# Model 8960 Series

## Digital Vibrating Wire Interfaces

Instruction Manual



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# 1. INTRODUCTION

GEOKON Model 8960 Series Addressable Vibrating Wire Interfaces incorporate state-of-the-art signal conditioning and digital addressing to enable Modbus RTU clients to read GEOKON vibrating wire sensors.

Interfaces are now manufactured with a pressure compensation vent to prevent condensation buildup in humid climates.

The 8960 interfaces allow reading both the vibrating wire and the thermistor built into the sensor.

Interfaces are queried using industry standard Modbus Remote Terminal Unit (RTU) protocol over a simple half-duplex RS-485 connection. The sensor is excited and measured by the interface, and the digitized measurement is then read.

## 1.1 8960 MODEL LIST

### 1.1.1 CABLE STYLE (CAB/12P)

| Model Number | Description |
|---|---|
| 8960-01C-CAB-SL | Addressable VW Interface for single sensor (non-bussed), 3 m cable length, bare leads |
| 8960-01C-CAB-VL | Addressable VW Interface for single sensor (non-bussed), customer specified cable length, bare leads |
| 8960-01C-12P-SL | Addressable Interface for single sensor (non-bussed), 3 m cable length, sensmetrics 12-pin connector |
| 8960-01C-12P-VL | Addressable Interface for single sensor (non-bussed), customer specified cable length, sensmetrics 12-pin connector |

***TABLE 1:*** *Cable Style Model List*

### 1.1.2 ENCLOSURE STYLE (CBL)

| Model Number | Description |
|---|---|
| 8960-01C-CBL | Single-Channel Addressable VW Interface in enclosure |
| 8960-04C-CBL | Four-Channel Addressable VW Interface in enclosure |
| 8960-08C-CBL | Eight-Channel Addressable VW Interface in enclosure |

***TABLE 2:*** *Enclosure Style Model List*

## 1.2 INCLUDED ACCESSORIES

| GeoNet Product Line | Part Number | Description | Quantity |
|---|---|---|---|
| Cable Style (CAB/12P) Interface | CON-959 | 2-Position Connector Housing | 1 |
| | CON-960 | 3-Position Connector Housing | 1 |
| Enclosure Style (CBL) Interface | N/A | N/A | N/A |

***TABLE 3:*** *List of Included Accessories by GeoNet Product Line*

## 1.3 ADDITIONAL ACCESSORIES (NOT INCLUDED)

| Part Number | Description |
|---|---|
| 8020-38 | Addressable Bus Converter |
| 8960-EXTENSION or -EXTENSION-V | Extension Cable with bare leads, 3 m (10') length. Varied cable lengths are available (-EXTENSION-V model). |

***TABLE 4:*** *Additional Accessories (Not Included)*

# 2. MODELS

## 2.1 ADDRESSABLE VIBRATING WIRE CABLE INTERFACE

The cable connector option will connect to one GEOKON vibrating wire gauge. Sensor cables are connected through a cable gland.

***FIGURE 1:*** *Cable Style (CAB/12P) Addressable VW Interface (Bare Leads shown)*

## 2.2 ADDRESSABLE VIBRATING WIRE ENCLOSURE INTERFACE

The enclosure option reads the quantity of gauges outlined below. Sensor cables are connected through cable glands.

### 2.2.1 SINGLE-CHANNEL ENCLOSURE INTERFACE

Single-channel interfaces will read one GEOKON vibrating wire gauge and integral thermistor.


***FIGURE 2:*** *Single-Channel Enclosure (CBL)*

### 2.2.2 FOUR-CHANNEL ENCLOSURE INTERFACE

Four-channel interfaces will read up to four GEOKON vibrating wire gauges and integral thermistors.


***FIGURE 3:*** *Four-Channel Enclosure (CBL)*

A four-channel interface can be configured as follows:

| Maximum Number of Gauges | Maximum Number of Load Cells |
|---|---|
| Four | One 3-gauge **or** one 4-gauge load cell<br>*Refer to Appendix J for load cell wiring tables* |

***TABLE 5:*** *Four-Channel Interface Gauge/Load Limits*

### 2.2.3 EIGHT-CHANNEL ENCLOSURE INTERFACE

Eight-channel interfaces will read up to eight GEOKON vibrating wire gauges and integral thermistors.


***FIGURE 4:*** *Eight-Channel Enclosure (CBL)*

An eight-channel interface can be configured as follows:

| Maximum Number of Gauges | Maximum Number of Load Cells |
|---|---|
| Eight | One 3-gauge **and** one 4-gauge load cell<br>Two 3-gauge **or** two 4-gauge load cells<br>One 6-gauge load cell<br>*Refer to Appendix J for load cell wiring tables* |

***TABLE 6:*** *Eight-Channel Interface Gauge/Load Limits*

# 3. INSTALLATION

Installation is different depending on the model number. Refer to the applicable procedure below.

## 3.1 INSTALLATION FOR 8960-01C-#-# (CAB/12P) CABLE INTERFACE

For added convenience, the Model 8960-01C Addressable Vibrating Wire (VW) Interface is assembled with the readout cable already attached.

***HARDWARE REQUIREMENTS***

Communications: RS-485, half-duplex

Data Rate: 115,200 baud

Power: 5V to 15V DC, 57mA (peak)

### 3.1.1 CONNECT THE SENSORS

To connect your sensor to the 8960 interface, attach the sensor cable using the following steps:

1. From one end of the sensor cable, trim off 2" to 3" of the jacket, exposing the five individual wires.
2. Trim all of the insulation off the shield wire, if applicable.
3. Cut the four remaining wires 6 mm (0.24") shorter than the shield wire.
4. Trim 6 mm (0.24") of insulation off each of these four wires. This short length reduces the possibility of a short circuit.

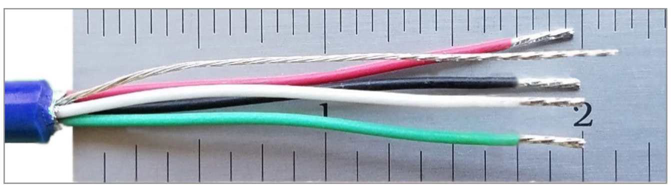

***FIGURE 5:*** *Wires Trimmed to Two Inches*

5. The ends of the wires should be as neat as possible (e.g., twisted, tinned, or ferruled), to ease insertion into the connectors of the interface.
6. Loosen the cable nut on the open end of the 8960 interface. See below.


***FIGURE 6:*** *Cable Nut*

7. Unscrew the instrument housing into two halves.
8. Remove and save the white plastic dowel. If you plan to eventually disconnect and store the 8960 interface, you should replace the dowel to ensure the housing remains water-tight.

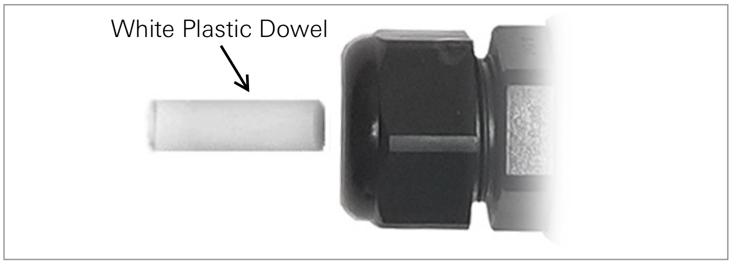


***FIGURE 7:*** *Plastic Dowel*

9. Slide the sensor cable through the cable nut and the cable gland.
10. For ease of wiring, the male half of the connector can be removed from the female half, which is mounted to the circuit board. To separate the two halves, pull with steady pressure on the male half until it comes free. Refer to the figure below.

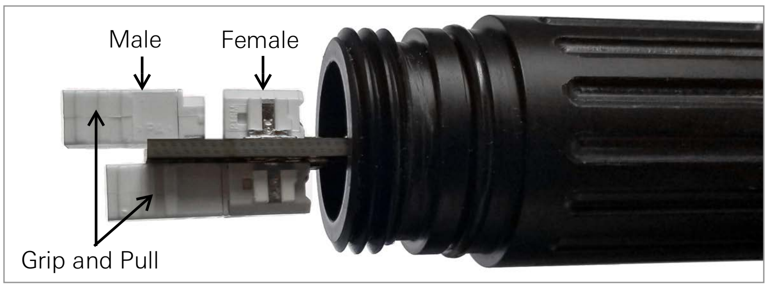


***FIGURE 8:*** *Detaching PCB Connectors*

11. Insert the shield wire into the **center** hole of the male three-wire connector. If the shield wire is not stiff enough to penetrate the center hole, double the thickness of the wire by bending the last 6 mm (0.24") of the shield wire over onto itself and try again. Refer to the figure below.

***FIGURE 9:*** *Doubled Shield Wire*

**Caution!** The shield wire must be inserted into the **center** hole of the three-hole connector; inserting the shield wire into any other position will cause a short and may damage the sensor and/or the interface.

12. Insert the two thermistor wires (white and green conductors are standard for GEOKON sensors) into the holes on either side of the shield wire **(hole choice does not matter)**.
13. Insert the remaining wires (red and black conductors are standard for GEOKON sensors) into the two-wire connector **(hole choice does not matter)**.
14. If the male halves of the connectors were removed from female halves, reinsert them to their counterparts on the circuit board. Refer to the figure below.

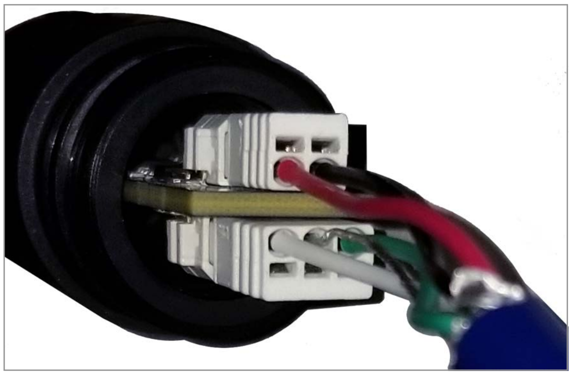

***FIGURE 10:*** *Connector Assembly*

15. Gently pull on each conductor of the cable to make sure the connections are secure.
16. Screw together the two halves of the housing.
17. Tighten the cable gland nut until it firmly grips the outer jacket of the cable. Doing this ensures that water does not enter the housing. **(Do not over tighten the nut; doing so may damage the plastic threads.)**
18. Connect the wires at the open end of the readout cable to the unit intended for reading the instrument. The wiring functions are displayed below:

| 8960-01C Conductor Color | Description |
|---|---|
| WHITE | Communication RS-485+ |
| GREEN | Communication RS-485- |
| RED | 12-volt power to the string |
| BLACK | Ground |
| SHIELD | Analog ground |

***TABLE 7:*** *8960-01C Wiring Functions*

### *RELEASING CONDUCTORS FROM THE INTERFACE CONNECTORS*

To release a conductor wire from the connector after it has been inserted, use the supplied screwdriver to push and hold in the small tab located just above the tinned end of the wire, as shown in the figure below. Then pull on the wire below the screwdriver.

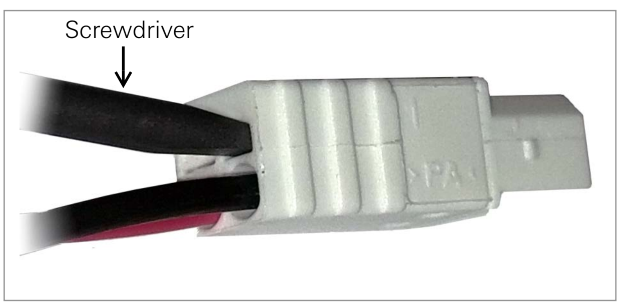


***FIGURE 11:*** *Releasing a Conductor*

## 3.2 INSTALLATION PROCEDURE FOR 8960-#-CBL ENCLOSURE INTERFACE

A general overview of the installation is shown in the steps below. Each step is described in detail in the sections that follow.

1. Connect the sensors
2. Connect additional interfaces
3. Connect a GeoNet Logger
4. Address the interface
5. Seal the interface

### 3.2.1 CONNECT THE SENSORS

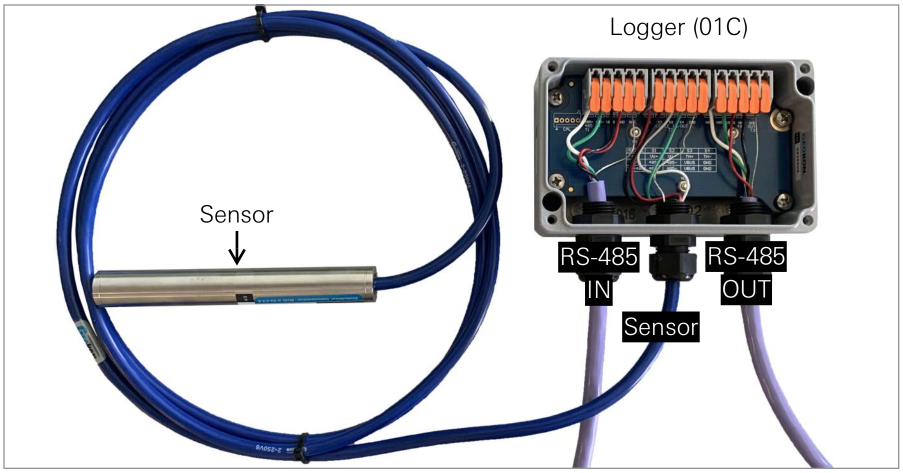


***FIGURE 12:*** *Sensor to Logger Connection*

For ease of wiring, sensor cables should be inserted into the cable glands on Multi-channel loggers in order from left to right (See Appendix I for labeled ports) and wired into the VW terminal blocks in sequence, starting with channel one. To connect a sensor using a cable gland connection:

1. Loosen the nut on the cable fitting and remove the white plastic dowel.
2. Slide the sensor cable through the cable gland nut and fitting.
3. Wire each conductor into the terminal block by pulling up (or pushing down) on an orange tab. Insert the bare end of the conductor into the terminal block, and then press the tab down (or release the tab). Refer to the wiring table below.

