Model 1450

DC-DC LVDT

Displacement Transducer

Instruction Manual

GEOKON®

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

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1. INTRODUCTION

GEOKON Model 1450 DC-DC Linear Variable Differential Transformer (LVDT) Displacement Transducers are designed for displacement or position measurement in dynamic and/or high-temperature applications. They utilize the Linear Variable Differential Transformer (LVDT) principle, a robust and reliable sensor type. The main benefit of LVDT transducers is that there is no electrical contact across the transducer position sensing element. This produces clean data with infinite resolution and gives the sensor a very long life. Model 1450 Transducers have all the benefits of the LVDT sensor principle with the added convenience of a DC (Direct Current) supply and output.

LVDT transducers utilize three coils: a primary coil, and two secondary coils connected in opposition. At the center of the measurement stroke, the voltages of the two secondary coils are equal, but because they are connected in opposition, the resulting output from the sensor is zero. The transfer of current between the primary and the secondary coils is controlled by the position of a magnetic core called an armature. As the armature moves away from center there is an increase in voltage in one of the secondary coils and a decrease in the other. This change in voltage is reflected in the sensor output. The sensor output can be converted to a measurement of displacement as described in Section 4. An oscillator/demodulator circuit built into the transducer supplies the excitation and converts the return signal to a DC voltage.

Model 1450 Transducers are connected to cable via a 6-pin connector, this allows the cable to easily disconnect and reconnect to the top of the transducer when necessary. An internal spring keeps tension on the bearing guided transducer shaft, pushing it outward to maintain contact with the surface being measured. This type of transducer is beneficial where it is not practical to connect the transducer shaft to the surface being measured. The Model 1450 can be used in place of, or in concert with, dial gauges to monitor displacements associated with pile load tests or used with Model 1800 Telltale systems to monitor piles or boreholes.

A side exit cable option, where the cable is spliced and permanently fixed to the side of the transducer, is also available. This style can be used in place of Model 4450 Transducers for the electronic readout of Model 1100 Extensometers.

2. APPLICATIONS

2.1 TYPICAL PILE MONITORING

Model 1450 LVDT Transducers can be used in place of or in concert with dial gauges to monitor displacements associated with pile load tests. Two configuration examples are shown below.

