frequency: | 1400-3500 Hz |
| Coil Resistance: | 180 Ω |
| Diameter: | 1.250", 32 mm |
| Length: | 7.375", 187 mm |
| Weight: | 1.5 lbs., 0.7 kg. |
| Materials: | 304 Stainles Steel |
| Electrical Cable: | 2 twisted pair (4 conductor) 22 AWG<br>Foil shield, PVC jacket, nominal OD=6.3 mm (0.250") |

Table A-1 Model 6300 Tilt Sensor Specifications

Notes:
[1] Consult the factory for other ranges.
[2] Depends on readout equipment. With averaging techniques it is possible to achieve 1 arc seco
[3] Derived using 2nd order polynomial.
[4] The output from the sensor is proportional to the sine of the angle of tilt

## A.2. Thermistor (see Appendix B also)

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:**

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

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 - EXCITATION AND READOUT PARAMETERS

**Model 6300 with Micro-10 Datalogger**

The Micro-10 Datalogger which uses the Campbell Scientific Measurement and Control Module can be used to continuously monitor the Model 6300.

The following parameters are recommended:

**Excitation**

The 2.5 volt excitation directly off the wiring panel is ideal for these sensors. The 5 volt supply from the AVW-1 and AVW-4 modules is also usable, but the 12 volt excitation should be avoided as it tends to overdrive the sensor.

**Excitation Frequency**

The starting and ending frequencies of the excitation sweep should be kept in a relatively narrow band for these sensors to maximize the stability and resolution of the output.

The frequency band for the full range is shown on the calibration sheets.

The frequencies can be determined from these. The highest and lowest frequencies shown can be used to determine the sweep parameters. After initial readings are obtained, parameters should be set to 200 Hz below the resonant frequency and 1-200 Hz above.

**Offset**

In order to maximize the 5 digit, high resolution output, the offset parameter can be used to remove the zero offset of the sensor.

In other words, if the installed reading is 4,300, the offset parameter could be set at -4300 which would theoretically change the resolution from 0.1 digit to 0.0001 digit.

For assistance in programming these parameters contact Geokon, Inc.

## Appendix D - Addressable Systems

The Addressable system allows all the borehole sensors to be connected to a single cable rather than have a separate cable for each sensor. The sensors are supplied in a string connected together by pre-determined lengths of cables specified by the customer.
The string of sensor is installed in a manner to that described in Section 2.
The cable is connected, via a 15 pin connector, to a special Geokon Model 8021-1X datalogger modified, by the addition of a Model 8031 Distributed Multiplexer, specifically for use with the addressable system

### Using the 8031 Distributed Multiplexer

***Description:***

The 8031 Distributed Multiplexer is a device that allows up to 256 individual VW transducers or MEMS type inclinometers (6001 or 6150) – both unidirectional and bidirectional - to be connected as "drops" off of a single bus. Each 8031 is addressed via RS-485 level ENABLE and CLOCK signals in the same manner as the Geokon model 8032 Multiplexer. Two modes of channel selection (clocking) are available:

**1) 16 channel mode** (**two clock pulses per channel**): This is the standard configuration, and uses the same ENABLE and CLOCK timing requirements as the Geokon model 8032 multiplexer in 16 channel mode.

**2) 32 channel mode (one clock pulse per channel)**. This is a custom configuration, and uses the same ENABLE and CLOCK timing requirements as the Geokon model 8032 multiplexer in 32 channel mode. Notify Geokon when ordering if this one clock pulse per channel version will be required.

The 8031 may be used with either the Micro-10 Datalogger (for both 6150/6001MEMS or VW transducers), the GK-403 VW Readout (VW transducers only) or any Data Acquisition System capable of providing the required ENABLE and CLOCK control signals. The 8031 circuit board may be mounted in the transducer housing, with its individual 1 of 256 channel address being set by on-board DIP switches. Depending on the application, a single 4, 5 or 6 twisted pair cable may be used to connect all of the 8031's and their associated transducers to the Micro-10, GK-403 or other Data Acquisition System.

The 8031 circuit board incorporates RC snubbers across the relay contacts to prevent contact arcing in power switching applications. If being used with VW, these snubber components (R3-R8 and C1-C6) will need to be removed.