**Caution!** To prevent a short circuit, do not allow bare leads to touch each other during or after wiring.

| Sensor to Interface Wiring | | |
|---|---|---|
| **Position** | **Conductor Color** | **Description** |
| VW+ | RED | Vibrating Wire+ |
| VW- | BLACK | Vibrating Wire- |
| TH+ | WHITE | Thermistor+ |
| TH- | GREEN | Thermistor- |
| SHD | BARE | Analog Ground (Shield) |

***TABLE 8:*** *Sensor to Interface Wiring*

4. Pull gently on each conductor to make sure it is secure.
5. Tighten the cable gland nut until it firmly grips the outer jacket of the cable. The cable gland nut must be properly tightened to prevent water entry. Do not over-tighten, because this might strip the plastic threads.
6. Pull gently on the cable to make sure it is held in place by the cable gland.

### 3.2.2 CONNECT TO ADDITIONAL INTERFACES

Skip to Section 3.2.3 if not connecting additional interfaces.

Multiple interfaces can be connected together (chained) using the RS-485 ports. The bus limit is 32 units or 64 channels. The maximum distance between the datalogger and the last interface in the chain and the datalogger is 1,200 m.

1. Wire one end of an RS-485 cable into the RS-485 OUT of the first interface in the chain and the other end into the RS-485 IN of the next interface. Refer to the wiring chart below. (RS-485 cables are connected in the same manner as sensor cables. See Section 3.2.1 for details.)

| Interface RS-485 Port Wiring | | |
|---|---|---|
| **Position** | **Conductor Color** | **Description** |
| 485+ | WHITE | RS-485 Data+ |
| 485- | GREEN | RS-485 Data- |
| 12V | RED | 12 V Bus |
| GND | BLACK | Bus Ground |
| SHD | BARE | Analog Ground (Shield) |

***TABLE 9:*** *Interface RS-485 Port Wiring*

2. Repeat the previous step until all interfaces in the chain are connected.
3. Set the termination switch for the **last** device in the chain to the ON position.

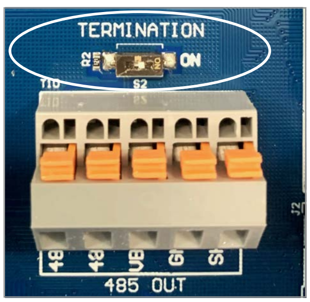


***FIGURE 13:*** *Termination Switch*

**Model 8960-01C-CBL single channel interface only:** When using the RS-485 OUT port to connect to another interface remove the termination resistor/jumper as shown below.

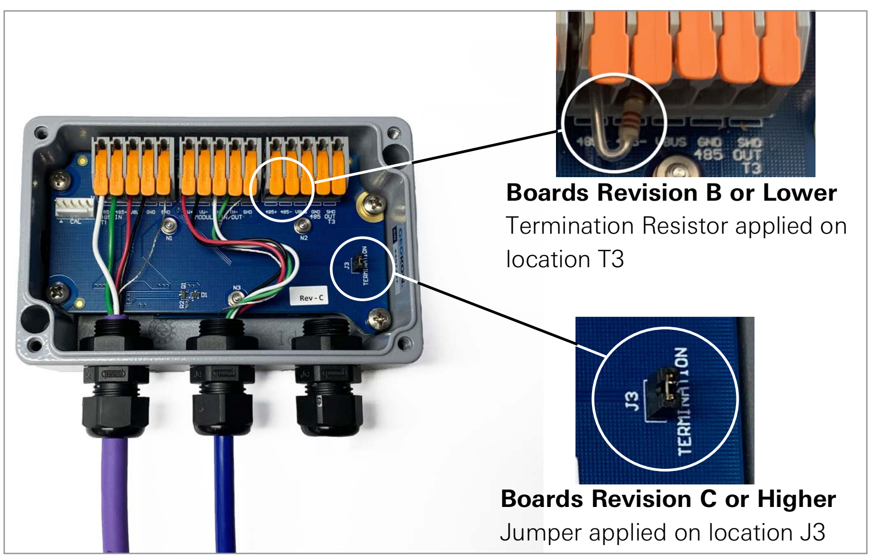


***FIGURE 14:*** *Terminator Resistor / Jumper Location for 8960-01C-CBL*

### 3.2.3 CONNECT A GEONET LOGGER

Connections can be made to GEOKON GeoNet Loggers/Dataloggers using the RS-485 ports.

1. It is best practice to connect to a GeoNet logger *before* the logger is powered on. If the connection is made after the logger is powered on, the additional channels will not be registered until the top of the next hour. Perform the procedure below to expedite the connection.
    a. Remove the batteries and move the power switch to the OFF position.
    b. Press and hold the reset button for 10 seconds.
    c. Press reset at least 5 additional times.
2. Wire one end of an RS-485 cable into the RS-485 IN of the first interface in the chain and the other end into the RS-485 connector of the datalogger (located just below the power switch). Refer to the wiring chart below. (RS-485 cables are connected in the same manner as sensor cables. See Section 3.2.1 for details.)

**Note:** Earlier multi-channel loggers had a "485_OUT" connector. Please disregard this connector.

| Interface RS-485 Port Wiring | | |
|---|---|---|
| **Position** | **Conductor Color** | **Description** |
| 485+ | WHITE | RS-485 Data+ |
| 485- | GREEN | RS-485 Data- |
| 12V | RED | 12 V Bus |
| GND | BLACK | Bus Ground |
| SHD | BARE | Analog Ground (Shield) |

***TABLE 10:*** *Interface RS-485 Port Wiring*

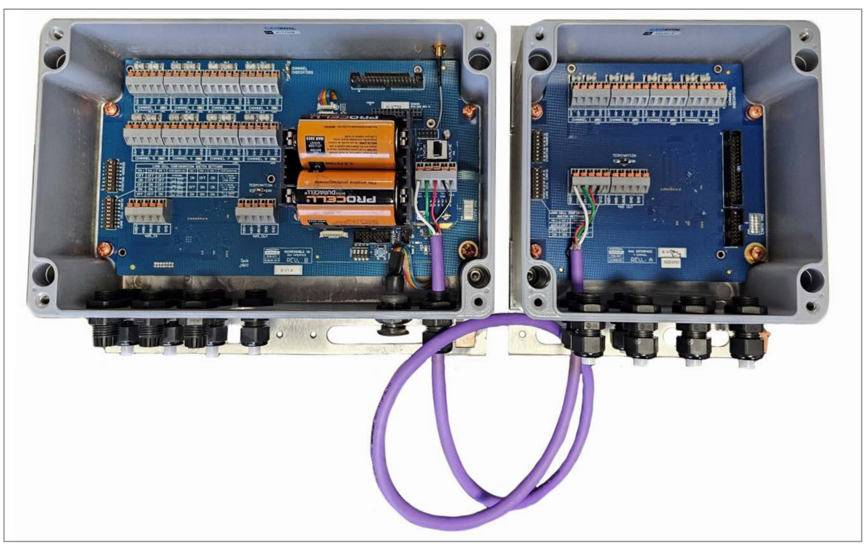

***FIGURE 15:*** *Model 8940 Datalogger (Left) Connected to Model 8960 Interface (Right)*

3. On multi-channel loggers set the termination switch to the OFF position (to the left).

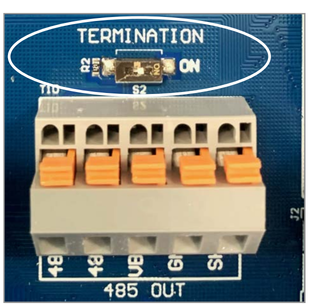


***FIGURE 16:*** *Termination Switch*

4. Channel Indicators can be used to verify which channels are read, and when. Turning off the indicators when they are not needed will conserve battery power.


***FIGURE 17:*** *Channel Indicators*

### 3.2.4 ADDRESS THE INTERFACE

#### *DETERMINING THE ADDRESS*

When using an interface to expand the capacity of a GeoNet Logger, the interface address must be set so that the channels (sensor inputs) of the interface are assigned correctly. The dip switches on the PCB are used to set the starting address (first channel) of the interface. The GeoNet Loggers will always be set to channel 1, as the first channel on the chain.

For example, a 4-channel logger reads channels 1-4; therefore, the starting address of a connected interface would be set to the next available channel, which is channel 5. Refer to the table below for more examples.

| GeoNet Logger Capacity | Set the First Interface to: |
|---|---|
| 1 Channel | Channel 2 |
| 4 Channels | Channel 5 |
| 8 Channels | Channel 9 |

***TABLE 11:*** *Interface RS-485 Port Wiring*

When connecting multiple interfaces in a chain, the starting address is determined by the total number of channels that precede it. For example, an interface proceeded by an eight-channel logger and two four-channel interfaces would have 16 channels preceding it (8+4+4=16); therefore, the next interface starting address would be set to channel 17.

#### *SETTING THE DIP SWITCHES*

Once the starting address for each interface has been determined, the DIP switches must be set accordingly. Each switch is assigned with a value (see Figure 18). Turn on the DIP switches which, when values are added together, will equal the starting address.

For example, if setting the starting address to 17, turn on switch numbers 1 and 5 (corresponding values 1+16=17).

For a complete list of addresses and switch combinations, see Appendix D.

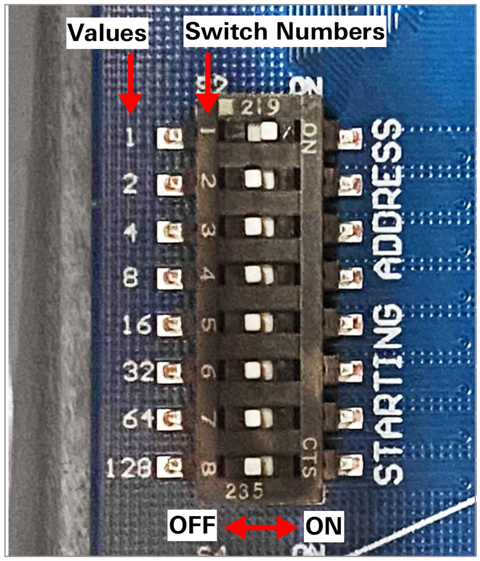


*FIGURE 18: Dip Switches*

### *ADDITIONAL INFORMATION AND CONSIDERATIONS*

The following rules and guidelines apply when setting a value:

- An address range can only be used once. The numbers within that range cannot be within the address range of another logger/interface on the same chain.
- Gaps between multiple address ranges are OK.
- The address ranges of the logger/interface(s) in the chain DO NOT need to be sequential when physically connected.
- The maximum channel value that can be set or included at the end of an address range is 250.

#### 3.2.5 SEAL THE INTERFACE

1. Record the serial number of the interfaces and the attached sensors. For multiple-channel interfaces, also record the channel to which each sensor has been connected.
2. Make sure the cover gasket and the mating ridge on the enclosure are clean and that the gasket is properly seated inside the groove on the cover. Place the cover on the unit.
3. Tighten the cover screws slowly. If using an electric screwdriver, **do not fully tighten the screws.** Perform the final tightening by hand. Work in a diagonal pattern.

**Note:** Make sure any unused openings are plugged with the provided dowel and the cable gland nut is tightened.

# 4. MODBUS RTU PROTOCOL

## 4.1 INTRODUCTION TO MODBUS

The Model 8960 Interface use the industry standard Modbus Remote Terminal Unit (RTU) protocol to communicate with the chosen readout method. As the name suggests, Modbus was designed to work on what is known as a **bus network**, meaning that every device receives every message that passes across the network. Model 8960 Interfaces use the RS-485 electrical interface because of its prevalence, simplicity, and success as a robust, industrial physical layer.

More information about Modbus can be found at the following website:

http://www.modbus.org/specs.php

## 4.2 MODBUS RTU OVERVIEW

The Modbus RTU protocol uses packets (messages made up of multiple sections) to communicate and transfer data between devices on the network. The general format of these packets is as follows:

1. Modbus Address (one byte) – The address of the specific device on the bus.
2. Function Code (one byte) – The action to be carried out by the server device.
3. Data (multi-byte) – The payload of the function code being sent.
4. Cyclic Redundancy Check or CRC (two bytes): A 16-bit data integrity check calculated over the other bytes in the packet.