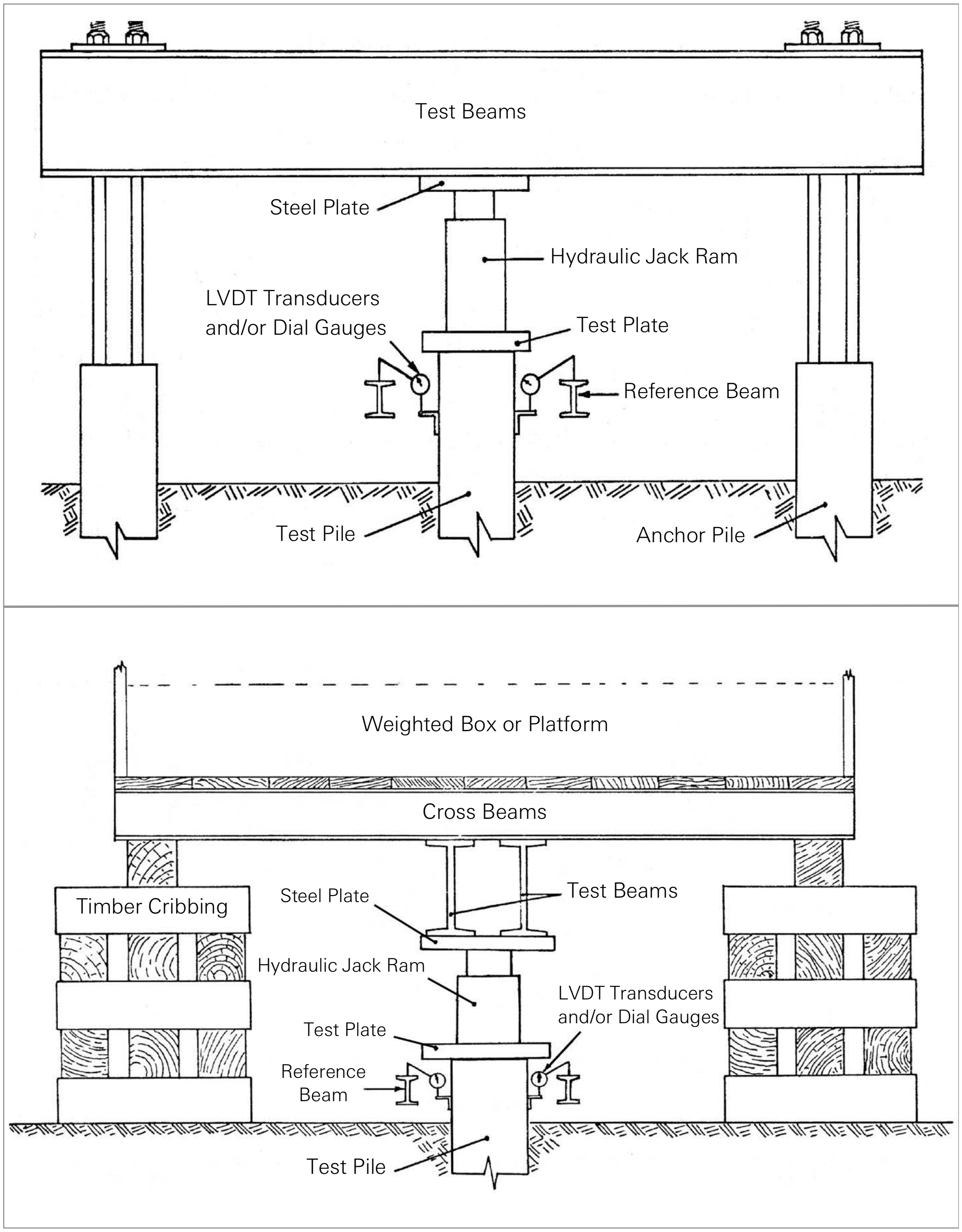

FIGURE 1: *Pile Monitoring Configuration Examples*

2.2 MODEL 1800 TELLTALES

Model 1450 LVDT Transducers can be used in place of, or in concert with, dial gauges to monitor piles and boreholes with the Model 1800 Telltale systems.

The Model 1800 Telltale is a simple means of measuring displacement between two points, typically in a vertically oriented position. The telltale system consists of a rod installed within a protective tubing to provide protection and a means for the rod to move freely along its alignment.

This system is typically installed in pile load tests or drilled boreholes in short term applications, where displacements of the tip relative to the ground surface are measured at the ground surface to evaluate deflection.

Model 1800 Manual

For more information about this system, refer to the [Model 1800 Instruction Manual.]

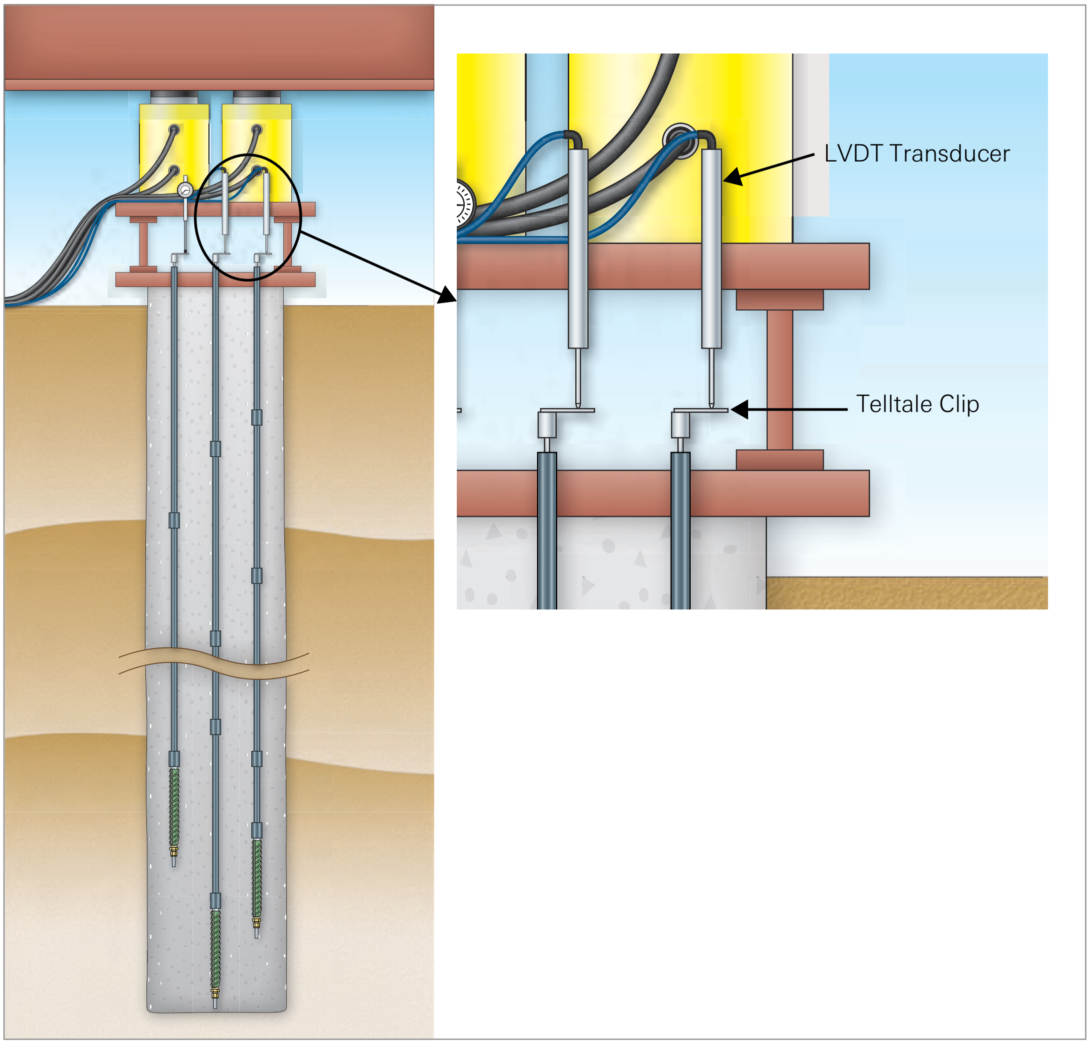

FIGURE 2: *Model 1800 Telltales*

2.3 MODEL 1100 BOREHOLE EXTENSOMETERS

Model 1450 LVDT Transducers can be used in place of Model 4450 Displacement Transducers for the electronic readout of Model 1100 Borehole Extensometers. The LVDT transducers are assembled into the extensometer in-house, making for a simplified installation process in the field. Using this installation method the transducers can not be set at a specific point within their range and are usually used to read extension only.

