INSTRUCTION MANUAL

In-Place Inclinometer

E1387-190109

This product should be installed and operated only by qualified personnel. Its misuse is potentially dangerous. The Company makes no warranty as to the information furnished in this manual and assumes no liability for damages resulting from the installation or use of this product. The information herein is subject to change without notification.

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1- INTRODUCTION

Introduction

The GEOSTRING system consists of a vertically installed casing and a string of GEOSTRING in-place inclinometer MEMS sensors. The casing provides access for the subsurface measurements and moves with the surrounding ground. The casing is installed in a borehole that passes through a suspected zone of movement into stable ground elow. The GEOSTRING sensors are installed in the casing and measure inclination from vertical. As ground movement occurs, the casing moves with it, changing the inclination of the sensors inside the casing.

The inclination measurements are then processed to provide displacement readings in millimeters or inches. In most applications, the sensors are connected to a data acquisition system and data processing is completed by a computer program.

System Components

Casing

- 70mm (2.75 in) ABS Inclinometer Casing, or
- 38mm (1.5 in) Schedule 40 PVC Pipe

Description	Length (m)	Length (ft)	Inclinometer Casing System 70 mm (2.75 in)	Schedule 40 PVC Pipe System 38 mm (1.5 in)
GEOSTRING Standard Segment				
5 Sensor GEOSTRING Segment (Standard)	3.048	10	FR-0387050100	FR-0387050200
GEOSTRING Custom Segments				
4 Sensor GEOSTRING Custom Segment	2.438	8	FR-0387050108	FR-0387050208
3 Sensor GEOSTRING Custom Segment	1.828	6	FR-0387050106	FR-0387050206
2 Sensor GEOSTRING Custom Segment	1.219	4	FR-0387050104	FR-0387050204
1 Sensor GEOSTRING Custom Segment	0.609	2	FR-0387050102	FR-0387050202
GEOSTRING Dummy Segments				
Dummy GEOSTRING Segment	1.524	5	40-0387040105	40-0387040205
Dummy GEOSTRING Segment	0.609	2	40-0387040102	40-0387040202
GEOSTRING Required Accessories				
Suspension Kit, GEOSTRING			40-0387040410	40-0387040420
Jumper Cable, GEOSTRING to Logger	50	164	40-0387040350	40-0387040350
Jumper Cable, GEOSTRING to Logger	25	82	40-0387040325	40-0387040325
Bottom Plug, GEOSTRING, 6 Pin Seacon			40-0387040500	40-0387040500
GEOSTRING Replacement Accessories				
Replacement Centralizer			40-0387040610	40-0387040620
GEOSTRING Clevis Pin with Head			40-0387040630	40-0387040630

Advantages

Real Time Monitoring :

The GEOSTRING system is ideal for continuous, unattended monitoring and can deliver readings in near-real time.

Convenient Shipping and Transport:

GEOSTRING systems have joints capable of bending to 90°, allowing for a compact shipping option. Five segments, each 3.048 meters (10 feet) long, can be shipped in a carton measuring approximately 64 x 64 x 64 cm (26 x 26 x 26 in) and which weighs less than 22 kilograms (50 pounds). This allows for the system to be shipped via common overnight carrier as well as fit in most standard vehicles.

Figure 1: GEOSTRING segment folded for transport

Flexible Configurations:

GEOSTRING systems have standard segment length of 3.048 m (10 ft)but can be custom ordered in lengths of 0.609, 1.219, 1.828 & 2.438 meters (2,4,6 & 8 feet) in order to instrument the precise length required.
The GEOSTRING system can also be installed with sensorless nodes at the top of the system, allowing the designer to economize by only monitoring the zone of interest and bypassing the upper layers.

Durable & Redeployable Components:

Nodes, cables, connectors and gage rods are exceptionally durable, making it practical to remove the systems at the end of the project and redeploy them on other projects.

Data Reduction:

The GEOSTRING system outputs the displacement as engineering units, requiring less computing power and a lighter load on your data acquisition system. The nodes are preloaded with the calibration information, allowing the segments to be installed in any order.