## 4.3 MODBUS TABLES

Modbus tables (maps) define the memory locations within each 8960 interface and what information they contain. For example, the most recent sensor reading is stored in a table. This reading is presented in different formats in different sections of the table. The register location and size of these variables is detailed in the table below.

| Variable | Type | Modbus Register | Decimal | Description |
|---|---|---|---|---|
| Frequency | float32 | 0x0100 | 256 | Measured frequency in Hz |
| Resistance | float32 | 0x0102 | 258 | Measured thermistor-reasistance |
| Trigger | unit16 | 0x0118 | 280 | Writing to this register initiates a sample |

***TABLE 12:*** *RAM Storage*

## 4.4 READING SENSORS WITH THE 8960-01C INTERFACES

While Modbus RTU supports roughly 20 different function codes, the simple functionality of a bused VW sensor eliminates the need for all but two of them. Specifically, the **Preset Single Register** (0x06) and the **Read Holding Registers** (0x03). The **Preset Single Register** function code is used to issue a 'trigger' command to the interface. This initiates a pluck and read sequence. The **Read Holding Registers** function code is used to read the values stored in 16-bit registers in the 8960. In this case, the measurement result occupies two 16-bit registers. The readings can be retrieved as frequency (Hz). An example of this trigger and subsequent query is shown in Tables 6 and 7.

| | |
|---|---|
| TX->01 06 0118 00 01 C9 F1 | Trigger address #1 |
| RX<-01 06 0118 00 01 C9 F1 | Sensor acknowledges the single write |
| TX->01 03 0100 00 02 C5 F7 | Get contents of 2 registers @ 0x0100 (gauge frequency) |
| RX<-01 03 71 58 45 4B 12 7B | Registers = 0x454B7158, 3255.08 Hz |
| TX->01 03 01 02 00 02 64 37 | Get contents of 2 registers @ 0x0102 (thermistor resistance) |
| RX<-01 03 5D 3A 45 51 3A FE | Registers = 0x45515D3A, 3349.83 Ω |

| | Device Address | Function Code | Data Address | Data to Write | *CRC |
|---|---|---|---|---|---|
| $HEX_{16}$ | 01 | 06 | 0118 | 0001 | C9F1 |
| $DEC_{10}$ | 1 | 6 | 280 | 1 | 51697 |

***TABLE 13:*** *Example Trigger Command - Sensor #1*

The following table shows the IEEE-754 floating point response as two parts, each one composed of two bytes. Because of how this information is stored in the memory, the two parts are received in reverse order. The complete floating point number in HEX is 0x454B7158 (3255.08).

| | Device Address | Function Code | Byte Count | Lower 16 bits | Upper 16 bits | *CRC |
|---|---|---|---|---|---|---|
| $HEX_{16}$ | 01 | 03 | 04 | 7158 | 454B | 127B |
| $DEC_{10}$ | 1 | 3 | 4 | 3255.08 | | 4731 |

***TABLE 14:*** *Example Response - Sensor #1, Floating Point Frequency Reading*

```
14:20:01.750 [TX] - 01 03 01 00 00 02 C5 F7
14:20:01.860 [RX] - 01 03 71 D1 45 4B C3 91
```

***FIGURE 19:*** *PC Terminal Program Screen Capture*

**Note:** The Modbus CRC is sent the least-significant byte (LSB) first. When calculating the CRC for the write of address 0118 in Table 5, the Modbus CRC algorithm will return 0xF1C9 (61897D). Our examples show the decimal value after the LSB and most-significant byte (MSB) are swapped.

### 4.5 EXCITATION SWEEPS

The Model 8960 Interface is designed to excite and measure all GEOKON VW transducers. It will automatically detect any resonant frequency between 400 and 5,000 Hz. There are no settings for sensor type.

The maximum time between sending a trigger and data availability is **370** milliseconds.

# 5. MODBUS AND CAMPBELL SCIENTIFIC DATALOGGERS

## 5.1 DESCRIPTION

CRBasic is the programming language used with all Campbell Scientific CRBasic data loggers. Campbell Scientific's LoggerNet software is typically used when programming in CRBasic.

Campbell Scientific's CR6 datalogger can directly communicate with the Model 8960 Interface, using the RS-485 protocol.

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

| Datalogger Connection | Conductor Color | 8960 Connection (RS-485 IN) |
|---|---|---|
| 12 V (OUT) | RED | 12 V |
| 485+ | WHITE | 485+ |
| 485- | GREEN | 485- |
| GND | BLACK | GND |
| SHIELD | BARE | SHD |

***TABLE 15:*** *Datalogger with built-in RS-485 Conversion to Model 8960 Wiring Table*

## 5.2 MODEL 8020-38 ADDRESSABLE BUS CONVERTER

Campbell Scientific's CR1000 and CR800 dataloggers do not support the RS-485 protocol. To accommodate this, GEOKON provides the Model 8020-38 RS-485 to TTL/USB converter.

The Model 8020-38 allows an 8960 to be connected to personal computers, readouts, dataloggers, and programmable logic controllers. The converter acts as a bridge using the TTL or USB protocols between readers and the GEOKON RS-485-enabled sensor strings.


***FIGURE 20:*** *Model 8020-38 RS-485 to TTL/USB Converter*

If utilizing a Model 8020-38 to connect the 8960 to a datalogger, wire the connections as shown in both tables below. (The dataloggers must have the appropriate port available.)

| Datalogger Connection | Conductor Color | 8020-38 Connection |
|---|---|---|
| V+ | RED | 12 V (IN) |
| TX | WHITE | TX (IN) |
| RX | GREEN | RX (OUT) |
| GND | BLACK | GND |
| SHD | BARE | SHIELD |

***TABLE 16:*** *Datalogger to Model 8020-38 Wiring*

| 8020-38 Connection | Conductor Color | 8960 Connection (RS-485 IN) |
|---|---|---|
| 12 V (OUT) | RED | 12 V |
| 485+ | WHITE | 485+ |
| 485- | GREEN | 485- |
| GND | BLACK | GND |
| SHIELD | BARE | SHD |

***TABLE 17:*** *Model 8020-38 to 8960 Wiring*

Model 8020-38 Manual

For more information, please refer to the Model 8020-38 Instruction Manual.

# 6. READING A VW INTERFACE WITH AN ADDRESSABLE STRING READER (ASR)

## 6.1 DESCRIPTION

Software Resources

The ASR is a free application that runs on a PC and is available for download at geokon.com/Software. The ASR uses a USB port to communicate with the 8020-38 module described in Section 5.2.

When connected to a PC's USB port, the 8020-38 supplies power to the VW Interface module.

Connect the 8020-38 to the RS-485 IN location of the first 8960 interface of the chain. Use the wiring table below and connect in the same manner as described in Section 3.2.1.

| 8020-38 Connection | Conductor Color | 8960 Connection (RS-485 IN) |
|---|---|---|
| 12 V (OUT) | RED | 12 V |
| 485+ | WHITE | 485+ |
| 485- | GREEN | 485- |
| GND | BLACK | GND |
| SHIELD | BARE | SHD |

***TABLE 18:*** *Model 8020-38 to 8960 Wiring Table*

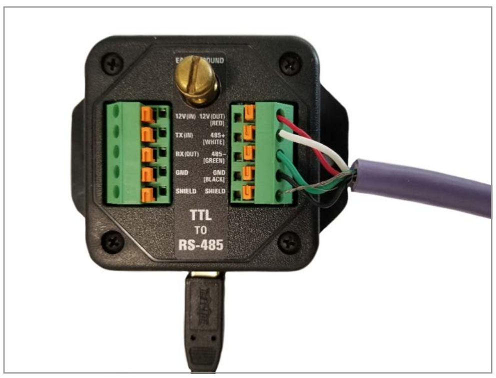


***FIGURE 21:*** *Model 8020-38 Connection to 8960*

## 6.2 ADDRESSABLE STRING READER

After downloading and installing the ASR, launch the application. The following screen will appear:

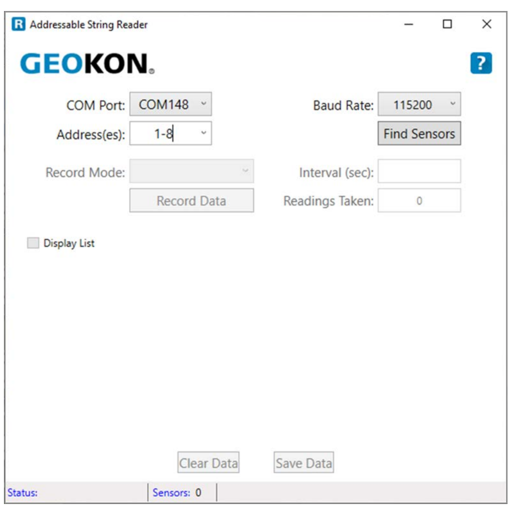


***FIGURE 22:*** *ASR Opening Screen*

1. Enter an address range where the lowest address will typically be 1 and the upper range will be the total number of sensor channels in the string.

   Example: If an 8960-08C-CAB is connected to the PC (via the 8020-38) the range should be entered as "1-8".

2. Ensure that the COM port is correctly set and then click on "Find Sensors". If the VW Interface was successfully found the screen below will be displayed.

In this example the 8020-38 is connected to the PC via COM148, the ASR has found 8 sensor channels and the sensor output for address (channel) 1 is currently being displayed in digits (frequency can also displayed). The individual channels of the 8960 device all share the 8960 unit serial number printed on the enclosure.

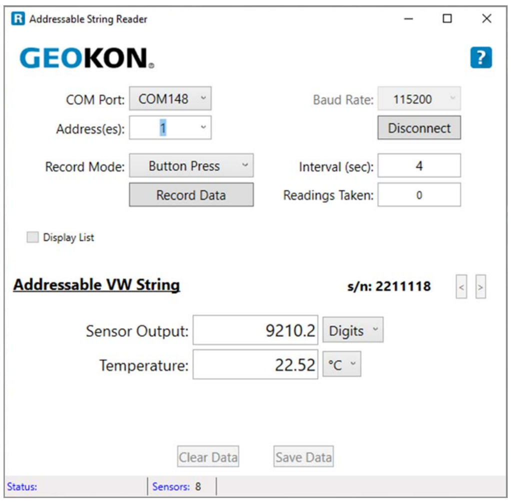


***FIGURE 23:*** *Sensor 1 Output Display*

3. From the "Address(es)" drop-down list, selecting "ALL" (Figure 24) enables the left and right arrow buttons on the right-hand side of the display (see Figure 25) and allows the user to easily scroll between sensor channels.

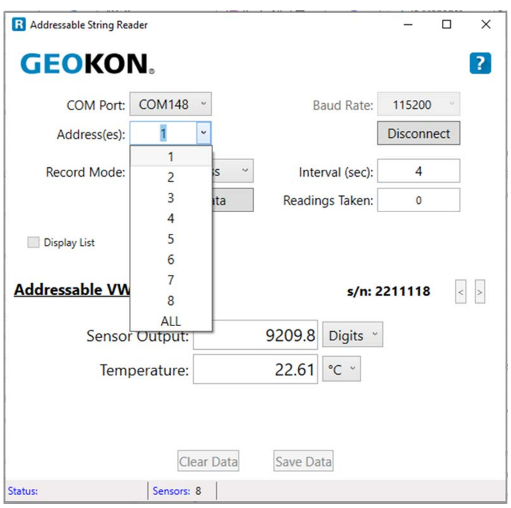


***FIGURE 24:*** *Address Selection*

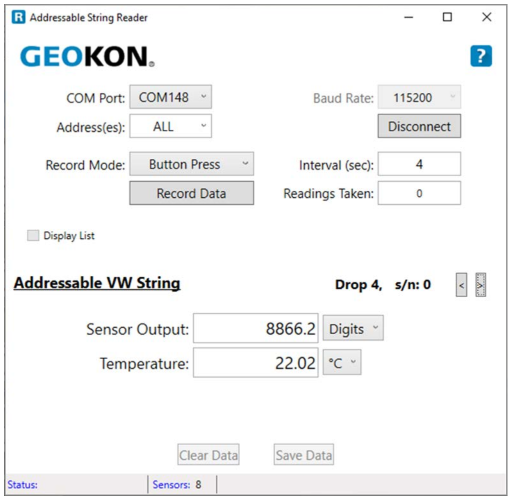


***FIGURE 25:*** *Drop Selection Buttons "<" and ">" Enabled*

4. Readings can be recorded one of two ways:
   - **Record manually:** Confirm "Button Press" is selected from the "Record Mode" drop-down list. Press the "Record Data" button.
   - **Record continuously:** Set a time interval in the "Interval (sec)" field. Select "Continuous" from the "Record Mode" drop-down list.
5. After one or more readings have been recorded, the "Display List" check box is enabled (Figure 26), allowing a "list" of readings to be displayed (Figure 27).