***Circuit Board Connector Pin-outs:***

| Connector | Pin | Signal | Description |
|---|---|---|---|
| J2 | 1 | +12V NET | +12V Power from the bus cable (twisted pair 1) |
| | 2 | GND NET | Power Ground from the bus cable (twisted pair 1) |
| | 3 | RESET NET | RS-485 RESET from the bus cable (twisted pair 2) |
| | 4 | /RESET NET | RS-485 /RESET from the bus cable (twisted pair 2) |
| | 5 | CLOCK NET | RS-485 CLOCK from the bus cable (twisted pair 3) |
| | 6 | /CLOCK NET | RS-485 /CLOCK from the bus cable (twisted pair 3) |
| J7 | 1 | THERM+ NET | Thermistor (+) from the bus cable (twisted pair 4) |
| | 2 | THERM- NET | Thermistor (–) from the bus cable (twisted pair 4) |
| | 3 | VA+/VW1+ NET | **6001/6150 A axis (+)** or **VW1 (+)*** from the bus cable (twisted pair 5) |
| | 4 | VA- NET | **6001/6150 A axis (–)** from the bus cable (twisted pair 5) |
| | 5 | VB+/VW1- NET | **6001/6150 B axis (+)** or **VW1 (-)*** from the bus cable (twisted pair 6) |
| | 6 | VB- NET | **6001/6150 B axis (–)** from the bus cable (twisted pair 6) |

*Note: If VW is being used, combine VW1+ and VW1- into a twisted pair (twisted pair 5) – otherwise combine VA+/VA- into a twisted pair (twisted pair 5) and VB+/VB- into a twisted pair (twisted pair 6).

| Connector | Pin | Signal | Description |
|---|---|---|---|
| J10 | 1 | VW2+ NET | **VW2 (+)** from the bus cable (twisted pair 6) |
| | 2 | VW2- NET | **VW2 (-)** from the bus cable (twisted pair 6) |
| J5 | 1 | VW1- | **Coil (-)** from VW transducer #1 |
| | 2 | VW1+ | **Coil (+)** from VW transducer #1 |
| | 3 | TH+ | **Therm (+)** from VW transducer #1 |
| | 4 | TH- | **Therm (-)** from VW transducer #1 |
| J9 | 1 | VW2- | **Coil (-)** from VW transducer #2 |
| | 2 | VW2+ | **Coil (+)** from VW transducer #2 |
| J4 | 1 | +12VX | +12V Power to 6150-2 or 6001-2 board |
| | 2 | GNDX | Power Ground to 6150-2 or 6001-2 board |
| | 3 | GNDA | Analog Ground to 6150-2 or 6001-2 board |
| | 5 | VA_IN | Channel A output from 6150-2 or 6001-2 board |
| | 6 | GNDA | Analog Ground to 6150-2 or 6001-2 board |
| J8 | 1 | +12VX | +12V Power to 6150-2 or 6001-2 board |
| | 2 | GNDX | Power Ground to 6150-2 or 6001-2 board |
| | 3 | GNDA | Analog Ground to 6150-2 or 6001-2 board |
| | 5 | VB_IN | Channel B output from 6150-2 or 6001-2 board |
| | 6 | GNDA | Analog Ground to 6150-2 or 6001-2 board |

***Circuit Board Jumper Settings:***

| Jumper | Position | Description |
|---|---|---|
| J1 & J6 | 1-2 | Use this setting for 6150 and 6001 applications (default) |
| | 3-4 | Use this setting for VW applications |

***Circuit Board DIP Switch Settings:***

| Switch | Position | Description |
|---|---|---|
| SW1 (1&2) | OFF | Removes RS-485 termination resistors from the circuit. * (default) |
| | ON | Adds RS-485 termination resistors to the circuit. * |

*Note: Keep SW1 OFF for all 8031's except the last one physically on the bus (the one furthest from the datalogger or GK-403).