2- INSTALLATION

Preparation

Verify that all system components have been received and are ready for installation.

Suspension Kit: One suspension kit is used for each string.

Figure 2: GEOSTRING suspension kit for PVC pipe

GEOSTRING segments or strings

Standard Configuration: Each standard GEOSTRING segment is either 3 m or 10 ft in length and has a male connector at the upper end and a female connector at the lower end. The segment consists of 5 nodes and each node has a 0.6 m or 2 ft gage length. The upper end can also be identified by its lack of joint on the node. The lower end has a universal joint, as can be seen in the images below.

Custom Configuration: GEOSTRING systems can be ordered with custom length string for long-term monitoring projects. The custom system has one male connector at the upper end and no female connectors. Please note that custom length systems cannot be reconfigured once they are manufactured and therefore are not eligible to be returned for credit.

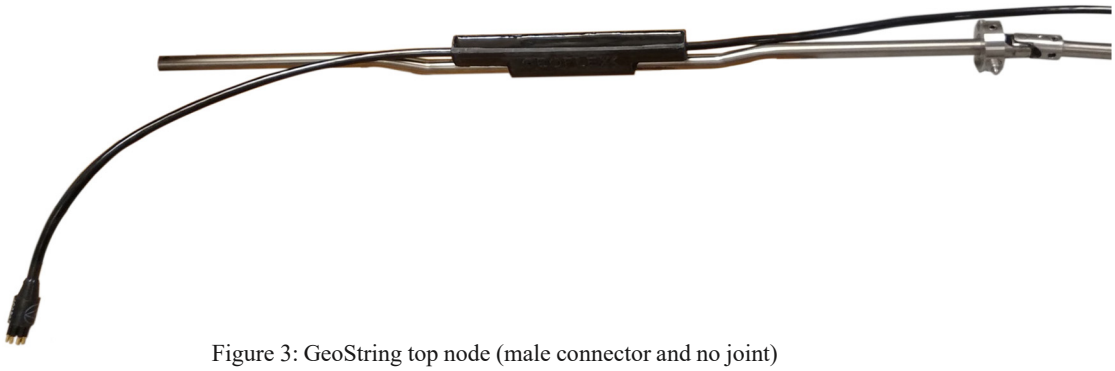


Figure 3: GeoString top node (male connector and no joint)

Figure 4: GEOSTRING bottom node (female connector and universal joint)

GEOSTRING Jumper Cable: One jumper cable is used for each string. The jumper cable has a female connector on one end and exposed inner conductor wires on the other for connection to the data logger.

GEOSTRING Bottom Plug: One bottom plug is used for each standard configuration string. The bottom plug has a male connector on one end and is used to protect the last node from water ingress via the connector.

Installation

Attach the Bottom Plug to the female connector on the first segment to be placed in the casing.

Insert the bottom end of the first segment into the casing.

If inclinometer casing is being used, verify that the centralizer standoffs are placed in the grooves orthogonal to the direction of movement. The X-axis direction is marked on the sensor and should point towards the direction of anticipated movement.

If PVC pipe is being used, roughly align the X-axis direction marking on the sensor with the direction of anticipated movement. Adjustments may be made once the entire string has been installed.

Continue to lower the segment into the casing until four nodes have been inserted. Fold the fifth node over the top edge of the casing. For deeper installations, a clamp (e.g. vise grips) may be attached to the upper node to protect it from accidentally dropping into the casing.

While lowering the nodes, the signal cable should be placed in the notch of the centralizer to avoid pinching it between the segment and the casing.

Connect the signal cables of the installed segment and the next segment to be installed. Note - it does not matter in which order the segments are installed, as the data logger will query the sensors and number them at start-up.

Remove the pin from the universal joint of the installed segment and insert the top node's gage rod, pinning it in place. Verify that the alignment of the sensors is the same for both segments.

Lower the nodes into the casing, repeating the above steps until all but one segment has been installed in the casing.

Attach the suspension kit to the top of the last segment.

Connect the last segment to the installed segments, as per above.