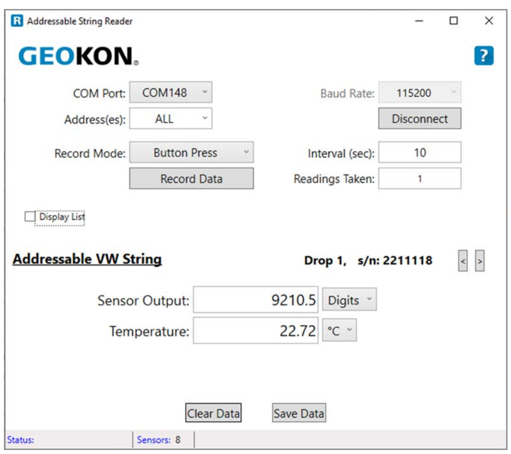


***FIGURE 26:*** *Display List Checkbox Enabled*

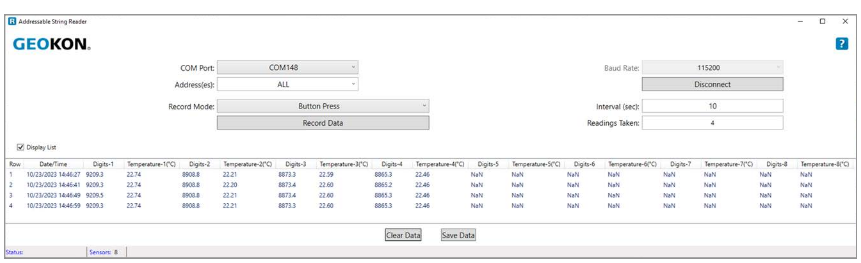


***FIGURE 27:*** *Readings List Enabled*

6. Readings can be saved to a .CSV file at any time by clicking on "Save Data". Help is available by clicking on the "?" button.

# APPENDIX A. SPECIFICATIONS

## A.1 MODEL 8960 DIGITAL VIBRATING WIRE INTERFACE

| **Power** | |
|---|---|
| Power Supply | 12 VDC |
| Current Per Sensor | 1.2 mA (idle) |
| Maximum Current | 35 mA (180Ω VW Coil)<br>57 mA (50Ω VW Coil) |
| Operating Temperature | -40 °C to 80 °C |
| **Communication** | |
| Interface | RS-485, Half-duplex (two-wire differential) |
| Protocol | Modbus RTU |
| Baud Rate | 115,200 bits/second |
| **Measurements** | |
| Frequency Range | 400 Hz to 6,500 Hz |
| Frequency Trueness | 0.082 Hz |
| Frequency Precision | 0.146 Hz (99% Confidence Interval) |
| Frequency Resolution | >0.002 Hz |
| Frequency Measurement Duration | < 370 ms |
| Thermistor Range | -20 ° C to +80 °C |
| Thermistor Accuracy | ±1% (25 °C thermistor point match) |
| Temperature Resolution | 10-bit, non-linear, 0.6 °C (worst case at -40 °C) |
| **Mechanical** | |
| Cable | 4 conductor, 2 twisted pairs, 6.35 mm (±0.25mm) diameter |
| Housing Dimensions | Cable Series (CAB): 100 x 25 mm (3.94 x 0.98")<br>Enclosure Series (CBL): See Appendix F |

***TABLE 19:*** *Specifications*

# APPENDIX B. MODBUS ADDRESSABLE SYSTEM

## B.1 MODBUS COMMUNICATIONS PARAMETERS

| Port Setting | Required Value |
|---|---|
| Bits per Second | 115,200 |
| Data bits | 8 |
| Parity | None |
| Stop bits | 1 |
| Flow Control | None |

***TABLE 20:*** *Modbus Communications Parameters*

## B.2 ERROR CODES

| Number | Name | Cause | Remedy |
|---|---|---|---|
| 2 | Temperature Sensor Range | Measured temperature out of range. Thermistor may be too hot, too cold, or damaged. | Use adjacent sensors to validate or estimate temperature. |
| 4 | Temperature Sensor Verify | Secondary temperature sensor differed too much from high accuracy primary sensor. | Use adjacent sensors to validate or estimate temperature. |
| 8 | System Reset | Unexpected interruption in prior measurement cycle. | Ensure supply voltage is sufficient. |

***TABLE 21:*** *Error Codes*

**Note:** The sensor stores and transmits errors in binary code to compact the information. Though unlikely, two errors could occur in one measurement cycle. The resulting code will be the sum of the error numbers, e.g., error 4 plus error 8 appears as number 12.

# APPENDIX C. CRBASIC PROGRAMMING

## C.1 SAMPLE PROGRAM

The following program uses a Model 8960 interface to directly connect to any single GEOKON vibrating wire sensor. The 8960 interface uses MODBUS RTU commands and returns a frequency (Hz) reading for the vibrating wire. It returns a resistance reading (Ohms) for the thermistor.

**Note:** 8960 MODBUS RTU table register numbers begin with 0. Campbell Scientific Dataloggers recognize the table register numbers as beginning with 1. All CRBasic register numbers are +1. Example: ModbusMaster won't send 0x118 unless "&H119" is entered in the command line.

```
'Define address of the 8960-01C
  Const Address = 1                    'address of Interface, used in variable declaration

'Constants used in Steinhart-Hart equation to calculate sensor temperature
'for 3k thermistor
  Const A = 1.4051E-3
  Const B = 2.369E-4
  Const C =1.019E-7

  Public ErrorCode                     'Error Code sent back from ModBus Command
  Public Hz(Address)                   'Frequency (Hz) from incoming data
  Public Digits(Address)               'Calculated Digits
  Public Res(Address)                  'Resistance (Ohms) from incoming data
  Public Celsius(Address)              'Calculated temperature (Celsius)
```

'Define Data Tables

```
DataTable(Test,1,-1)
  Sample (Address,Digits(),IEEE4)
  Sample (Address,Celsius(),IEEE4)
EndTable
```

'Main Program

```
BeginProg
   'Open COMport with RS-485 communications at 115200 baud rate
      SerialOpen (ComC1,115200,16,0,50,3)          'CR6 program
      SerialOpen (Com1,115200,16,0,50)             'CR1000 program
   'Read the interface/sensor every 30 seconds
      Scan (30,Sec,0,0)
   'Reset temporary storage for both Resistance and Hz so not to retain
   'previous reading
      Res (Address) = 0
      Hz (Address) = 0
   'Flush Serial between readings
      SerialFlush (ComC1)
   'Write to register 0x118 to trigger interface
   'NOTE: ModbusMaster won't send 0x118 unless "&H119" is entered
      ModbusMaster (ErrorCode,ComC1,115200,Count,6,1,&H119,1,1,10,0)
   'Delay after triggering the measurement
      Delay (1,1,Sec)
   'Use Modbus command to retrieve Hertz from string
      ModbusMaster (ErrorCode,ComC1,115200,Count,3,Hz(Address),&H101,1,1,10,0)
   'Calculate Digits from Hertz
      Digits(Address) = (Hz(Address)^2)/1000
   'Use Modbus command to retrieve thermistor resistance
      ModbusMaster (ErrorCode,ComC1,115200,Address,3,Res(Address),&H103,1,1,10,0)
   'Calculate thermistor temperature from Ohms to Celsius using Steinhart-Hart
   'equation
      Celsius(Address) = 1/(A+B*LN(Res(Address))+C*LN(Res(Address))^3)-273.15
   Next
   'Call Table to store Data
      CallTable Test
   NextScan
EndProg
```

# APPENDIX D. COMPLETE ADDRESS LIST

## D.1 ADDRESS LIST AND SWITCH COMBINATIONS

Available starting addresses and corresponding DIP switches are listed below.

| Starting Address | Turn ON DIP Switches | Starting Address | Turn ON DIP Switches | Starting Address | Turn ON DIP Switches | Starting Address | Turn ON DIP Switches | Starting Address | Turn ON DIP Switches |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 51 | 1,2,16,32 | 101 | 1,4,32,64 | 151 | 1,2,4,16,128 | 201 | 1,8,64,128 |
| 2 | 2 | 52 | 4,16,32 | 102 | 2,4,32,64 | 152 | 8,16,128 | 202 | 2,8,64,128 |
| 3 | 1,2 | 53 | 1,4,16,32 | 103 | 1,2,4,32,64 | 153 | 1,8,16,128 | 203 | 1,2,8,64,128 |
| 4 | 4 | 54 | 2,4,16,32 | 104 | 8,32,64 | 154 | 2,8,16,128 | 204 | 4,8,64,128 |
| 5 | 1,4 | 55 | 1,2,4,16,32 | 105 | 1,8,32,64 | 155 | 1,2,8,16,128 | 205 | 1,4,8,64,128 |
| 6 | 2,4 | 56 | 8,16,32 | 106 | 2,8,32,64 | 156 | 4,8,16,128 | 206 | 2,4,8,64,128 |
| 7 | 1,2,4 | 57 | 1,8,16,32 | 107 | 1,2,8,32,64 | 157 | 1,4,8,16,128 | 207 | 1,2,4,8,64,128 |
| 8 | 8 | 58 | 2,8,16,32 | 108 | 4,8,32,64 | 158 | 2,4,8,16,128 | 208 | 16,64,128 |
| 9 | 1,8 | 59 | 1,2,8,16,32 | 109 | 1,4,8,32,64 | 159 | 1,2,4,8,16,128 | 209 | 1,16,64,128 |
| 10 | 2,8 | 60 | 4,8,16,32 | 110 | 2,4,8,32,64 | 160 | 32,128 | 210 | 2,16,64,128 |
| 11 | 1,2,8 | 61 | 1,4,8,16,32 | 111 | 1,2,4,8,32,64 | 161 | 1,32,128 | 211 | 1,2,16,64,128 |
| 12 | 4,8 | 62 | 2,4,8,16,32 | 112 | 16,32,64 | 162 | 2,32,128 | 212 | 4,16,64,128 |
| 13 | 1,4,8 | 63 | 1,2,4,8,16,32 | 113 | 1,16,32,64 | 163 | 1,2,32,128 | 213 | 1,4,16,64,128 |
| 14 | 2,4,8 | 64 | 64 | 114 | 2,16,32,64 | 164 | 4,32,128 | 214 | 2,4,16,64,128 |
| 15 | 1,2,4,8 | 65 | 1,64 | 115 | 1,2,16,32,64 | 165 | 1,4,32,128 | 215 | 1,2,4,16,64,128 |
| 16 | 16 | 66 | 2,64 | 116 | 4,16,32,64 | 166 | 2,4,32,128 | 216 | 8,16,64,128 |
| 17 | 1,16 | 67 | 1,2,64 | 117 | 1,4,16,32,64 | 167 | 1,2,4,32,128 | 217 | 1,8,16,64,128 |
| 18 | 2,16 | 68 | 4,64 | 118 | 2,4,16,32,64 | 168 | 8,32,128 | 218 | 2,8,16,64,128 |
| 19 | 1,2,16 | 69 | 1,4,64 | 119 | 1,2,4,16,32,64 | 169 | 1,8,32,128 | 219 | 1,2,8,16,64,128 |
| 20 | 4,16 | 70 | 2,4,64 | 120 | 8,16,32,64 | 170 | 2,8,32,128 | 220 | 4,8,16,64,128 |
| 21 | 1,4,16 | 71 | 1,2,4,64 | 121 | 1,8,16,32,64 | 171 | 1,2,8,32,128 | 221 | 1,4,8,16,64,128 |
| 22 | 2,4,16 | 72 | 8,64 | 122 | 2,8,16,32,64 | 172 | 4,8,32,128 | 222 | 2,4,8,16,64,128 |
| 23 | 1,2,4,16 | 73 | 1,8,64 | 123 | 1,2,8,16,32,64 | 173 | 1,4,8,32,128 | 223 | 1,2,4,8,16,64,128 |
| 24 | 8,16 | 74 | 2,8,64 | 124 | 4,8,16,32,64 | 174 | 2,4,8,32,128 | 224 | 32,64,128 |
| 25 | 1,8,16 | 75 | 1,2,8,64 | 125 | 1,4,8,16,32,64 | 175 | 1,2,4,8,32,128 | 225 | 1,32,64,128 |
| 26 | 2,8,16 | 76 | 4,8,64 | 126 | 2,4,8,16,32,64 | 176 | 16,32,128 | 226 | 2,32,64,128 |
| 27 | 1,2,8,16 | 77 | 1,4,8,64 | 127 | 1,2,4,8,16,32,64 | 177 | 1,16,32,128 | 227 | 1,2,32,64,128 |
| 28 | 4,8,16 | 78 | 2,4,8,64 | 128 | 128 | 178 | 2,16,32,128 | 228 | 4,32,64,128 |
| 29 | 1,4,8,16 | 79 | 1,2,4,8,64 | 129 | 1,128 | 179 | 1,2,16,32,128 | 229 | 1,4,32,64,128 |
| 30 | 2,4,8,16 | 80 | 16,64 | 130 | 2,128 | 180 | 4,16,32,128 | 230 | 2,4,32,64,128 |
| 31 | 1,2,4,8,16 | 81 | 1,16,64 | 131 | 1,2,128 | 181 | 1,4,16,32,128 | 231 | 1,2,4,32,64,128 |
| 32 | 32 | 82 | 2,16,64 | 132 | 4,128 | 182 | 2,4,16,32,128 | 232 | 8,32,64,128 |
| 33 | 1,32 | 83 | 1,2,16,64 | 133 | 1,4,128 | 183 | 1,2,4,16,32,128 | 233 | 1,8,32,64,128 |
| 34 | 2,32 | 84 | 4,16,64 | 134 | 2,4,128 | 184 | 8,16,32,128 | 234 | 2,8,32,64,128 |
| 35 | 1,2,32 | 85 | 1,4,16,64 | 135 | 1,2,4,128 | 185 | 1,8,16,32,128 | 235 | 1,2,8,32,64,128 |
| 36 | 4,32 | 86 | 2,4,16,64 | 136 | 8,128 | 186 | 2,8,16,32,128 | 236 | 4,8,32,64,128 |
| 37 | 1,4,32 | 87 | 1,2,4,16,64 | 137 | 1,8,128 | 187 | 1,2,8,16,32,128 | 237 | 1,4,8,32,64,128 |
| 38 | 2,4,32 | 88 | 8,16,64 | 138 | 2,8,128 | 188 | 4,8,16,32,128 | 238 | 2,4,8,32,64,128 |
| 39 | 1,2,4,32 | 89 | 1,8,16,64 | 139 | 1,2,8,128 | 189 | 1,4,8,16,32,128 | 239 | 1,2,4,8,32,64,128 |
| 40 | 8,32 | 90 | 2,8,16,64 | 140 | 4,8,128 | 190 | 2,4,8,16,32,128 | 240 | 16,32,64,128 |
| 41 | 1,8,32 | 91 | 1,2,8,16,64 | 141 | 1,4,8,128 | 191 | 1,2,4,8,16,32,128 | 241 | 1,16,32,64,128 |
| 42 | 2,8,32 | 92 | 4,8,16,64 | 142 | 2,4,8,128 | 192 | 64,128 | 242 | 2,16,32,64,128 |
| 43 | 1,2,8,32 | 93 | 1,4,8,16,64 | 143 | 1,2,4,8,128 | 193 | 1,64,128 | 243 | 1,2,16,32,64,128 |
| 44 | 4,8,32 | 94 | 2,4,8,16,64 | 144 | 16,128 | 194 | 2,64,128 | 244 | 4,16,32,64,128 |
| 45 | 1,4,8,32 | 95 | 1,2,4,8,16,64 | 145 | 1,16,128 | 195 | 1,2,64,128 | 245 | 1,4,16,32,64,128 |
| 46 | 2,4,8,32 | 96 | 32,64 | 146 | 2,16,128 | 196 | 4,64,128 | 246 | 2,4,16,32,64,128 |
| 47 | 1,2,4,8,32 | 97 | 1,32,64 | 147 | 1,2,16,128 | 197 | 1,4,64,128 | 247 | 1,2,4,16,32,64,128 |
| 48 | 16,32 | 98 | 2,32,64 | 148 | 4,16,128 | 198 | 2,4,64,128 | 248 | 8,16,32,64,128 |
| 49 | 1,16,32 | 99 | 1,2,32,64 | 149 | 1,4,16,128 | 199 | 1,2,4,64,128 | 249 | 1,8,16,32,64,128 |
| 50 | 2,16,32 | 100 | 4,32,64 | 150 | 2,4,16,128 | 200 | 8,64,128 | 250 | 2,8,16,32,64,128 |