Model 1100 Borehole Extensometers are used for monitoring displacements along the axis of the instrument in various applications (tunnels, shoring sidewalls, earthen dams, landslides, etc.). A series of borehole anchors interconnected by fiberglass, composite/graphite, or stainless steel connecting rods are installed at predetermined depths, with the deepest anchor installed in stable ground to serve as a static reference point. If a stable point cannot be established with the deepest anchor, the head of the extensometer can serve as the reference point but it must be tied into an external survey system.

Model 1100 Manual

The measurement from the top of the connecting rod relative to the anchor reveals the magnitude of movement and also narrows down the identification of zones of movement.

For more information about this system, refer to the Model 1100 Instruction Manual.

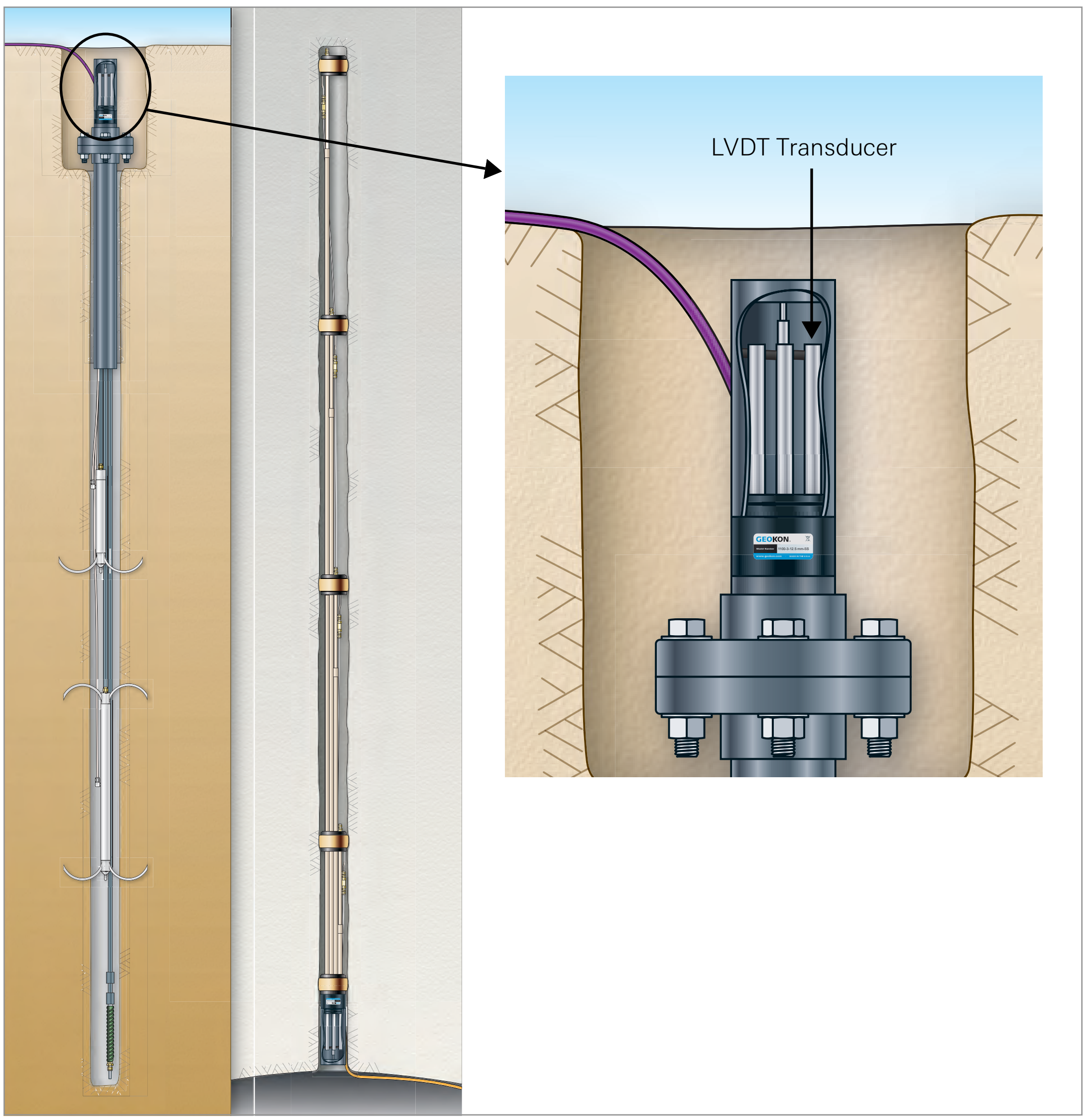

***FIGURE 3:** Model 1100 Borehole Extenosmeter*

3. INSTALLATION

3.1 INSTALLING THE TRANSDUCER

The Model 1450 LVDT Transducer is useful in several different applications. Refer to the applicable installation sections below.