Lower the last segment into the casing, aligning the suspension kit so that it is firmly seated on the top of the casing. The male connector should extend out of the casing.

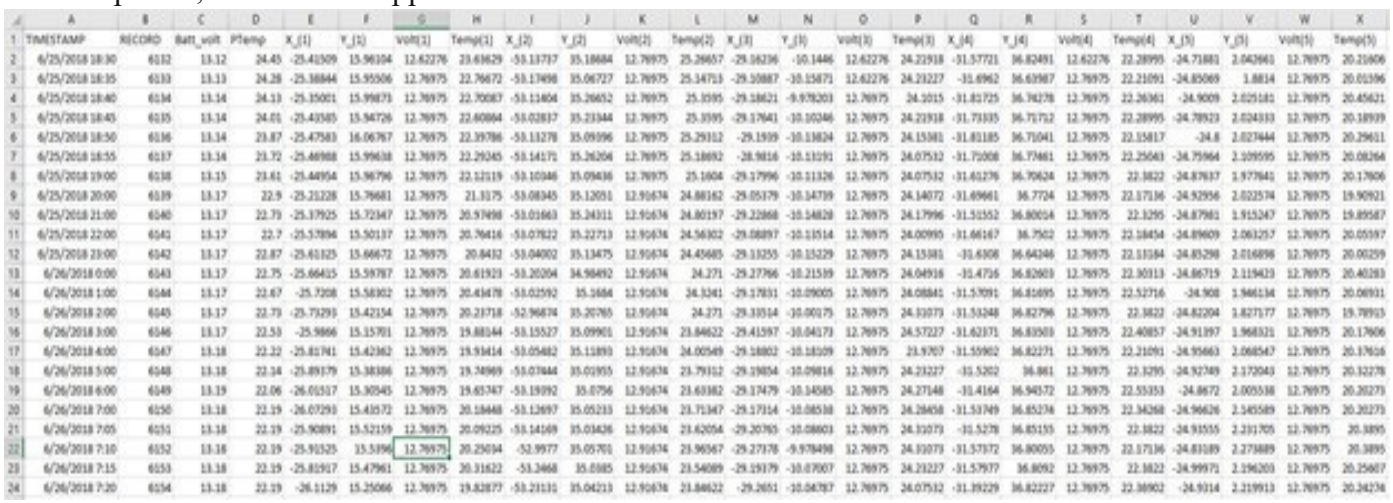
Attach the jumper cable to the male connector and to the data logger.

3- DATA REDUCTION/DATA FORMAT

Data Format

1. The Campbell Data Logger outputs a *.dat file. This file contains the readings in a comma-separated format, which can be imported into a spreadsheet program, such as Microsoft Excel™.