***TABLE 22:*** *Address List and Switch Combinations*

# APPENDIX E. THERMISTOR TEMPERATURE DERIVATION

## E.1 3KΩ THERMISTOR RESISTANCE (STANDARD)

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 1:*** *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 23:*** *3KΩ Thermistor Resistance*

## E.2 8.2KΩ THERMISTOR RESISTANCE

Thermistor Type: Thermometrics BRBR55KA822J

Resistance to Temperature Equation:

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

***EQUATION 2:*** *8.5KΩ Thermistor Resistance*

Where:
T = Temperature in °C
LnR = Natural Log of Thermistor Resistance
A = $1.02569 \times 10^{-3}$
B = $2.369 \times 10^{-4}$
C = $1.019 \times 10^{-7}$
**Note:** Coefficients calculated over the –50 to +150 °C span.

| Ohms | Temp | LnR | $LnR^3$ | Calc. Temp | Diff | F.S. Error | Ohms | Temp | LnR | $LnR^3$ | Calc. Temp | Diff | F.S. Error |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 113898 | -30 | 11.643 | 1578.342 | -30.17 | 0.17 | 0.06 | 407.62 | 120 | 6.010 | 217.118 | 120.00 | 0.00 | 0.00 |
| 86182 | -25 | 11.364 | 1467.637 | -25.14 | 0.14 | 0.05 | 360.8 | 125 | 5.888 | 204.162 | 125.00 | 0.00 | 0.00 |
| 65805 | -20 | 11.094 | 1365.581 | -20.12 | 0.12 | 0.04 | 320.21 | 130 | 5.769 | 191.998 | 130 | 0.00 | 0.00 |
| 50684.2 | -15 | 10.833 | 1271.425 | -15.10 | 0.10 | 0.03 | 284.95 | 135 | 5.652 | 180.584 | 135 | 0.00 | 0.00 |
| 39360 | -10 | 10.581 | 1184.457 | -10.08 | 0.08 | 0.03 | 254.2 | 140 | 5.538 | 169.859 | 140.01 | -0.01 | 0.00 |
| 30807.4 | -5 | 10.336 | 1104.068 | -5.07 | 0.07 | 0.02 | 227.3 | 145 | 5.426 | 159.773 | 145.02 | -0.02 | -0.01 |
| 24288.4 | 0 | 10.098 | 1029.614 | -0.05 | 0.05 | 0.02 | 203.77 | 150 | 5.317 | 150.314 | 150.03 | -0.03 | -0.01 |
| 19294.6 | 5 | 9.868 | 960.798 | 4.96 | 0.04 | 0.01 | 183.11 | 155 | 5.210 | 141.428 | 155.04 | -0.04 | -0.01 |
| 15424.2 | 10 | 9.644 | 896.871 | 9.98 | 0.02 | 0.01 | 164.9 | 160 | 5.105 | 133.068 | 160.06 | -0.06 | -0.02 |
| 12423 | 15 | 9.427 | 837.843 | 14.98 | 0.02 | 0.01 | 148.83 | 165 | 5.003 | 125.210 | 165.08 | -0.08 | -0.03 |
| 10061.4 | 20 | 9.216 | 782.875 | 19.99 | 0.01 | 0.00 | 134.64 | 170 | 4.903 | 117.837 | 170.09 | -0.09 | -0.03 |
| 8200 | 25 | 9.012 | 731.893 | 25.00 | 0.00 | 0.00 | 122.1 | 175 | 4.805 | 110.927 | 175.08 | -0.08 | -0.03 |
| 6721.54 | 30 | 8.813 | 684.514 | 30.01 | -0.01 | 0.00 | 110.95 | 180 | 4.709 | 104.426 | 180.07 | -0.07 | -0.02 |
| 5540.74 | 35 | 8.620 | 640.478 | 35.01 | -0.01 | 0.00 | 100.94 | 185 | 4.615 | 98.261 | 185.10 | -0.10 | -0.04 |
| 4592 | 40 | 8.432 | 599.519 | 40.02 | -0.02 | -0.01 | 92.086 | 190 | 4. 523 | 92.512 | 190.09 | -0.09 | -0.03 |
| 3825.3 | 45 | 8.249 | 561.392 | 45.02 | -0.02 | -0.01 | 84.214 | 195 | 4.433 | 87.136 | 195.05 | -0.05 | -0.02 |
| 3202.92 | 50 | 8.072 | 525.913 | 50.01 | -0.01 | -0.01 | 77.088 | 200 | 4.345 | 82.026 | 200.05 | -0.05 | -0.02 |
| 2693.7 | 55 | 7.899 | 492.790 | 55.02 | -0.02 | -0.01 | 70.717 | 205 | 4.259 | 77.237 | 205.02 | -0.02 | -0.01 |
| 2276.32 | 60 | 7.730 | 461.946 | 60.02 | -0.02 | -0.01 | 64.985 | 210 | 4.174 | 72.729 | 210.00 | 0.00 | 0.00 |
| 1931.92 | 65 | 7.566 | 433.157 | 65.02 | -0.02 | -0.01 | 59.819 | 215 | 4.091 | 68.484 | 214.97 | 0.03 | 0.01 |
| 1646.56 | 70 | 7.406 | 406.283 | 70.02 | -0.02 | -0.01 | 55.161 | 220 | 4.010 | 64.494 | 219.93 | 0.07 | 0.02 |
| 1409.58 | 75 | 7.251 | 381.243 | 75.01 | -0.01 | 0.00 | 50.955 | 225 | 3.931 | 60.742 | 224.88 | 0.12 | 0.04 |
| 1211.14 | 80 | 7.099 | 357.808 | 80.00 | 0.00 | 0.00 | 47.142 | 230 | 3.853 | 57.207 | 229.82 | 0.18 | 0.06 |
| 1044.68 | 85 | 6.951 | 335.915 | 85.00 | 0.00 | 0.00 | 43.673 | 235 | 3.777 | 53.870 | 234.77 | 0.23 | 0.08 |
| 903.64 | 90 | 6.806 | 315.325 | 90.02 | -0.02 | -0.01 | 40.533 | 240 | 3.702 | 50.740 | 239.69 | 0.31 | 0.11 |
| 785.15 | 95 | 6.666 | 296.191 | 95.01 | -0.01 | 0.00 | 37.671 | 245 | 3.629 | 47.788 | 244.62 | 0.38 | 0.13 |
| 684.37 | 100 | 6.528 | 278.253 | 100.00 | 0.00 | 0.00 | 35.055 | 250 | 3.557 | 45.001 | 249.54 | 0.46 | 0.16 |
| 598.44 | 105 | 6.394 | 261.447 | 105.00 | 0.00 | 0.00 | 32.677 | 255 | 3.487 | 42.387 | 254.44 | 0.56 | 0.19 |
| 524.96 | 110 | 6.263 | 245.705 | 110.00 | 0.00 | 0.00 | 30.496 | 260 | 3.418 | 39.917 | 259.34 | 0.66 | 0.23 |
| 461.91 | 115 | 6.135 | 230.952 | 115.00 | 0.00 | 0.00 | | | | | | | |

***TABLE 24:*** *8.2KΩ Thermistor Resistance*

## E.3 10KΩ THERMISTOR RESISTANCE (HIGH TEMP.)

Thermistor Type: US Sensor 103JL1A

Resistance to Temperature Equation:

$$T = \frac{1}{A + B(LnR) + C(LnR)^3 + D(LnR)^5} - 273.15$$

***EQUATION 3:*** *10KΩ Thermistor Resistance*

Where:
T = Temperature in °C
LnR = Natural Log of Thermistor Resistance
A = $1.127670 \times 10^{-3}$
B = $2.344442 \times 10^{-4}$
C = $8.476921 \times 10^{-8}$
D = $1.175122 \times 10^{-11}$