SW2 Address Table: (channel 1 default)

| | **SW1 POSITION** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Channel** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
| 1 | OFF | OFF | OFF | OFF | OFF | OFF | OFF | ON |
| 2 | OFF | OFF | OFF | OFF | OFF | OFF | ON | OFF |
| 3 | OFF | OFF | OFF | OFF | OFF | OFF | ON | ON |
| 4 | OFF | OFF | OFF | OFF | OFF | ON | OFF | OFF |
| 5 | OFF | OFF | OFF | OFF | OFF | ON | OFF | ON |
| 6 | OFF | OFF | OFF | OFF | OFF | ON | ON | OFF |
| 7 | OFF | OFF | OFF | OFF | OFF | ON | ON | ON |
| 8 | OFF | OFF | OFF | OFF | ON | OFF | OFF | OFF |
| 9 | OFF | OFF | OFF | OFF | ON | OFF | OFF | ON |
| 10 | OFF | OFF | OFF | OFF | ON | OFF | ON | OFF |
| 11 | OFF | OFF | OFF | OFF | ON | OFF | ON | ON |
| 12 | OFF | OFF | OFF | OFF | ON | ON | OFF | OFF |
| 13 | OFF | OFF | OFF | OFF | ON | ON | OFF | ON |
| 14 | OFF | OFF | OFF | OFF | ON | ON | ON | OFF |
| 15 | OFF | OFF | OFF | OFF | ON | ON | ON | ON |
| 16 | OFF | OFF | OFF | ON | OFF | OFF | OFF | OFF |
| 17 | OFF | OFF | OFF | ON | OFF | OFF | OFF | ON |
| 18 | OFF | OFF | OFF | ON | OFF | OFF | ON | OFF |
| 19 | OFF | OFF | OFF | ON | OFF | OFF | ON | ON |
| 20 | OFF | OFF | OFF | ON | OFF | ON | OFF | OFF |
| 21 | OFF | OFF | OFF | ON | OFF | ON | OFF | ON |
| 22 | OFF | OFF | OFF | ON | OFF | ON | ON | OFF |
| 23 | OFF | OFF | OFF | ON | OFF | ON | ON | ON |
| 24 | OFF | OFF | OFF | ON | ON | OFF | OFF | OFF |
| 25 | OFF | OFF | OFF | ON | ON | OFF | OFF | ON |
| 26 | OFF | OFF | OFF | ON | ON | OFF | ON | OFF |
| 27 | OFF | OFF | OFF | ON | ON | OFF | ON | ON |
| 28 | OFF | OFF | OFF | ON | ON | ON | OFF | OFF |
| 29 | OFF | OFF | OFF | ON | ON | ON | OFF | ON |
| 30 | OFF | OFF | OFF | ON | ON | ON | ON | OFF |
| 31 | OFF | OFF | OFF | ON | ON | ON | ON | ON |
| 32 | OFF | OFF | ON | OFF | OFF | OFF | OFF | OFF |
| 33 | OFF | OFF | ON | OFF | OFF | OFF | OFF | ON |
| 34 | OFF | OFF | ON | OFF | OFF | OFF | ON | OFF |
| 35 | OFF | OFF | ON | OFF | OFF | OFF | ON | ON |
| 36 | OFF | OFF | ON | OFF | OFF | ON | OFF | OFF |
| 37 | OFF | OFF | ON | OFF | OFF | ON | OFF | ON |
| 38 | OFF | OFF | ON | OFF | OFF | ON | ON | OFF |
| 39 | OFF | OFF | ON | OFF | OFF | ON | ON | ON |
| 40 | OFF | OFF | ON | OFF | ON | OFF | OFF | OFF |
| 41 | OFF | OFF | ON | OFF | ON | OFF | OFF | ON |
| 42 | OFF | OFF | ON | OFF | ON | OFF | ON | OFF |
| 43 | OFF | OFF | ON | OFF | ON | OFF | ON | ON |
| 44 | OFF | OFF | ON | OFF | ON | ON | OFF | OFF |
| 45 | OFF | OFF | ON | OFF | ON | ON | OFF | ON |
| 46 | OFF | OFF | ON | OFF | ON | ON | ON | OFF |
| 47 | OFF | OFF | ON | OFF | ON | ON | ON | ON |
| 48 | OFF | OFF | ON | ON | OFF | OFF | OFF | OFF |
| 49 | OFF | OFF | ON | ON | OFF | OFF | OFF | ON |
| 50 | OFF | OFF | ON | ON | OFF | OFF | ON | OFF |
| 51 | OFF | OFF | ON | ON | OFF | OFF | ON | ON |
| 52 | OFF | OFF | ON | ON | OFF | ON | OFF | OFF |
| 53 | OFF | OFF | ON | ON | OFF | ON | OFF | ON |
| 54 | OFF | OFF | ON | ON | OFF | ON | ON | OFF |
| 55 | OFF | OFF | ON | ON | OFF | ON | ON | ON |
| 56 | OFF | OFF | ON | ON | ON | OFF | OFF | OFF |
| 57 | OFF | OFF | ON | ON | ON | OFF | OFF | ON |
| 58 | OFF | OFF | ON | ON | ON | OFF | ON | OFF |
| 59 | OFF | OFF | ON | ON | ON | OFF | ON | ON |
| 60 | OFF | OFF | ON | ON | ON | ON | OFF | OFF |
| 61 | OFF | OFF | ON | ON | ON | ON | OFF | ON |
| 62 | OFF | OFF | ON | ON | ON | ON | ON | OFF |
| 63 | OFF | OFF | ON | ON | ON | ON | ON | ON |
| 64 | OFF | ON | OFF | OFF | OFF | OFF | OFF | OFF |
| 65 | OFF | ON | OFF | OFF | OFF | OFF | OFF | ON |
| 66 | OFF | ON | OFF | OFF | OFF | OFF | ON | OFF |
| 67 | OFF | ON | OFF | OFF | OFF | OFF | ON | ON |
| 68 | OFF | ON | OFF | OFF | OFF | ON | OFF | OFF |
| 69 | OFF | ON | OFF | OFF | OFF | ON | OFF | ON |