2. Once imported, the data will appear as below:



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
1	TIMESTAMP	RECORD	Batt_volt	PTemp	X_(1)	Y_(1)	Volt(1)	Temp(1)	X_(2)	Y_(2)	Volt(2)	Temp(2)	X_(3)	Y_(3)	Volt(3)	Temp(3)	X_(4)	Y_(4)	Volt(4)	Temp(4)	X_(5)	Y_(5)	Volt(5)	Temp(5)
2	6/25/2018 18:30	6132	13.12	24.45	-25.41509	15.96104	12.62276	23.63629	-53.13737	35.18684	12.76975	25.28657	-29.16236	-10.1446	12.62276	24.22918	-31.57721	16.82491	12.62276	22.28995	-24.71881	2.042661	12.76975	20.21606
3	6/25/2018 18:35	6133	13.13	24.28	-25.38844	15.95506	12.76975	22.76672	-53.17498	35.06727	12.76975	25.14713	-29.10887	-10.15871	12.62276	24.21227	-31.6962	16.63987	12.76975	22.21091	-24.85069	1.8814	12.76975	20.01596
4	6/25/2018 18:40	6134	13.14	24.13	-25.35001	15.99873	12.76975	22.70087	-53.11404	35.26652	12.76975	25.3395	-29.18621	-9.978203	12.76975	24.1015	-31.81725	16.74278	12.76975	22.26361	-24.9009	2.025181	12.76975	20.45621
5	6/25/2018 18:45	6135	13.14	24.01	-25.41585	15.94726	12.76975	22.60864	-53.02837	35.23344	12.76975	25.3395	-29.17641	-10.10246	12.76975	24.21918	-31.73335	16.71712	12.76975	22.28995	-24.78923	2.024333	12.76975	20.18939
6	6/25/2018 18:50	6136	13.14	23.87	-25.47583	16.06767	12.76975	22.39786	-53.11278	35.09396	12.76975	25.29312	-29.1939	-10.11824	12.76975	24.15381	-31.81185	16.71041	12.76975	22.15817	-24.8	2.027444	12.76975	20.29611
7	6/25/2018 18:55	6137	13.14	23.72	-25.46988	15.99638	12.76975	22.29245	-53.14171	35.26204	12.76975	25.18692	-28.9816	-10.11191	12.76975	24.07512	-31.71008	16.77461	12.76975	22.25043	-24.75964	2.109595	12.76975	20.08264
8	6/25/2018 19:00	6138	13.15	23.61	-25.44954	15.96796	12.76975	22.12119	-53.10346	35.09436	12.76975	25.1604	-29.17996	-10.11326	12.76975	24.07512	-31.61276	16.70624	12.76975	22.1822	-24.87637	1.977641	12.76975	20.17606
9	6/25/2018 20:00	6139	13.17	22.9	-25.21228	15.78681	12.76975	21.3175	-53.08345	35.12051	12.91674	24.88162	-29.05179	-10.14739	12.76975	24.14072	-31.69661	16.7724	12.76975	22.17136	-24.92956	2.022574	12.76975	19.90921
10	6/25/2018 21:00	6140	13.17	22.73	-25.17925	15.72147	12.76975	20.57498	-53.01663	35.24311	12.91674	24.80197	-29.22868	-10.14828	12.76975	24.17996	-31.51552	16.80054	12.76975	22.3295	-24.87981	1.915247	12.76975	19.85587
11	6/25/2018 22:00	6141	13.17	22.7	-25.57894	15.50137	12.76975	20.76416	-53.07822	35.22713	12.91674	24.56302	-29.08897	-10.11514	12.76975	24.00995	-31.66167	16.7502	12.76975	22.18454	-24.89609	2.063257	12.76975	20.05197
12	6/25/2018 23:00	6142	13.17	22.87	-25.61025	15.66672	12.76975	20.8432	-53.04002	35.13475	12.91674	24.45685	-29.13255	-10.15229	12.76975	24.1581	-31.6308	16.64246	12.76975	22.13184	-24.85298	2.016898	12.76975	20.00259
13	6/26/2018 0:00	6143	13.17	22.75	-25.66415	15.59787	12.76975	20.61923	-53.20204	34.98492	12.91674	24.271	-29.27766	-10.21539	12.76975	24.04916	-31.4716	16.82603	12.76975	22.30313	-24.86719	2.119423	12.76975	20.40283
14	6/26/2018 1:00	6144	13.17	22.67	-25.7208	15.58302	12.76975	20.41478	-53.02592	35.1684	12.91674	24.3241	-29.17831	-10.09005	12.76975	24.08841	-31.57091	16.81695	12.76975	22.52716	-24.908	1.946134	12.76975	20.08931
15	6/26/2018 2:00	6145	13.17	22.73	-25.73293	15.42154	12.76975	20.21718	-52.96874	35.20765	12.91674	24.271	-29.33514	-10.00175	12.76975	24.31073	-31.53248	16.82796	12.76975	22.3822	-24.82204	1.827177	12.76975	19.78915
16	6/26/2018 3:00	6146	13.17	22.53	-25.9866	15.15701	12.76975	19.88144	-53.15527	35.09901	12.91674	23.84622	-29.41597	-10.04173	12.76975	24.57227	-31.62371	16.83503	12.76975	22.40857	-24.91197	1.968321	12.76975	20.17606
17	6/26/2018 4:00	6147	13.18	22.22	-25.81741	15.42362	12.76975	19.93414	-53.05482	35.11893	12.91674	24.00549	-29.16802	-10.16109	12.76975	23.9707	-31.55902	16.82271	12.76975	22.21091	-24.95663	2.068547	12.76975	20.17616
18	6/26/2018 5:00	6148	13.18	22.14	-25.89179	15.38386	12.76975	19.74969	-53.07844	35.01955	12.91674	23.79112	-29.19854	-10.09816	12.76975	24.23227	-31.5202	16.861	12.76975	22.3295	-24.92749	2.172043	12.76975	20.32278
19	6/26/2018 6:00	6149	13.19	22.06	-26.01517	15.30545	12.76975	19.65747	-53.19392	35.0756	12.91674	23.63382	-29.17479	-10.14585	12.76975	24.27148	-31.4164	16.94572	12.76975	22.53353	-24.8672	2.005538	12.76975	20.20273
20	6/26/2018 7:00	6150	13.18	22.19	-26.07293	15.43572	12.76975	20.18448	-53.12697	35.05233	12.91674	23.71347	-29.17314	-10.08538	12.76975	24.28458	-31.53749	16.85234	12.76975	22.34268	-24.96626	2.145589	12.76975	20.20273
21	6/26/2018 7:05	6151	13.18	22.19	-25.90891	15.52159	12.76975	20.09225	-53.14169	35.03426	12.91674	23.62054	-29.20765	-10.08603	12.76975	24.31073	-31.5278	16.85155	12.76975	22.3822	-24.93555	2.191705	12.76975	20.3895
22	6/26/2018 7:10	6152	13.18	22.19	-25.91525	15.5396	12.76975	20.25034	-52.9977	35.05701	12.91674	23.96567	-29.27178	-9.978498	12.76975	24.31073	-31.57372	16.80055	12.76975	22.17136	-24.83189	2.273889	12.76975	20.3895
23	6/26/2018 7:15	6153	13.18	22.19	-25.81917	15.47961	12.76975	20.31622	-53.2468	35.0385	12.91674	23.54089	-29.19179	-10.07007	12.76975	24.23227	-31.57977	16.8092	12.76975	22.1822	-24.99971	2.196203	12.76975	20.25607
24	6/26/2018 7:20	6154	13.18	22.19	-26.1129	15.25066	12.76975	19.82877	-53.23131	35.04213	12.91674	23.84622	-29.2651	-10.04787	12.76975	24.07512	-31.39229	16.82227	12.76975	22.36902	-24.9314	2.219913	12.76975	20.24274