**Note:** Coefficients optimized for a curve **J** Thermistor over the temperature range of 0 °C to +250 °C.

| Ohms | Temp | Ohms | Temp | Ohms | Temp | Ohms | Temp | Ohms | Temp | Ohms | Temp | Ohms | Temp | Ohms | Temp |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 32,650 | 0 | 7,402 | 32 | 2,157 | 64 | 763.5 | 96 | 316.6 | 128 | 148.4 | 160 | 76.5 | 192 | 42.8 | 224 |
| 31,029 | 1 | 7,098 | 33 | 2,083 | 65 | 741.2 | 97 | 308.7 | 129 | 145.1 | 161 | 75.0 | 193 | 42.1 | 225 |
| 29,498 | 2 | 6,808 | 34 | 2,011 | 66 | 719.6 | 98 | 301.0 | 130 | 142.0 | 162 | 73.6 | 194 | 41.4 | 226 |
| 28,052 | 3 | 6,531 | 35 | 1,942 | 67 | 698.7 | 99 | 293.5 | 131 | 138.9 | 163 | 72.2 | 195 | 40.7 | 227 |
| 26,685 | 4 | 6,267 | 36 | 1,876 | 68 | 678.6 | 100 | 286.3 | 132 | 135.9 | 164 | 70.8 | 196 | 40.0 | 228 |
| 25,392 | 5 | 6,015 | 37 | 1,813 | 69 | 659.1 | 101 | 279.2 | 133 | 133.0 | 165 | 69.5 | 197 | 39.3 | 229 |
| 24,170 | 6 | 5,775 | 38 | 1,752 | 70 | 640.3 | 102 | 272.4 | 134 | 130.1 | 166 | 68.2 | 198 | 38.7 | 230 |
| 23,013 | 7 | 5,545 | 39 | 1,693 | 71 | 622.2 | 103 | 265.8 | 135 | 127.3 | 167 | 66.9 | 199 | 38.0 | 231 |
| 21,918 | 8 | 5,326 | 40 | 1,637 | 72 | 604.6 | 104 | 259.3 | 136 | 124.6 | 168 | 65.7 | 200 | 37.4 | 232 |
| 20,882 | 9 | 5,117 | 41 | 1,582 | 73 | 587.6 | 105 | 253.1 | 137 | 122.0 | 169 | 64.4 | 201 | 36.8 | 233 |
| 19,901 | 10 | 4,917 | 42 | 1,530 | 74 | 571.2 | 106 | 247.0 | 138 | 119.4 | 170 | 63.3 | 202 | 36.2 | 234 |
| 18,971 | 11 | 4,725 | 43 | 1,480 | 75 | 555.3 | 107 | 241.1 | 139 | 116.9 | 171 | 62.1 | 203 | 35.6 | 235 |
| 18,090 | 12 | 4,543 | 44 | 1,432 | 76 | 539.9 | 108 | 235.3 | 140 | 114.5 | 172 | 61.0 | 204 | 35.1 | 236 |
| 17,255 | 13 | 4,368 | 45 | 1,385 | 77 | 525.0 | 109 | 229.7 | 141 | 112.1 | 173 | 59.9 | 205 | 34.5 | 237 |
| 16,463 | 14 | 4,201 | 46 | 1,340 | 78 | 510.6 | 110 | 224.3 | 142 | 109.8 | 174 | 58.8 | 206 | 33.9 | 238 |
| 15,712 | 15 | 4,041 | 47 | 1,297 | 79 | 496.7 | 111 | 219.0 | 143 | 107.5 | 175 | 57.7 | 207 | 33.4 | 239 |
| 14,999 | 16 | 3,888 | 48 | 1,255 | 80 | 483.2 | 112 | 213.9 | 144 | 105.3 | 176 | 56.7 | 208 | 32.9 | 240 |
| 14,323 | 17 | 3,742 | 49 | 1,215 | 81 | 470.1 | 113 | 208.9 | 145 | 103.2 | 177 | 55.7 | 209 | 32.3 | 241 |
| 13,681 | 18 | 3,602 | 50 | 1,177 | 82 | 457.5 | 114 | 204.1 | 146 | 101.1 | 178 | 54.7 | 210 | 31.8 | 242 |
| 13,072 | 19 | 3,468 | 51 | 1,140 | 83 | 445.3 | 115 | 199.4 | 147 | 99.0 | 179 | 53.7 | 211 | 31.3 | 243 |
| 12,493 | 20 | 3,340 | 52 | 1,104 | 84 | 433.4 | 116 | 194.8 | 148 | 97.0 | 180 | 52.7 | 212 | 30.8 | 244 |
| 11,942 | 21 | 3,217 | 53 | 1,070 | 85 | 421.9 | 117 | 190.3 | 149 | 95.1 | 181 | 51.8 | 213 | 30.4 | 245 |
| 11,419 | 22 | 3,099 | 54 | 1,037 | 86 | 410.8 | 118 | 186.1 | 150 | 93.2 | 182 | 50.9 | 214 | 29.9 | 246 |
| 10,922 | 23 | 2,986 | 55 | 1,005 | 87 | 400.0 | 119 | 181.9 | 151 | 91.3 | 183 | 50.0 | 215 | 29.4 | 247 |
| 10,450 | 24 | 2,878 | 56 | 973.8 | 88 | 389.6 | 120 | 177.7 | 152 | 89.5 | 184 | 49.1 | 216 | 29.0 | 248 |
| 10,000 | 25 | 2,774 | 57 | 944.1 | 89 | 379.4 | 121 | 173.7 | 153 | 87.7 | 185 | 48.3 | 217 | 28.5 | 249 |
| 9,572 | 26 | 2,675 | 58 | 915.5 | 90 | 369.6 | 122 | 169.8 | 154 | 86.0 | 186 | 47.4 | 218 | 28.1 | 250 |
| 9,165 | 27 | 2,579 | 59 | 887.8 | 91 | 360.1 | 123 | 166.0 | 155 | 84.3 | 187 | 46.6 | 219 | | |
| 8,777 | 28 | 2,488 | 60 | 861.2 | 92 | 350.9 | 124 | 162.3 | 156 | 82.7 | 188 | 45.8 | 220 | | |
| 8,408 | 29 | 2,400 | 61 | 835.4 | 93 | 341.9 | 125 | 158.6 | 157 | 81.1 | 189 | 45.0 | 221 | | |
| 8,057 | 30 | 2,316 | 62 | 810.6 | 94 | 333.2 | 126 | 155.1 | 158 | 79.5 | 190 | 44.3 | 222 | | |
| 7,722 | 31 | 2,235 | 63 | 786.6 | 95 | 324.8 | 127 | 151.7 | 159 | 78.0 | 191 | 43.5 | 223 | | |