- Section 3.1.1: Standard Installation (Typical Pile Monitoring and Installation With Model 1800 Telltales)
- Section 3.1.2: Installation With Model 1100 Borehole Extensometers

3.1.1 STANDARD INSTALLATION

The installation process is identical for typical pile monitoring installations and for use with Model 1800 Telltales. For more information on these applications, see Section 2. Perform the steps below to mount the transducer:

1. Remove the protective cap from the 6-pin on the readout cable and from the top side of the transducer. Save the caps for future use.

FIGURE 4: *6-Pin and Top Side Protective Caps*

2. Connect the readout cable to the transducer via the 6-pin connector.

Caution! Whenever disconnecting the cable from the transducer is necessary, re-install the protective caps to seal the connecting ends from water damage.

FIGURE 5: *6-Pin and Top Side Protective Caps*

3. Connect the readout cable to an ohmmeter and 6-18 Volt DC regulated power supply using the wiring chart below.

Warning! Incorrect connection may cause permanent and irreparable damage to the transducer.

RDP LVDT Internal Wiring	6-Pin Wiring	10-Pin Wiring	GEOKON Cable #02-250V6 (Blue)	Designation	Hookup for Reading LVDTs
Yellow	F	N/C	N/C	Tied to Brown	N/C
Brown	A	N/C	N/C	Tied to Yellow	N/C
Red	B	A	Red	+6 to +18 VDC	Power Supply +
Blue	C	B	Black	Power Ground	Power Supply -
Green	D	C	White	LVDT Output +	Ohmmeter +
Black	E	D	Green	LVDT Output -	Ohmmeter -
Copper Shield	N/C	E	Shield	Shield	N/C

TABLE 1: *Model 1450 DC-DC LVDT Transducer Wiring*

4. Carefully remove the protective cap from the bottom side of the transducer (Figure 6), taking care to let the spring loaded shaft extend slowly.

Warning! Do not allow the shaft to spring out forcefully or it could damage the internal components of the transducer.

FIGURE 6: *Bottom Side Protective Cap with Caution Label*

5. Position the transducer in place with the tip of the transducer shaft in contact with the measuring surface. See Section A.3 for optional mounting accessories

6. Adjust the transducer against the measurement surface to set it anywhere within its range to monitor expected settlement or heave. Refer to the individual calibration certificate to find the linear range (total range of the sensor), and the sensitivity (Millivolt/mm or Volt/inch readings). A reading of 0 millivolts or Volts is the midrange reading for all LVDT transducers. See Appendix E for an example certificate

7. Secure the transducer in place.

3.1.2 INSTALLATION WITH MODEL 1100 BOREHOLE EXTENSOMETERS

Model 1100 Manual

The LVDT transducers are already mounted into the extensometer head assembly in-house. For full installation instructions, refer to the Model 1100 Instruction Manual.

Please note the exceptions from a standard 1100 Extemsometer installation below:

- When removing the protective cover, the transducers will already be installed.
- After securing the extensometer system into the borehole and removing all hardware from the tube mount:
  - ☐ Thread the LVDT measurement rods onto the connecting rods.
  - ☐ Re-install the transducer mount, confirm the tips of the transducer shafts seat inside the pockets of the LVDT measurement rods.

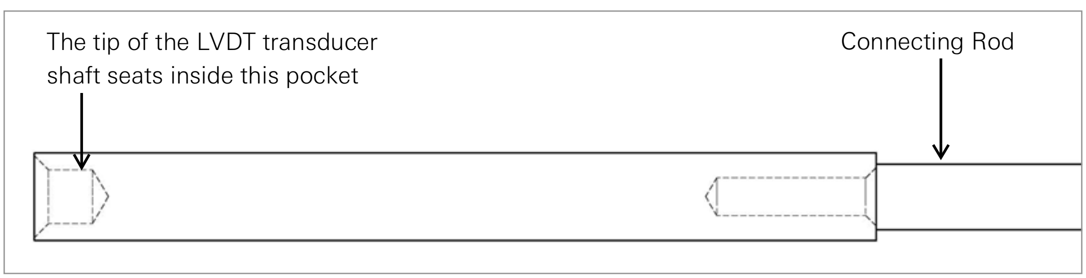

FIGURE 7: *LVDT Measurement Rod*

- The LVDT transducers cannot be set to a specific range.
- The LVDT transducers are pre-wired to the readout cable in-house.
- To take readings, connect the readout cable to an ohmmeter and 6-18 Volt DC regulated power supply using the wiring chart in Appendix C.

Warning! Incorrect connection may cause permanent and irreparable damage to the transducer.

3.2 SPLICING AND JUNCTION BOXES

Cable used for making splices should be a high-quality twisted pair type, with 100% shielding and an integral shield drain wire. When splicing, it is very important that the shield drain wires be spliced together. Splice kits recommended by GEOKON incorporate casts that are placed around the splice and then filled with epoxy to waterproof the connections. When properly made, this type of splice is equal or superior to the cable 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 readouts and dataloggers are also available. Contact GEOKON for specific application information.

3.3 LIGHTNING PROTECTION

In settings where lightning strikes are a concern, GEOKON offers the Model 4999-12L/LE Surge Protection Module:

FIGURE 8: *Model 4999-12L/LE*

Model 4999-12L/LE

The module features replaceable surge protection circuitry in the event that it is damaged by a lightning strike. The Module is installed between a strain gauge and the datalogger or terminal box it is connected to. Consult GEOKON and the Model 4999-12L/LE Instruction Manual for additional information.