| | SW1 POSITION | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Channel** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
| 70 | OFF | ON | OFF | OFF | OFF | ON | ON | OFF |
| 71 | OFF | ON | OFF | OFF | OFF | ON | ON | ON |
| 72 | OFF | ON | OFF | OFF | ON | OFF | OFF | OFF |
| 73 | OFF | ON | OFF | OFF | ON | OFF | OFF | ON |
| 74 | OFF | ON | OFF | OFF | ON | OFF | ON | OFF |
| 75 | OFF | ON | OFF | OFF | ON | OFF | ON | ON |
| 76 | OFF | ON | OFF | OFF | ON | ON | OFF | OFF |
| 77 | OFF | ON | OFF | OFF | ON | ON | OFF | ON |
| 78 | OFF | ON | OFF | OFF | ON | ON | ON | OFF |
| 79 | OFF | ON | OFF | OFF | ON | ON | ON | ON |
| 80 | OFF | ON | OFF | ON | OFF | OFF | OFF | OFF |
| 81 | OFF | ON | OFF | ON | OFF | OFF | OFF | ON |
| 82 | OFF | ON | OFF | ON | OFF | OFF | ON | OFF |
| 83 | OFF | ON | OFF | ON | OFF | OFF | ON | ON |
| 84 | OFF | ON | OFF | ON | OFF | ON | OFF | OFF |
| 85 | OFF | ON | OFF | ON | OFF | ON | OFF | ON |
| 86 | OFF | ON | OFF | ON | OFF | ON | ON | OFF |
| 87 | OFF | ON | OFF | ON | OFF | ON | ON | ON |
| 88 | OFF | ON | OFF | ON | ON | OFF | OFF | OFF |
| 89 | OFF | ON | OFF | ON | ON | OFF | OFF | ON |
| 90 | OFF | ON | OFF | ON | ON | OFF | ON | OFF |
| 91 | OFF | ON | OFF | ON | ON | OFF | ON | ON |
| 92 | OFF | ON | OFF | ON | ON | ON | OFF | OFF |
| 93 | OFF | ON | OFF | ON | ON | ON | OFF | ON |
| 94 | OFF | ON | OFF | ON | ON | ON | ON | OFF |
| 95 | OFF | ON | OFF | ON | ON | ON | ON | ON |
| 96 | OFF | ON | ON | OFF | OFF | OFF | OFF | OFF |
| 97 | OFF | ON | ON | OFF | OFF | OFF | OFF | ON |
| 98 | OFF | ON | ON | OFF | OFF | OFF | ON | OFF |
| 99 | OFF | ON | ON | OFF | OFF | OFF | ON | ON |
| 100 | OFF | ON | ON | OFF | OFF | ON | OFF | OFF |
| 101 | OFF | ON | ON | OFF | OFF | ON | OFF | ON |
| 102 | OFF | ON | ON | OFF | OFF | ON | ON | OFF |
| 103 | OFF | ON | ON | OFF | OFF | ON | ON | ON |
| 104 | OFF | ON | ON | OFF | ON | OFF | OFF | OFF |
| 105 | OFF | ON | ON | OFF | ON | OFF | OFF | ON |
| 106 | OFF | ON | ON | OFF | ON | OFF | ON | OFF |
| 107 | OFF | ON | ON | OFF | ON | OFF | ON | ON |
| 108 | OFF | ON | ON | OFF | ON | ON | OFF | OFF |
| 109 | OFF | ON | ON | OFF | ON | ON | OFF | ON |
| 110 | OFF | ON | ON | OFF | ON | ON | ON | OFF |
| 111 | OFF | ON | ON | OFF | ON | ON | ON | ON |
| 112 | OFF | ON | ON | ON | OFF | OFF | OFF | OFF |
| 113 | OFF | ON | ON | ON | OFF | OFF | OFF | ON |
| 114 | OFF | ON | ON | ON | OFF | OFF | ON | OFF |
| 115 | OFF | ON | ON | ON | OFF | OFF | ON | ON |
| 116 | OFF | ON | ON | ON | OFF | ON | OFF | OFF |
| 117 | OFF | ON | ON | ON | OFF | ON | OFF | ON |
| 118 | OFF | ON | ON | ON | OFF | ON | ON | OFF |
| 119 | OFF | ON | ON | ON | OFF | ON | ON | ON |
| 120 | OFF | ON | ON | ON | ON | OFF | OFF | OFF |
| 121 | OFF | ON | ON | ON | ON | OFF | OFF | ON |
| 122 | OFF | ON | ON | ON | ON | OFF | ON | OFF |
| 123 | OFF | ON | ON | ON | ON | OFF | ON | ON |
| 124 | OFF | ON | ON | ON | ON | ON | OFF | OFF |
| 125 | OFF | ON | ON | ON | ON | ON | OFF | ON |
| 126 | OFF | ON | ON | ON | ON | ON | ON | OFF |
| 127 | OFF | ON | ON | ON | ON | ON | ON | ON |
| 128 | ON | OFF | OFF | OFF | OFF | OFF | OFF | OFF |
| 129 | ON | OFF | OFF | OFF | OFF | OFF | OFF | ON |
| 130 | ON | OFF | OFF | OFF | OFF | OFF | ON | OFF |
| 131 | ON | OFF | OFF | OFF | OFF | OFF | ON | ON |
| 132 | ON | OFF | OFF | OFF | OFF | ON | OFF | OFF |
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| 134 | ON | OFF | OFF | OFF | OFF | ON | ON | OFF |
| 135 | ON | OFF | OFF | OFF | OFF | ON | ON | ON |
| 136 | ON | OFF | OFF | OFF | ON | OFF | OFF | OFF |
| 137 | ON | OFF | OFF | OFF | ON | OFF | OFF | ON |
| 138 | ON | OFF | OFF | OFF | ON | OFF | ON | OFF |
| 139 | ON | OFF | OFF | OFF | ON | OFF | ON | ON |
| 140 | ON | OFF | OFF | OFF | ON | ON | OFF | OFF |
| 141 | ON | OFF | OFF | OFF | ON | ON | OFF | ON |
| 142 | ON | OFF | OFF | OFF | ON | ON | ON | OFF |
| 143 | ON | OFF | OFF | OFF | ON | ON | ON | ON |