***TABLE 25:*** *10KΩ Thermistor Resistance*

# APPENDIX F. UNIT DIMENSIONS OF ENCLOSURE SERIES

## F.1 SINGLE-CHANNEL ENCLOSURE (01C-CBL) MODELS

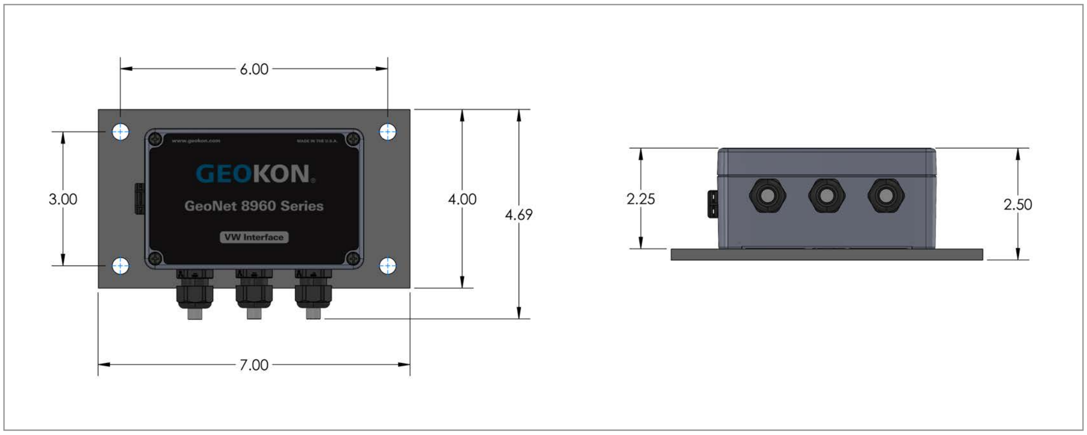


***FIGURE 28:*** *Single-Channel Enclosure (01C-CBL) Models*

## F.2 FOUR-CHANNEL ENCLOSURE (04C-CBL) MODELS

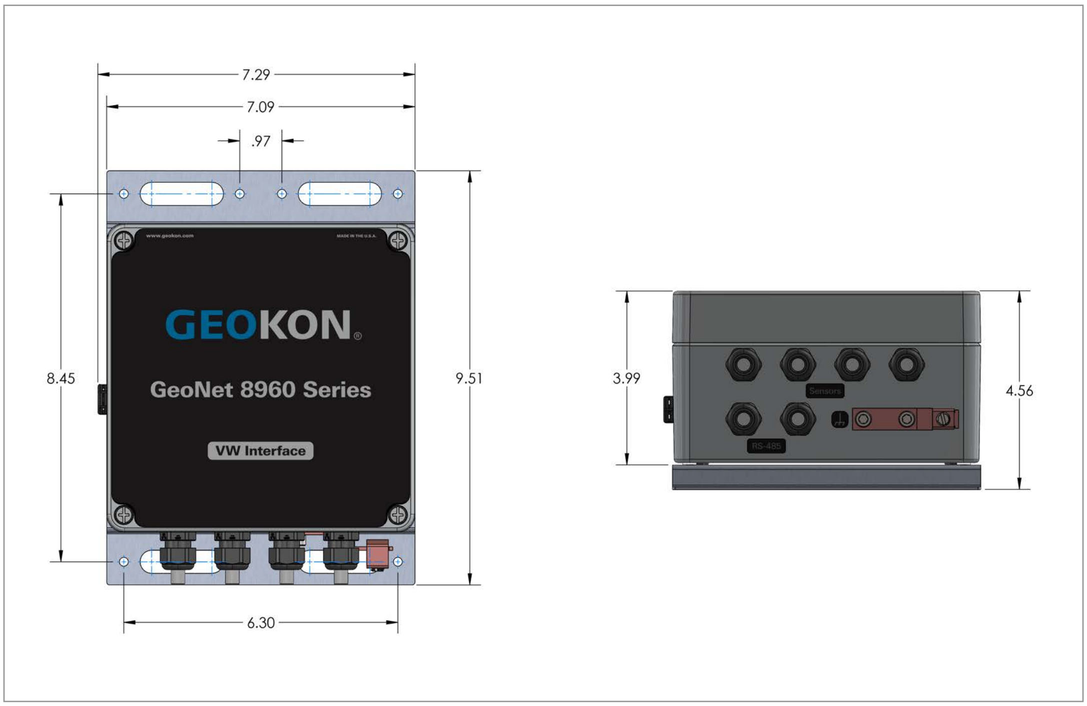


***FIGURE 29:*** *Four-Channel Enclosure (04C-CBL) Models*

## F.3 EIGHT-CHANNEL ENCLOSURE (08C-CBL) MODELS

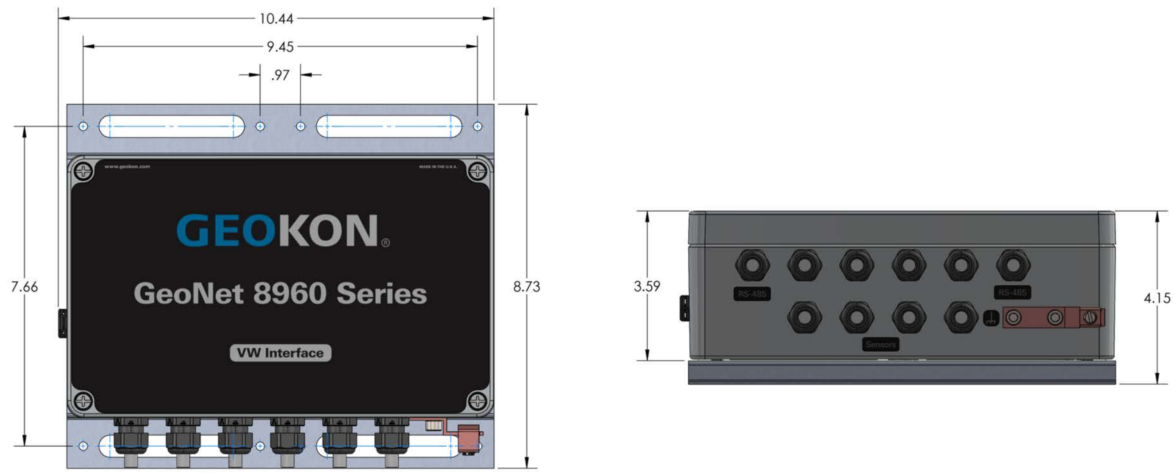


***FIGURE 30:*** *Eight-Channel Enclosure (08C-CBL) Models*

# APPENDIX G. MOUNTING BRACKET DIMENSIONS

## G.1 SINGLE-CHANNEL ENCLOSURE (01C-CBL) MODELS

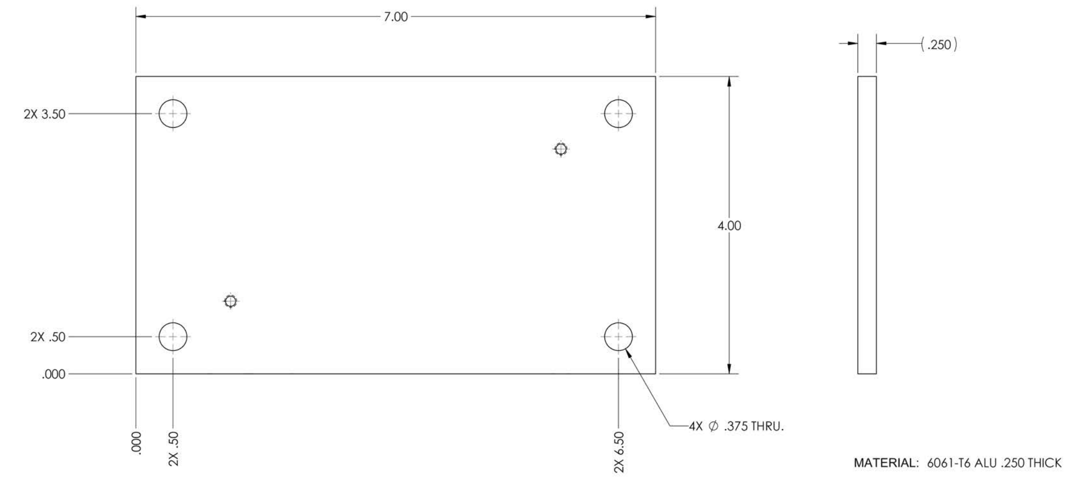


***FIGURE 31:*** *Single-Channel Enclosure (01C-CBL) Models*

## G.2 FOUR-CHANNEL ENCLOSURE (04C-CBL) MODELS

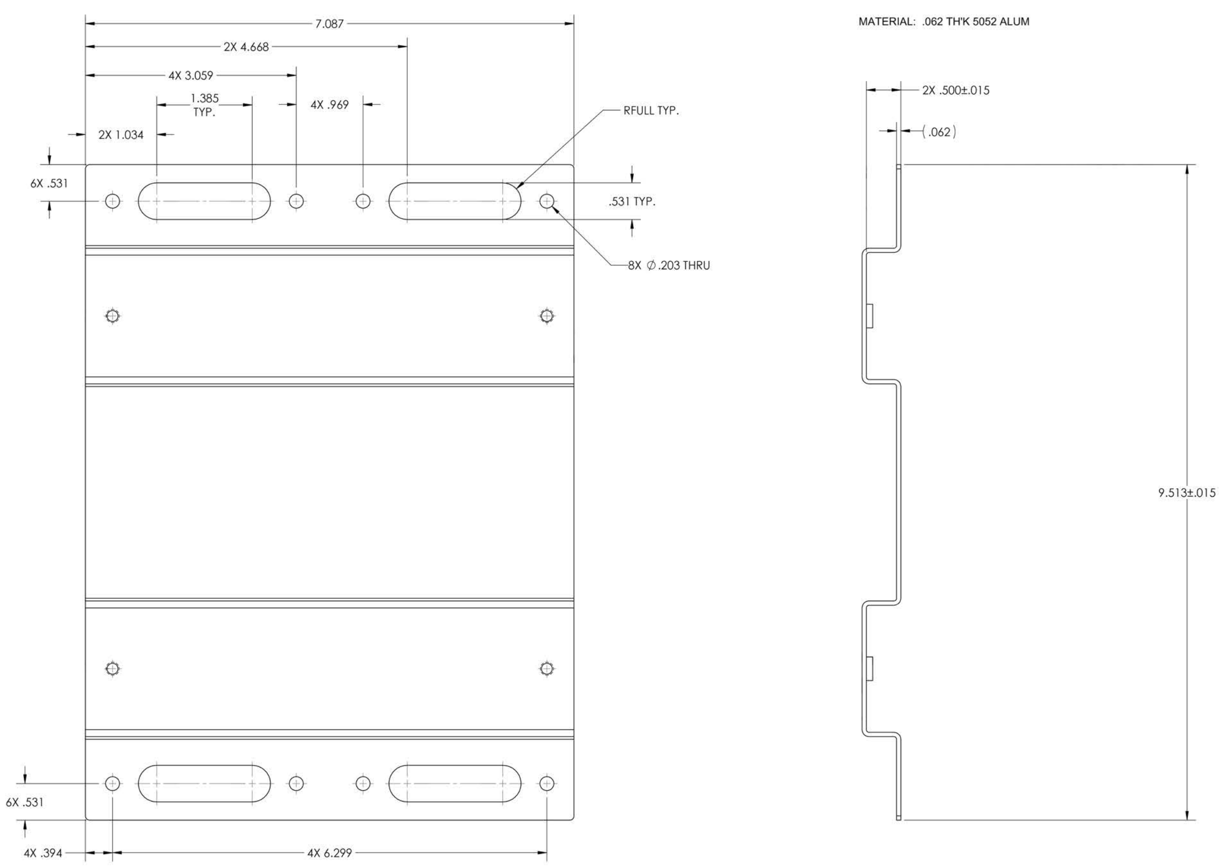


***FIGURE 32:*** *Four-Channel Enclosure (04C-CBL) Models*

## G.3 EIGHT-CHANNEL ENCLOSURE (08C-CBL) MODELS

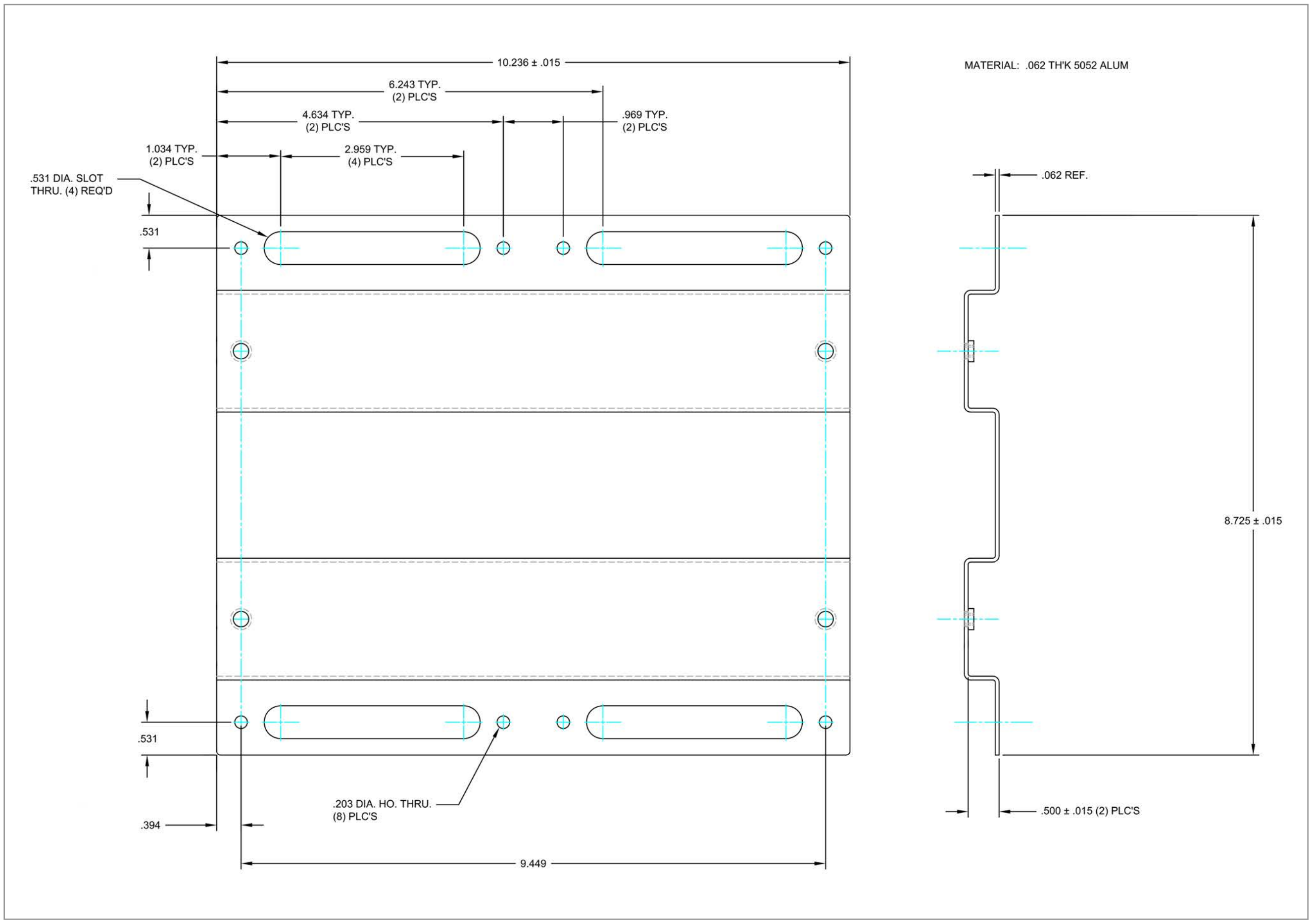


***FIGURE 33:*** *Eight-Channel Enclosure (08C-CBL) Models*

# APPENDIX H.   COMPONENTS (TYPICAL REPLACEMENT PARTS)

## H.1   SINGLE-CHANNEL CABLE (12P AND CAB) MODELS

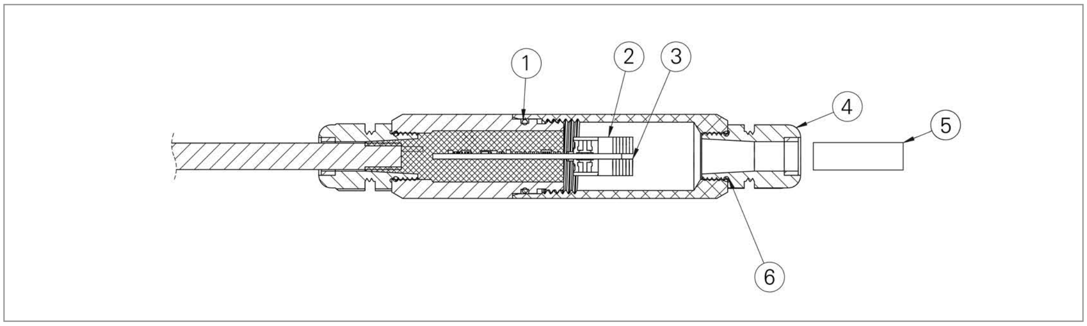


***FIGURE 34:*** *Single-Channel Cable (12P and CAB) Models*

| Item No. | Part Number | Description |
|---|---|---|
| 1 | ORB-018 | Buna O-Ring |
| 2 | CON-959 | 2 Position Connector |
| 3 | CON-960 | 3 Position Connector |
| 4 | CON-A365 | Cable Fitting |
| 5 | CON-A341 | Dowel Pin |
| 6 | SEAL-09 | Seal Ring for CON-A365 |

***TABLE 26:*** *Single-Channel Cable (12P and CAB) Models Components Parts List*

## H.2   SINGLE-CHANNEL ENCLOSURE (01C-CBL) MODELS

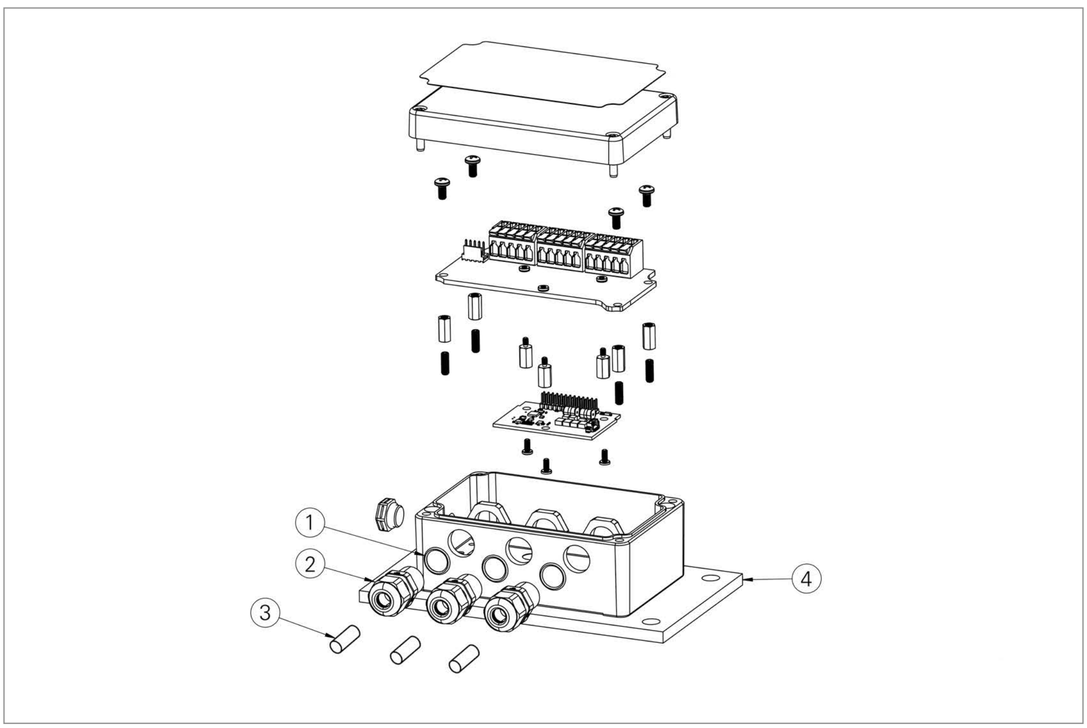


***FIGURE 35:*** *Single-Channel Enclosure (01C-CBL) Models*

| Item No. | Part Number | Description |
|---|---|---|
| 1 | SEAL-09 | Seal Ring for CON-A331 |
| 2 | CON-A331 | Cable Fitting |
| 3 | CON-A342 | Dowel Pin |
| 4 | A6191-1 | Mounting Bracket |