3. The columns consist of the following:

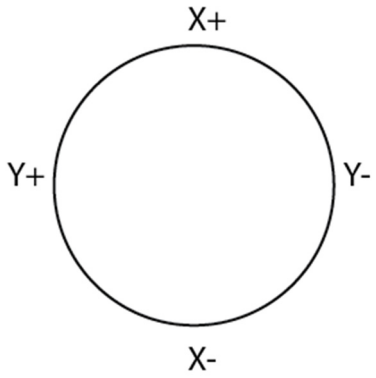
a. TIMESTAMP - date and time the reading was taken.
b. RECORD - consecutive reading that was taken since last data logger reboot.
c. Batt_volt - voltage of data logger battery at time of reading.
d. PTemp - temperature measured at the data logger.
e. X_(n) - X-axis tilt reading, in mm/m
f. Y_(n) - Y-axis tilt reading, in mm/m
g. Volt(n) - voltage input to the sensor, in V
h. Temp(n) - temperature measured by sensor node, in °C

where n = sensor node location (1 is the top sensor, 2 is second from the top, etc.)

Calculations

Calculating Tilt in mm/m

It is not necessary to calculate tilt, as the GEOSTRING system outputs the tilt in mm/m natively. The sign of the result indicates the direction of the tilt. The X+ direction of the sensor node is marked on every node.