**SW1 POSITION**

| Channel | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 144 | ON | OFF | OFF | ON | OFF | OFF | OFF | OFF |
| 145 | ON | OFF | OFF | ON | OFF | OFF | OFF | ON |
| 146 | ON | OFF | OFF | ON | OFF | OFF | ON | OFF |
| 147 | ON | OFF | OFF | ON | OFF | OFF | ON | ON |
| 148 | ON | OFF | OFF | ON | OFF | ON | OFF | OFF |
| 149 | ON | OFF | OFF | ON | OFF | ON | OFF | ON |
| 150 | ON | OFF | OFF | ON | OFF | ON | ON | OFF |
| 151 | ON | OFF | OFF | ON | OFF | ON | ON | ON |
| 152 | ON | OFF | OFF | ON | ON | OFF | OFF | OFF |
| 153 | ON | OFF | OFF | ON | ON | OFF | OFF | ON |
| 154 | ON | OFF | OFF | ON | ON | OFF | ON | OFF |
| 155 | ON | OFF | OFF | ON | ON | OFF | ON | ON |
| 156 | ON | OFF | OFF | ON | ON | ON | OFF | OFF |
| 157 | ON | OFF | OFF | ON | ON | ON | OFF | ON |
| 158 | ON | OFF | OFF | ON | ON | ON | ON | OFF |
| 159 | ON | OFF | OFF | ON | ON | ON | ON | ON |
| 160 | ON | OFF | ON | OFF | OFF | OFF | OFF | OFF |
| 161 | ON | OFF | ON | OFF | OFF | OFF | OFF | ON |
| 162 | ON | OFF | ON | OFF | OFF | OFF | ON | OFF |
| 163 | ON | OFF | ON | OFF | OFF | OFF | ON | ON |
| 164 | ON | OFF | ON | OFF | OFF | ON | OFF | OFF |
| 165 | ON | OFF | ON | OFF | OFF | ON | OFF | ON |
| 166 | ON | OFF | ON | OFF | OFF | ON | ON | OFF |
| 167 | ON | OFF | ON | OFF | OFF | ON | ON | ON |
| 168 | ON | OFF | ON | OFF | ON | OFF | OFF | OFF |
| 169 | ON | OFF | ON | OFF | ON | OFF | OFF | ON |
| 170 | ON | OFF | ON | OFF | ON | OFF | ON | OFF |
| 171 | ON | OFF | ON | OFF | ON | OFF | ON | ON |
| 172 | ON | OFF | ON | OFF | ON | ON | OFF | OFF |
| 173 | ON | OFF | ON | OFF | ON | ON | OFF | ON |
| 174 | ON | OFF | ON | OFF | ON | ON | ON | OFF |
| 175 | ON | OFF | ON | OFF | ON | ON | ON | ON |
| 176 | ON | OFF | ON | ON | OFF | OFF | OFF | OFF |
| 177 | ON | OFF | ON | ON | OFF | OFF | OFF | ON |
| 178 | ON | OFF | ON | ON | OFF | OFF | ON | OFF |
| 179 | ON | OFF | ON | ON | OFF | OFF | ON | ON |