Important! When using a Model 4999-12L for protection, power suppy voltage should be limited to 12 Volts.

4. TAKING READINGS

The most important reading is the first reading; it is the base reading to which all subsequent readings will be compared. Most installations are subject to a bedding-in process during which slight movements can occur. These movements generally cease after two or three days but can sometimes take longer.

All readings should be compared with previous readings as soon as they are taken. In this way, sudden changes of readings can be instantly checked to see if they are real or a reading error. If the changes are real, the observer is alerted to the possibility of serious ground movements, or to possible instrument damage, and can look for further evidence of either.

Readings are taken with an ohmmeter and 6-18 Volt DC regulated power supply, use the applicable wiring chart in Section 2 or in Appendix C.

Warning! Incorrect connection may cause permanent and irreparable damage to the transducer.

4.1 MEASURING TEMPERATURES (MODEL 1100 APPLICATIONS):

Model 1100 Borehole Extensometers are equipped with a thermistor for reading temperature. The thermistor gives a varying resistance output as the temperature changes.

GEOKON Model GK-404 and GK-406 readouts will read the thermistor and display the temperature in degrees Celsius. For further details and instruction consult the corresponding Manual(s) at geokon.com/Readouts.

Readouts

DIGITAL READOUTS:

- **GK-404**

  The Model GK-404 VW Readout is a portable, low-power, hand-held unit capable of running for more than 20 hours continuously on two AA batteries. It is designed for the readout of all GEOKON Vibrating Wire instruments, and is capable of displaying the reading in digits, frequency (Hz), period (µs), or microstrain (µε). The GK-404 displays the temperature of the transducer (embedded thermistor) with a resolution of 0.1 °C.

- **GK-406**

  The Model GK-406 is a field-ready device able to quickly measure a sensor, save data, and communicate results with custom PDF reports and spreadsheet output. Measurements are geo-located with the integrated GPS allowing the GK-406 to verify locations and lead the user to the sensor locations. The large color display and VSPECT™ technology create confidence of getting the best measurement possible both in the field and in the office.

USING AN OHMMETER TO READ TEMPERATURES:

Connect an ohmmeter to the thermistor leads indicated on the applicable wiring table in Appendix C. Since the resistance changes with temperature are large, the effect of cable resistance is usually insignificant. For long cables a correction can be applied equal to approximately 48.5Ω per km (14.7Ω per 1000') at 20 °C. Multiply these factors by two to account for both directions

Look up the temperature for the measured resistance in Appendix B.

5. DATA REDUCTION

The output of the transducer can be converted to a displacement using Equation 1. This is the displacement from midrange (at midrange the transducer will read 0 millivolts or Volts). To find displacement from the initial reading, perform the equation below for both initial and subsequent readings and subtract to find the difference.

$$D = \left(\frac{1}{S}\right)V$$

EQUATION 1: *Convert Transducer Output to Millimeters or Inches*

Where:

D = Displacement in Millimeters or inches

S = Sensitivity factor (mV/mm or V/inch) shown on the calibration certificate provided with the transducer.

V = Output of the transducer in millivolts or Volts

Consider the examples below, which use the sensitivity factors (29.71 mV/mm or 0.755 V/inch) from the sample calibration certificate shown in Appendix E. Please note both examples show the displacement from midrange.

EXAMPLE 1:

Displacement Unit: millimeters

If the sensitivity factor is 29.71 mV/mm and transducer output is 25.75 millivolts:

$$D = \left(\frac{1}{29.71}\right) 25.75$$

$$D = 0.867 \text{ millimeters}$$

EXAMPLE 2:

Displacement Unit: inches

If the sensitivity factor is 0.755 V/inch and transducer output is 0.55 Volts:

$$D = \left(\frac{1}{0.755}\right) 0.55$$

$$D = 0.728 \text{ inches}$$

Technical Support

6. TROUBLESHOOTING

Maintenance and troubleshooting of the sensor is confined to periodic checks of cable connections and maintenance of terminals. The transducers themselves are sealed and are not user serviceable. **Sensors should not be opened in the field.**

Should difficulties arise, consult the following list of problems and possible solutions. For additional troubleshooting and support visit geokon.com/Technical-Support.

SYMPTOM: THERMISTOR RESISTANCE IS TOO HIGH / TOO LOW (MODEL 1100 APPLICATIONS ONLY)

- ☐ Check for an open circuit. Check all connections, terminals, and plugs. If a cut or short is in the cable, splice according to instructions in Section 3.2.

SYMPTOM: SENSOR READING UNSTABLE

- ☐ Make sure the shield drain wire is connected to ground.
- ☐ Isolate the readout from the ground by placing it on a piece of wood or another insulator.
- ☐ Check for sources of nearby electrical noise such as motors, generators, antennas, or electrical cables. Move the sensor cable away from these sources if possible. Contact the factory for available filtering and shielding equipment.
- ☐ The sensor may have been damaged by over-ranging or shock.
- ☐ Check the readouts with another gauge to ensure it is functioning properly.

SYMPTOM: SENSOR FAILS TO GIVE A READING

- ☐ The sensor may have been damaged by over-ranging, shock, or incorrect wiring.
- ☐ Check the readout with another gauge to ensure it is functioning properly.