***TABLE 27:*** *Single-Channel Enclosure (01C-CBL) Models Components Parts List*

## H.3 FOUR-CHANNEL ENCLOSURE (04C-CBL) MODELS

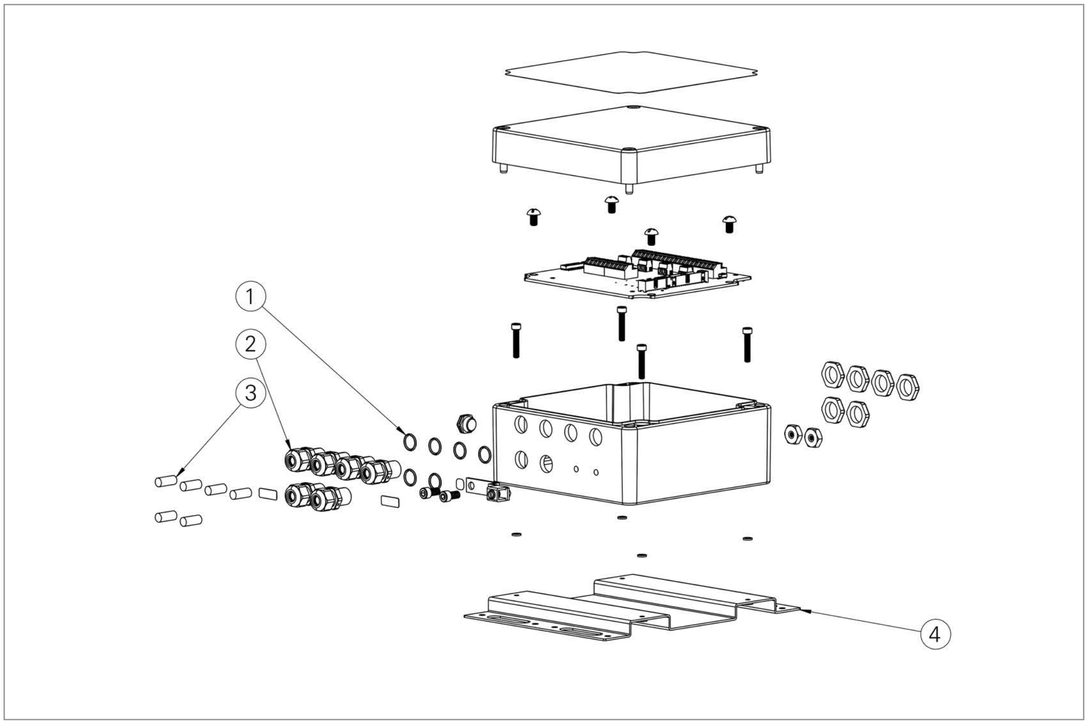


***FIGURE 36:*** *Four-Channel Enclosure (04C-CBL) Models*

| Item No. | Part Number | Description |
|---|---|---|
| 1 | SEAL-09 | Seal Ring for CON-A331 |
| 2 | CON-A331 | Cable Fitting |
| 3 | CON-A342 | Dowel Pin |
| 4 | C8800-4 | Mounting Bracket |

***TABLE 28:*** *Four-Channel Enclosure (04C-CBL) Models Components Parts List*

## H.4 EIGHT-CHANNEL ENCLOSURE (08C-CBL) MODELS

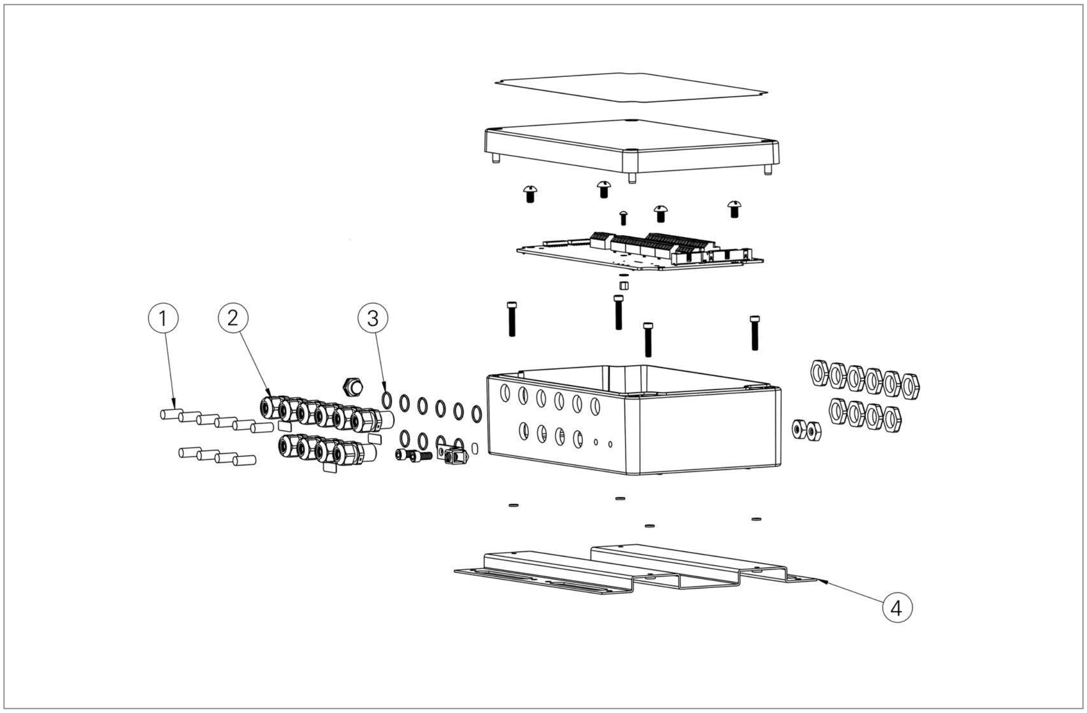


***FIGURE 37:*** *Eight-Channel Enclosure (08C-CBL) Models*

| Item No. | Part Number | Description |
|---|---|---|
| 1 | CON-A342 | Dowel Pin |
| 2 | CON-A331 | Cable Fitting |
| 3 | SEAL-09 | Seal Ring for CON-A331 |
| 4 | C8800-6 | Mounting Bracket |

***TABLE 29:*** *Eight-Channel Enclosure (08C-CBL) Models Components Parts List*

## APPENDIX I. SENSOR AND RS-485 WIRING PORTS

### I.1 MODEL 8960-01C-CBL WIRING PORTS

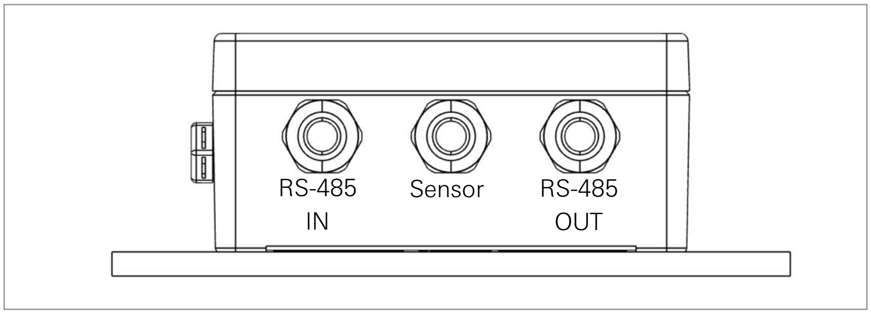


***FIGURE 38:*** *Model 8960-01C-CBL*

### I.2 MODEL 8960-04C-CBL WIRING PORTS

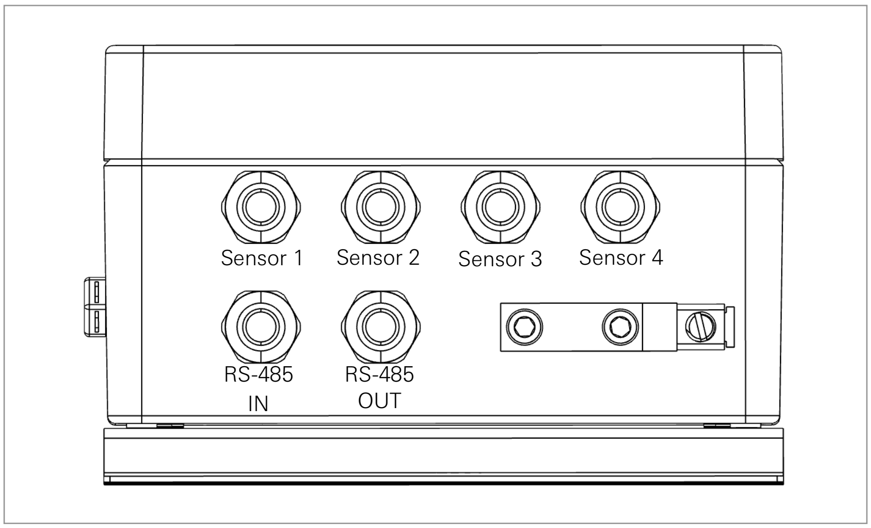


***FIGURE 39:*** *Model 8960-04C-CBL*

### I.3 MODEL 8960-08C-CBL WIRING PORTS

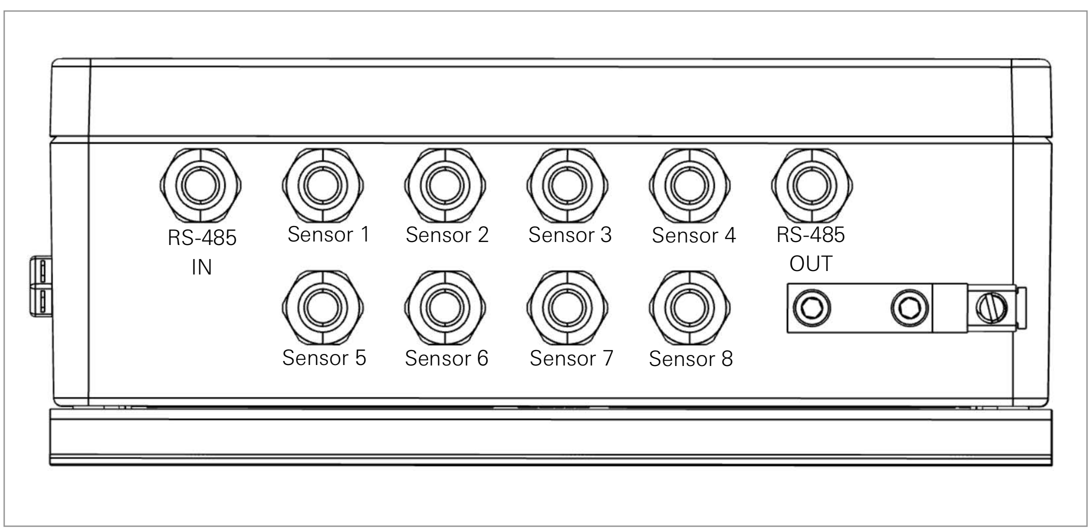


***FIGURE 40:*** *Model 8960-08C-CBL*

# APPENDIX J. VIBRATING WIRE LOAD CELL WIRING

## J.1 WIRING SINGLE LOAD CELL

| 8CH Interface[1] | Function | 3-Gauge Load Cell Violet Cable | 4-Gauge Load Cell Violet Cable | 6 Gauge Load Cell Orange Cable |
|---|---|---|---|---|
| Channel 1 VW+ | Gauge #1 | Red | Red | Red |
| Channel 2 VW+ | Gauge #2 | Red's Black | Red's Black | Red's Black |
| Channel 3 VW+ | Gauge #3 | White | White | White |
| Channel 4 VW+ | Gauge #4 | NC | White's Black | White's Black |
| Channel 5 VW+ | Gauge #5 | NC | NC | Green |
| Channel 6 VW+ | Gauge #6 | NC | NC | Green's Black |
| Channel 1 SHD | Shield | All Shields | All Shields | All Shields |
| VW- Channels[2] | Common | White's Black[3] | Green | Blue |
| Channel 1 TH + | Thermistor | Green[3] | Blue | Yellow |
| Channel 1 TH - | Thermistor | Green's Black | Blue's Black | Yellow's Black |

***TABLE 30:*** *Single Load Cell Wiring*

**Note:**

[1] Where second Load Cell is being included, retain relative channel position count up from channel 5.

[2] Common "VW-" between all channels associated with each VW Load Cell

[3] White's black and Green wires are switched on GEOKON three-gauge VW load cells prior to serial number 3313.

## J.2 LOAD CELL CONFIGURATION SWITCH SETTINGS

| POS 1 | POS 2 | POS 3 | Configuration |
|---|---|---|---|
| OFF | OFF | OFF | Std. No Load Cell |
| ON | OFF | OFF | One 3-Gauge Load Cell |
| OFF | ON | OFF | One 4-Gauge Load Cell |
| ON | ON | OFF | Two 3-Gauge Load Cells, second starting at channel 5 |
| OFF | OFF | ON | Two 4-Gauge Load Cells, second starting at channel 5 |
| ON | OFF | ON | One 3-Gauge Load Cell & One 4-Gauge Load Cell starting at channel 5 |
| OFF | ON | ON | One 4-Gauge Load Cell & One 3-Gauge Load Cell starting at channel 5 |
| ON | ON | ON | One 6-Gauge Load Cell |

***TABLE 31:*** *Load Cell Configuration Switch Settings*

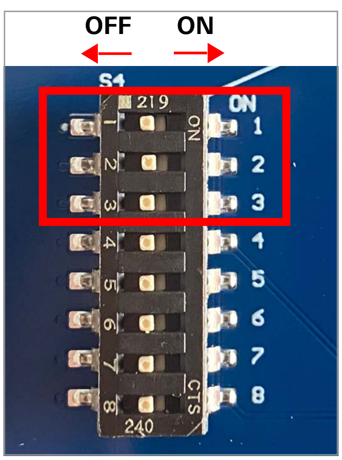


***FIGURE 41:*** *Load Cell Configuration Switch*

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