| 180 | ON | OFF | ON | ON | OFF | ON | OFF | OFF |
| 181 | ON | OFF | ON | ON | OFF | ON | OFF | ON |
| 182 | ON | OFF | ON | ON | OFF | ON | ON | OFF |
| 183 | ON | OFF | ON | ON | OFF | ON | ON | ON |
| 184 | ON | OFF | ON | ON | ON | OFF | OFF | OFF |
| 185 | ON | OFF | ON | ON | ON | OFF | OFF | ON |
| 186 | ON | OFF | ON | ON | ON | OFF | ON | OFF |
| 187 | ON | OFF | ON | ON | ON | OFF | ON | ON |
| 188 | ON | OFF | ON | ON | ON | ON | OFF | OFF |
| 189 | ON | OFF | ON | ON | ON | ON | OFF | ON |
| 190 | ON | OFF | ON | ON | ON | ON | ON | OFF |
| 191 | ON | OFF | ON | ON | ON | ON | ON | ON |
| 192 | ON | ON | OFF | OFF | OFF | OFF | OFF | OFF |
| 193 | ON | ON | OFF | OFF | OFF | OFF | OFF | ON |
| 194 | ON | ON | OFF | OFF | OFF | OFF | ON | OFF |
| 195 | ON | ON | OFF | OFF | OFF | OFF | ON | ON |
| 196 | ON | ON | OFF | OFF | OFF | ON | OFF | OFF |
| 197 | ON | ON | OFF | OFF | OFF | ON | OFF | ON |
| 198 | ON | ON | OFF | OFF | OFF | ON | ON | OFF |
| 199 | ON | ON | OFF | OFF | OFF | ON | ON | ON |
| 200 | ON | ON | OFF | OFF | ON | OFF | OFF | OFF |
| 201 | ON | ON | OFF | OFF | ON | OFF | OFF | ON |
| 202 | ON | ON | OFF | OFF | ON | OFF | ON | OFF |
| 203 | ON | ON | OFF | OFF | ON | OFF | ON | ON |
| 204 | ON | ON | OFF | OFF | ON | ON | OFF | OFF |
| 205 | ON | ON | OFF | OFF | ON | ON | OFF | ON |
| 206 | ON | ON | OFF | OFF | ON | ON | ON | OFF |
| 207 | ON | ON | OFF | OFF | ON | ON | ON | ON |
| 208 | ON | ON | OFF | ON | OFF | OFF | OFF | OFF |
| 209 | ON | ON | OFF | ON | OFF | OFF | OFF | ON |
| 210 | ON | ON | OFF | ON | OFF | OFF | ON | OFF |
| 211 | ON | ON | OFF | ON | OFF | OFF | ON | ON |
| 212 | ON | ON | OFF | ON | OFF | ON | OFF | OFF |
| 213 | ON | ON | OFF | ON | OFF | ON | OFF | ON |
| 214 | ON | ON | OFF | ON | OFF | ON | ON | OFF |
| 215 | ON | ON | OFF | ON | OFF | ON | ON | ON |
| 216 | ON | ON | OFF | ON | ON | OFF | OFF | OFF |
| 217 | ON | ON | OFF | ON | ON | OFF | OFF | ON |