Calculating Tilt in Degrees

$$Tilt(degrees) = \arcsin(Tilt_{mm/m}/1000)$$

Calculating Deviation

To calculate deviation over the gauge length of the sensor node, use one of the formulas below:

$$Deviation_{mm} = Tilt_{mm/m} \times 0.6m$$

or

$$Deviation_{in} = Tilt_{mm/m} \times (24\ in / 1000\ in)$$

Calculating Displacement

Displacement (movement) is the change in deviation:

$$Displacement = Deviation_{current} - Deviation_{initial}$$

4- CONNECTION TO DATA LOGGERS

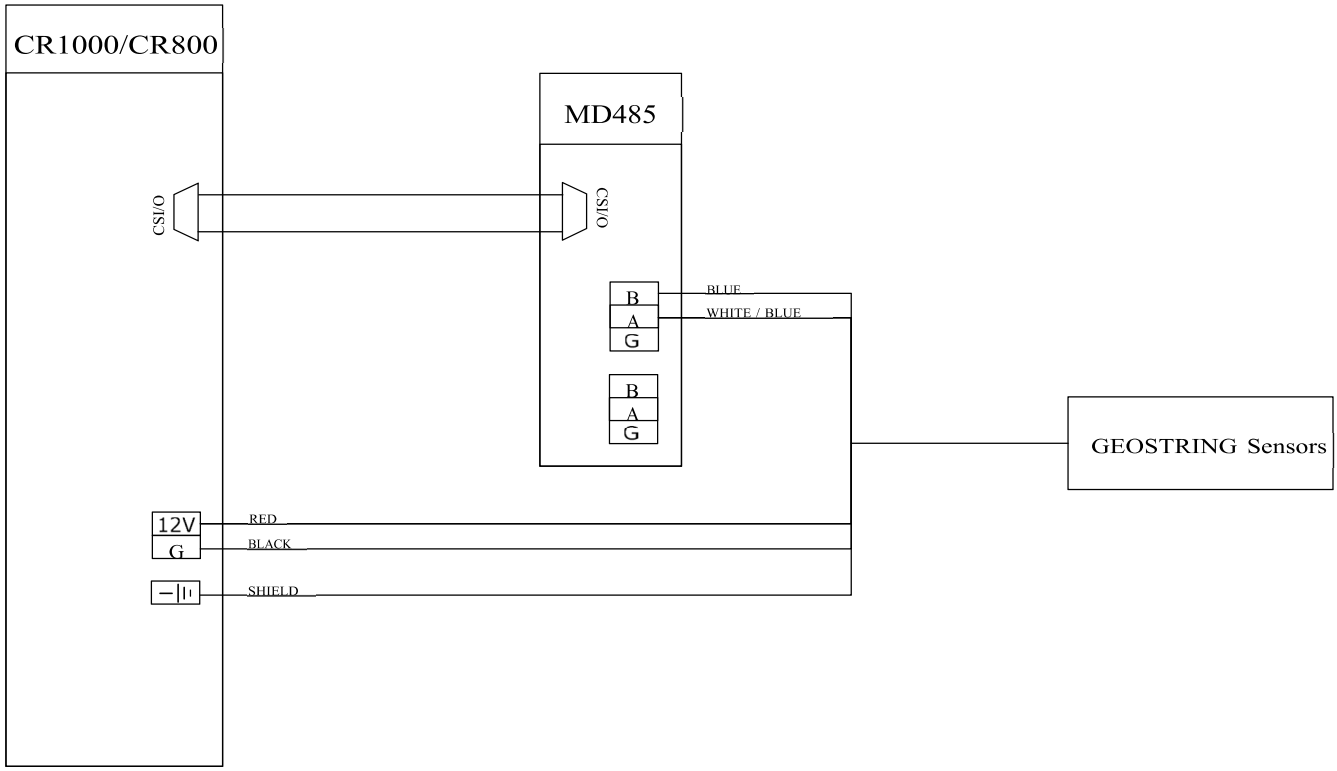
Overview

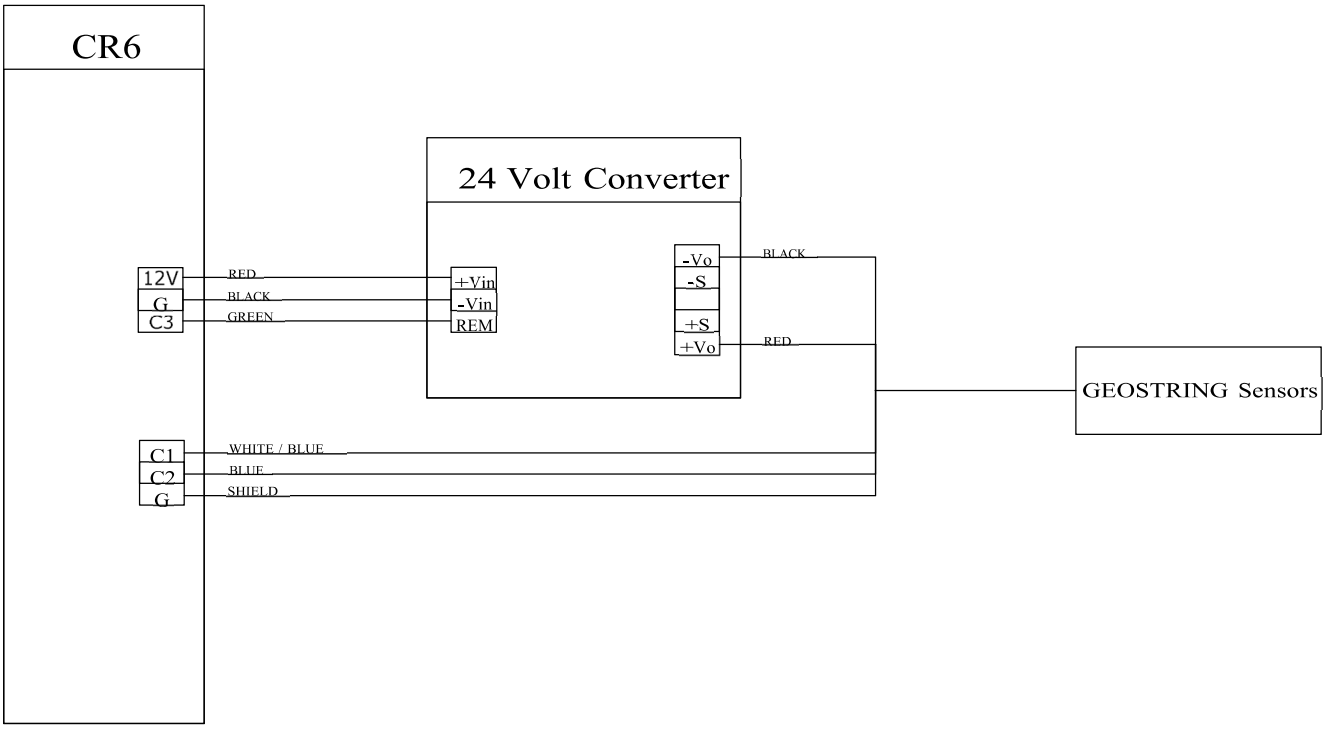
These instructions provide information needed for reading the GEOSTRING system with the Campbell Scientific CR300, CR800, CR1000, CR1000X or CR6 data loggers. Please note that the diagrams presented on the following page are examples and do not cover every potential connection type. A wiring diagram will be provided with each data logger system that is purchased.

Limitations

The last sensor node in the chain must receive 8 volts. This limits the number of sensor nodes that can be connected based on the distance of the chain from the data logger.

Number of Nodes	Jumper Length, m (12V supply)	Jumper Length, m (24V supply)
10	320	-
25	122	-
50	52	215
75	24	139
100	5	97
125	-	69
150	-	47
175	-	28
200	-	12


CR1000/CR800
MD485
CS I/O
CS I/O
B
A
G
BLUE
WHITE / BLUE
B
A
G
GEOSTRING Sensors
12V
G
RED
BLACK
SHIELD


CR6
24 Volt Converter
12V
G
C3
RED
BLACK
GREEN
+Vin
-Vin
REM
-Vo
-S
+S
+Vo
BLACK
RED
GEOSTRING Sensors
C1
C2
G
WHITE / BLUE
BLUE
SHIELD