APPENDIX A. SPECIFICATIONS

A.1 MODEL 1450 SPECIFICATIONS

Model	1450-1	1450-2	1450-4	1450-6
Available Ranges	±12.5 mm (±0.5")	±25 mm (±1")	±50 mm (±2")	±75 mm (±3")
Linearity (% F.S.)	<±0.5/±0.25/±0.1			
Excitation/Supply (Acceptable)	5V to 18V dc, 60 mA typical			
Output	±2.2V			
Output Load	2k Ohms (minimum)			
Output Ripple	30 mV (peak-to-peak)			
Output Impedance	2 Ohms			
Thermal Coefficient (Span)	±0.017% F.S. /°F (typical)			
Operating Temperature Range	-40 to +70 °C			
Electrical Output Bandwidth	200 Hz (flat)			
Cable Type	Two twisted pair (four conductor) 22 AWG Foil shield, PVC jacket, nominal OD=6.3 mm (0.250") (Recommended length, <15 meters)			

TABLE 2: *Model 1450 DC-DC LVDT Transducer Specifications*

A.2 MODEL 1450 DIMENSIONS

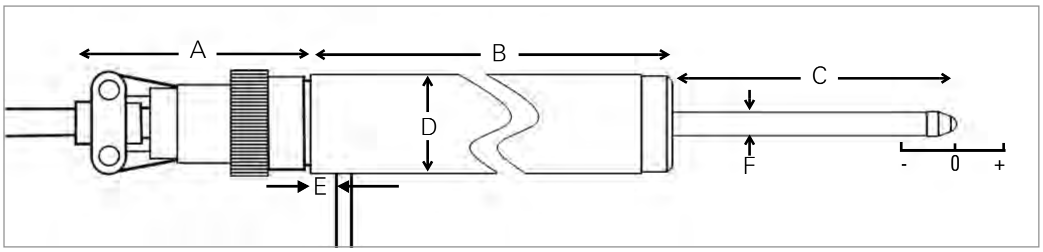

FIGURE 9: *Model 1450 DC-DC LVDT Transducer Dimensions*

Model	1450-1	1450-2	1450-4	1450-6
A (6-Pin Style Only)	50 mm (2")			
B	182 mm (7.17")	210 mm (8.27")	324 mm (12.76")	436 mm (17.17")
C (Nominal)	38 mm (1.5")	63 mm (2.5")	75 mm (3")	114 mm (4.5")
Spring Force at C (Nominal)	1.4 N (5 oz)	2 N (7 oz)	1.8 N (6 oz)	6 N (1 lb.)
Spring Rate (Nominal)	0.6 N/cm (2 oz/inch)	0.3 N/cm (3 oz/inch)	0.2 N/cm (2 oz/inch)	0.4 N/cm (3 oz/inch)
D	20.6 mm (0.81")			
E (Side Cable Exit Only)	9 mm (0.35")			
F	4.75 mm (0.187")			
Inward Over-Travel	0 mm (0.0")	3 mm (0.1")	8 mm (0.3")	15 mm (0.6")
Output Over-Travel	13 mm (0.51")	10 mm (0.39")	14 mm (0.55")	15 mm (0.59")

TABLE 3: *Model 1450 DC-DC LVDT Transducer Dimensions*

A.3 OPTIONAL MOUNTING ACCESSORIES

A mounting bracket (Model 1450-7) and magnetic mounting base with swivel post (Model 1450-8) are available to facilitate mounting the LVDT sensors.