| Channel | SW1 POSITION 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 218 | ON | ON | OFF | ON | ON | OFF | ON | OFF |
| 219 | ON | ON | OFF | ON | ON | OFF | ON | ON |
| 220 | ON | ON | OFF | ON | ON | ON | OFF | OFF |
| 221 | ON | ON | OFF | ON | ON | ON | OFF | ON |
| 222 | ON | ON | OFF | ON | ON | ON | ON | OFF |
| 223 | ON | ON | OFF | ON | ON | ON | ON | ON |
| 224 | ON | ON | ON | OFF | OFF | OFF | OFF | OFF |
| 225 | ON | ON | ON | OFF | OFF | OFF | OFF | ON |
| 226 | ON | ON | ON | OFF | OFF | OFF | ON | OFF |
| 227 | ON | ON | ON | OFF | OFF | OFF | ON | ON |
| 228 | ON | ON | ON | OFF | OFF | ON | OFF | OFF |
| 229 | ON | ON | ON | OFF | OFF | ON | OFF | ON |
| 230 | ON | ON | ON | OFF | OFF | ON | ON | OFF |
| 231 | ON | ON | ON | OFF | OFF | ON | ON | ON |
| 232 | ON | ON | ON | OFF | ON | OFF | OFF | OFF |
| 233 | ON | ON | ON | OFF | ON | OFF | OFF | ON |
| 234 | ON | ON | ON | OFF | ON | OFF | ON | OFF |
| 235 | ON | ON | ON | OFF | ON | OFF | ON | ON |
| 236 | ON | ON | ON | OFF | ON | ON | OFF | OFF |
| 237 | ON | ON | ON | OFF | ON | ON | OFF | ON |
| 238 | ON | ON | ON | OFF | ON | ON | ON | OFF |
| 239 | ON | ON | ON | OFF | ON | ON | ON | ON |
| 240 | ON | ON | ON | ON | OFF | OFF | OFF | OFF |
| 241 | ON | ON | ON | ON | OFF | OFF | OFF | ON |
| 242 | ON | ON | ON | ON | OFF | OFF | ON | OFF |
| 243 | ON | ON | ON | ON | OFF | OFF | ON | ON |
| 244 | ON | ON | ON | ON | OFF | ON | OFF | OFF |
| 245 | ON | ON | ON | ON | OFF | ON | OFF | ON |
| 246 | ON | ON | ON | ON | OFF | ON | ON | OFF |
| 247 | ON | ON | ON | ON | OFF | ON | ON | ON |
| 248 | ON | ON | ON | ON | ON | OFF | OFF | OFF |
| 249 | ON | ON | ON | ON | ON | OFF | OFF | ON |
| 250 | ON | ON | ON | ON | ON | OFF | ON | OFF |
| 251 | ON | ON | ON | ON | ON | OFF | ON | ON |
| 252 | ON | ON | ON | ON | ON | ON | OFF | OFF |
| 253 | ON | ON | ON | ON | ON | ON | OFF | ON |
| 254 | ON | ON | ON | ON | ON | ON | ON | OFF |
| 255 | ON | ON | ON | ON | ON | ON | ON | ON |
| 256 | OFF | OFF | OFF | OFF | OFF | OFF | OFF | OFF |

***Model 8031 Specifications:***

Board Dimensions: 4.5”(L) x 1.155”(W) x 0.4”(H)

Power Requirements: +12V (+/- 3V)
110mA (max) when active
700uA (max) standby

Operating Temperature: 0-70° C

Contact Resistance: 100 mΩ (typ)

Contact Breakdown Voltage: 1500 Vrms

Relay open/close time: 4mS (max)