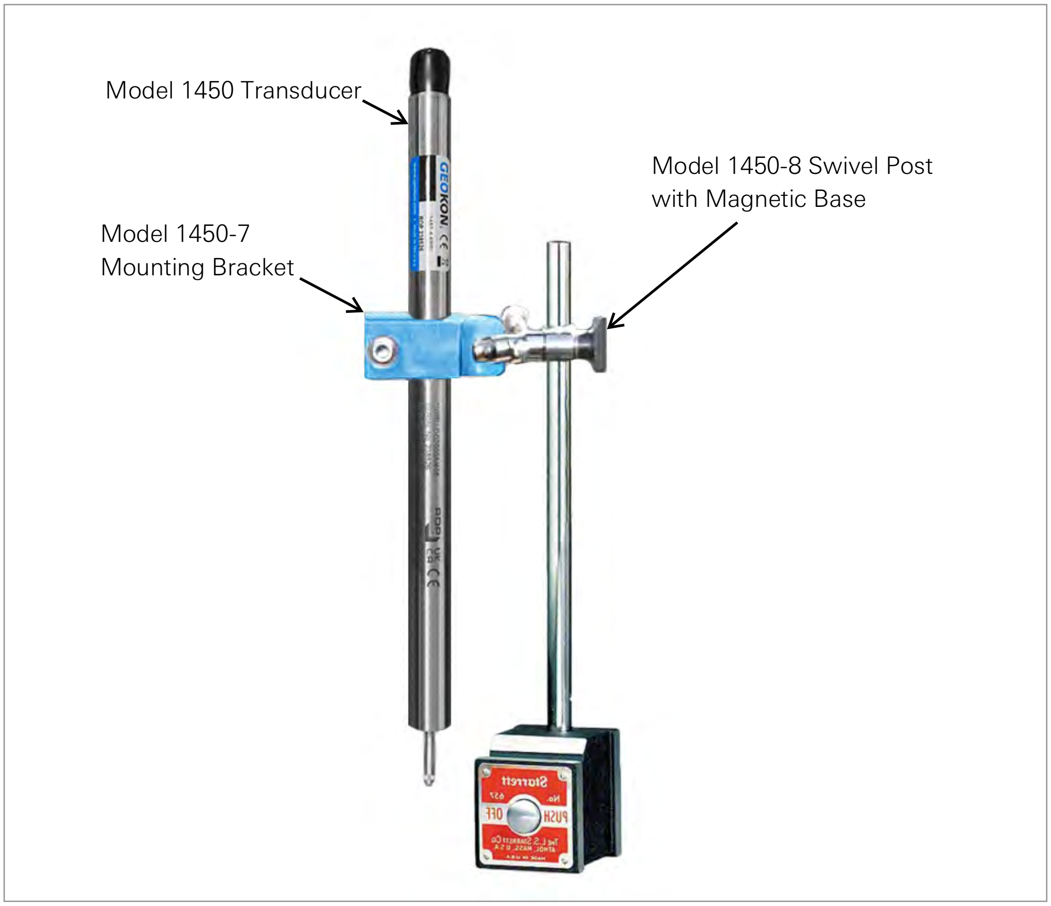

FIGURE 10: *Optional Mounting Accessories*

APPENDIX B. THERMISTOR TEMPERATURE DERIVATION

B.1 3KΩ THERMISTOR RESISTANCE

Thermistor Types include YSI 44005, Dale #1C3001–B3, Alpha #13A3001–B3, and Honeywell 192–302LET–A01

Resistance to Temperature Equation:

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

EQUATION 2: *3KΩ Thermistor Resistance*

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

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

TABLE 4: *3KΩ Thermistor Resistance*

APPENDIX C. WIRING CHARTS FOR MODEL 1100 BOREHOLE EXTENSOMETERS

These wiring charts are specific to Model 1100 Borehole Extensometers with Model 1450 DC-DC LVDT Displacement Transducers installed. Wiring charts are dependent on the quantity of transducers.

Warning! Incorrect connection may cause permanent and irreparable damage to the transducer.

Internal Wiring	GEOKON **Cable #04-375V9 (Violet)**	**Function/Description**	**Hookup for Reading LVDTs**
Red	Red	+6 to +18 VDC	Power Supply +
Blue	Black of Red	Power Ground	Power Supply -
Green	White	LVDT 1 Output +	Ohmmeter +
Black	Black of White	LVDT 1 Output -	Ohmmeter -
Blue	Blue	Thermistor	N/C
Black of Blue	Black of Blue	Thermistor	N/C
N/C	Shields (4)	Ground	N/C

TABLE 5: *Wiring for One Transducer*

Internal Wiring	GEOKON **Cable #04-375V9 (Violet)**	**Function/Description**	**Hookup for Reading LVDTs**
Red	Red	+6 to +18 VDC	Power Supply +
Blue	Black of Red	Power Ground	Power Supply -
Green	White	LVDT 1 Output +	Ohmmeter +
Black	Black of White	LVDT 1 Output -	Ohmmeter -
Green	Green	LVDT 2 Output +	Ohmmeter +
Black	Black of Green	LVDT 2 Output -	Ohmmeter -
Blue	Blue	Thermistor	N/C
Black of Blue	Black of Blue	Thermistor	N/C
N/C	Shields (5)	Ground	N/C

TABLE 6: *Wiring for Two Transducers*

Internal Wiring	GEOKON **Cable #05-375V12 (Tan)**	**Function/Description**	**Hookup for Reading LVDTs**
Red	Red	+6 to +18 VDC	Power Supply +
Blue	Black of Red	Power Ground	Power Supply -
Green	White	LVDT 1 Output +	Ohmmeter +
Black	Black of White	LVDT 1 Output -	Ohmmeter -
Green	Green	LVDT 2 Output +	Ohmmeter +
Black	Black of Green	LVDT 2 Output -	Ohmmeter -
Green	Blue	LVDT 3 Output +	Ohmmeter +
Black	Black of Blue	LVDT 3 Output -	Ohmmeter -
Yellow	Yellow	Thermistor	N/C
Black of Yellow	Black of Yellow	Thermistor	N/C
N/C	Shields (6)	Ground	N/C

TABLE 7: *Wiring for Three Transducers*

Internal Wiring	GEOKON **Cable #06-500V7 (Orange)**	**Function/Description**	**Hookup for Reading LVDTs**
Red	Red	+6 to +18 VDC	Power Supply +
Blue	Black of Red	Power Ground	Power Supply -
Green	White	LVDT 1 Output +	Ohmmeter +
Black	Black of White	LVDT 1 Output -	Ohmmeter -
Green	Green	LVDT 2 Output +	Ohmmeter +
Black	Black of Green	LVDT 2 Output -	Ohmmeter -
Green	Blue	LVDT 3 Output +	Ohmmeter +
Black	Black of Blue	LVDT 3 Output -	Ohmmeter -
Green	Yellow	LVDT 4 Output +	Ohmmeter +
Black	Black of Yellow	LVDT 4 Output -	Ohmmeter -
Brown	Brown	Thermistor	N/C
Black of Brown	Black of Brown	Thermistor	N/C
N/C	Shields (7)	Ground	N/C

TABLE 8: *Wiring for Four Transducers*

Internal Wiring	GEOKON **Cable #12-625V5 (Brown)**	**Function/Description**	**Hookup for Reading LVDTs**
Red	Red	+6 to +18 VDC	Power Supply +
Blue	Black of Red	Power Ground	Power Supply -
Green	White	LVDT 1 Output +	Ohmmeter +
Black	Black of White	LVDT 1 Output -	Ohmmeter -
Green	Green	LVDT 2 Output +	Ohmmeter +
Black	Black of Green	LVDT 2 Output -	Ohmmeter -
Green	Blue	LVDT 3 Output +	Ohmmeter +
Black	Black of Blue	LVDT 3 Output -	Ohmmeter -
Green	Yellow	LVDT 4 Output +	Ohmmeter +
Black	Black of Yellow	LVDT 4 Output -	Ohmmeter -
Green	Brown	LVDT 5 Output +	Ohmmeter +
Black	Black of Brown	LVDT 5 Output -	Ohmmeter -
White	White	Thermistor	N/C
Red of White	Red of White	Thermistor	N/C
N/C	Shields (8)	Ground	N/C

TABLE 9: *Wiring for Five Transducers*

APPENDIX D. CRBASIC PROGRAMMING

D.1 SAMPLE CR6 PROGRAM

The following sample program reads one sensor.

```
'CR6 Datalogger with 8032 Multiplexer
'To read 4ea model 1450 RDP LVDTs connected to Multiplexer

'Zero readings and Gage factor are set to store Volts by default for 1450.


'Wiring:
'Multiplexer Enable U5
'Multiplexer Clock C4
'Model 1450 LVDT Supply SW12V and Ground
'Model 1450 LVDT Output Diff Ch U1/U2

Public Result(4)            'Result of 1450 sensors being stored
Public BattV                'Datalogger voltage from battery
Public PTemp_C              'Datalogger panel temperature in degrees Celsius
Public GageFactor(4)        'Calibration factor for sensor
Public ZeroReading(4)       'Zero reading for sensor

Dim Var(16)                 'Generic Variable
Dim I                       'Generic Counter

Const CRControlB = C4       'C4 for clocking through MUX channels

'Define Data Tables

DataTable(Test,1,True,-1)
  Sample(1,BattV,IEEE4)          'Battery Voltage
  Sample(1,PTemp_C,IEEE4)        'Panel temperature
  Sample(4,Result(1),IEEE4)      '1450 Sensor readings
EndTable


Sub PulseP (Chan)
  'Subroutine to Clock through each MUX channel
  'Chan Parameter Determines 32 or 16 Channel mode. When 32 Channel mode
  'only one PulsePort per clock is needed 16 Channel mode requires both
  'PulsePorts to clock through
  If Chan >= 16 Then PulsePort(CRControlB,10000)
  If Chan = 16 Then PulsePort(CRControlB,10000)
EndSub


Sub ReadVolt
  'Commands to retrieve Voltage from 1450 LVDT
  'Power up sensor with SW12 volts
  SW12(1,1)
  'Delay to allow power to reach desired voltage
  Delay (1,100,mSec)

  'Command to retrieve voltage from sensor
  VoltDiff (Var(14),1,AutoRange,U1,False,0,60,.001,0)
  'Apply Zero Reading and Gage Factor
  Result(I)=(Var(14)-ZeroReading(I))*GageFactor(I)

  'Clear variable used
  Var(14)=0

  'Power down before clocking through channel on MUX
  SW12(1,0)
  'Delay to allow power to reach desired voltage
  Delay (1,100,mSec)
EndSub

'Main Program

BeginProg
   'Zero readings for 4ea Model 1450 RDP LVDTs
   ZeroReading(1) = 0
   ZeroReading(2) = 0
   ZeroReading(3) = 0
   ZeroReading(4) = 0

   'Gage factor for 4ea Model 1450 RDP LVDTs
```

```
GageFactor(1) = 1
GageFactor(2) = 1
GageFactor(3) = 1
GageFactor(4) = 1

'Main Scan
    'Scan every 60 Seconds
Scan(60,Sec,1,0)
    'Read Datalogger Battery Voltage measurement 'BattV'
    Battery(BattV)
    'Read Panel Temperature measurement 'PTemp_C'
    PanelTemp(PTemp_C,_60Hz)

    'Raise the control port to enable MUX #1
    PortSet (U5,1)
    Delay (0,125,mSec)

    'Determine channel position of MUX
    For I=1 To 4
        'Clock through MUX channels Parameter is either 16 or 32 channel mode.
        Call PulseP(16)

        'Read Model 1450
        Call ReadVolt

    Next
    'Lower the control port to deactivate MUX port enabled
    PortSet (U5,2)

    'Call Table to store Data
    CallTable (Table1)
NextScan
```

APPENDIX E. TYPICAL CALIBRATION CERTIFICATE

<< RDP CALIBRATION CERTIFICATE >>

Type LDC3000A	Serial N° 184513	
Linear Range ±75mm(2.95275")	Cal Temp 21 °C	Cal Load 10k
Sensitivity 29.71mV/mm(0.755V/Inch)	with +15VDC	Energising Supply
Linearity 0.15%	Calibrated by	

UNCERTAINTY OF CALIBRATION: 42.0 microns.
This expanded uncertainty is with a level of confidence of approximately 95%

FIGURE 11: *Typical Calibration Certificate*